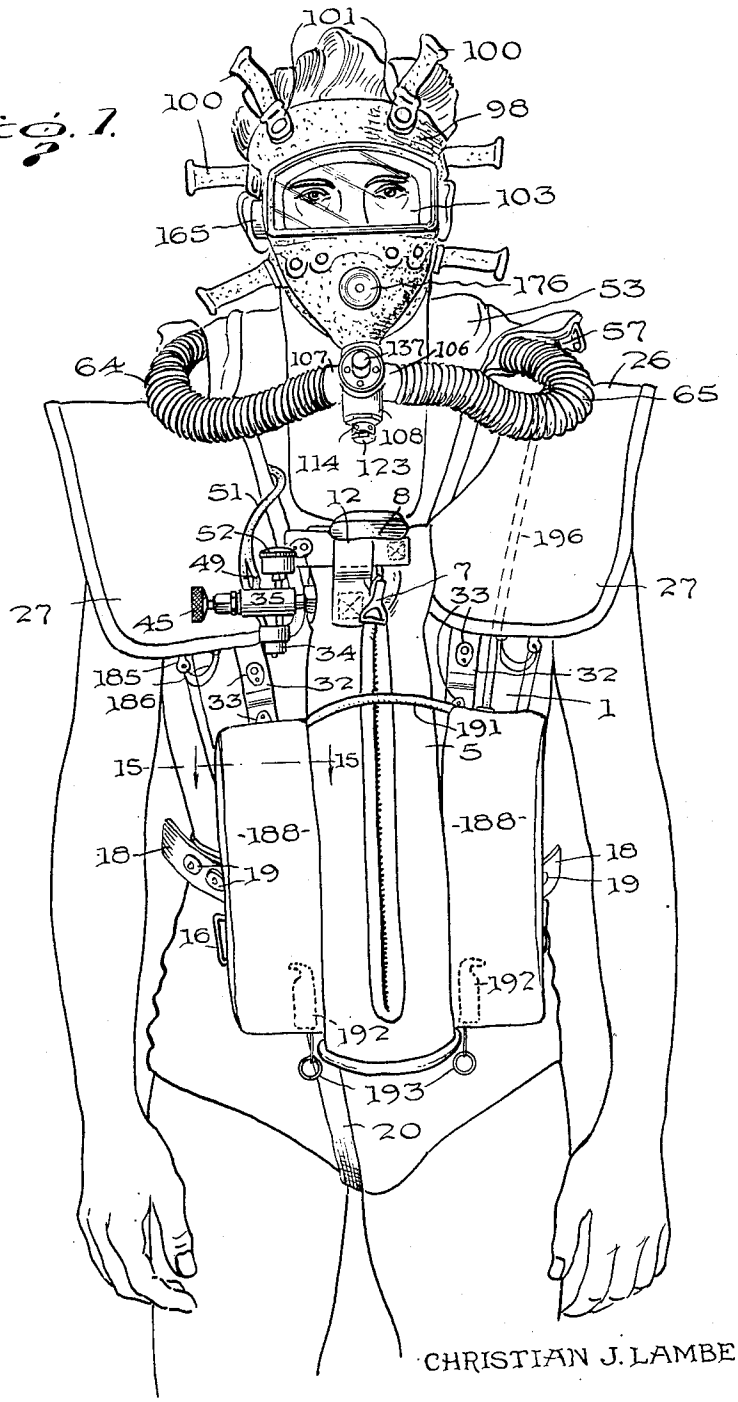
Dec. 14, 1948. C. J. LAMBERTSEN 2,456,130

BREATHING APPARATUS

Filed Jan. 31, 1945 9 Sheets-Sheet 1

Fig. 1.



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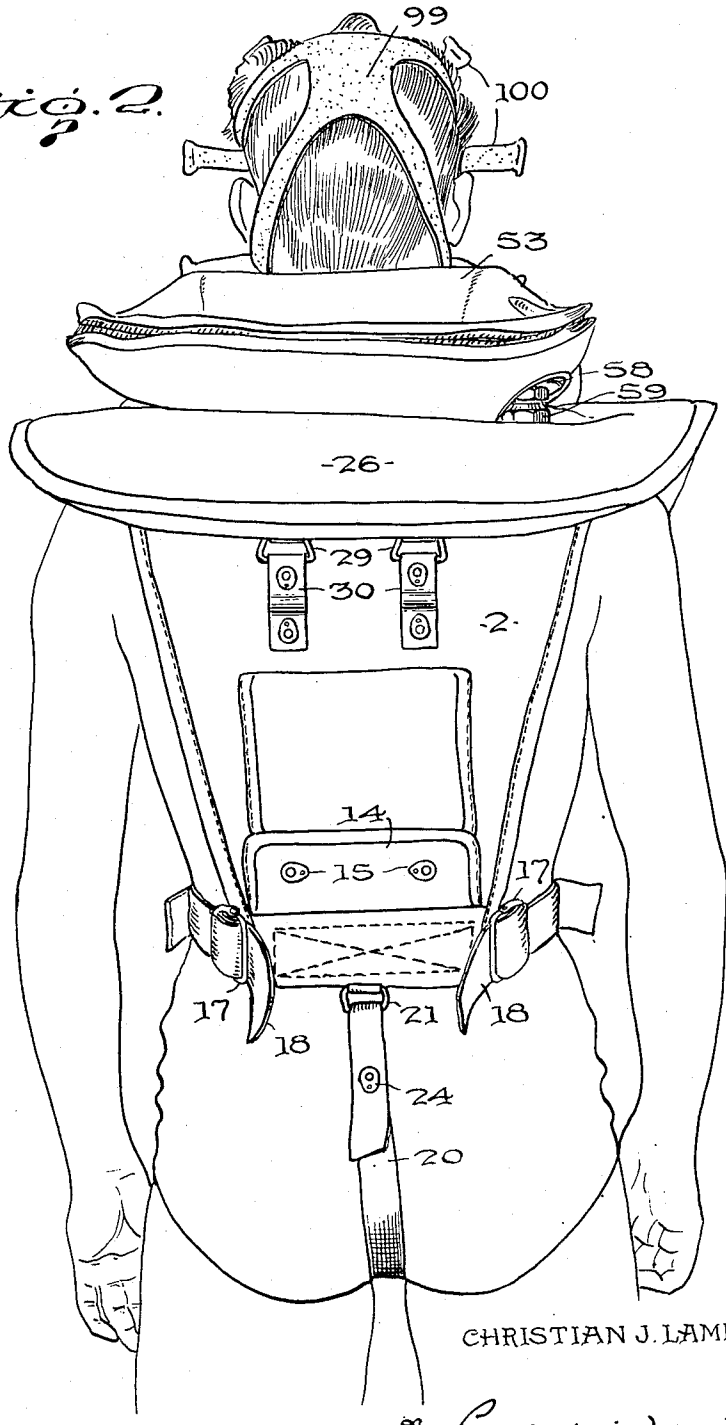
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BREATHING APPARATUS

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Fig. 2.



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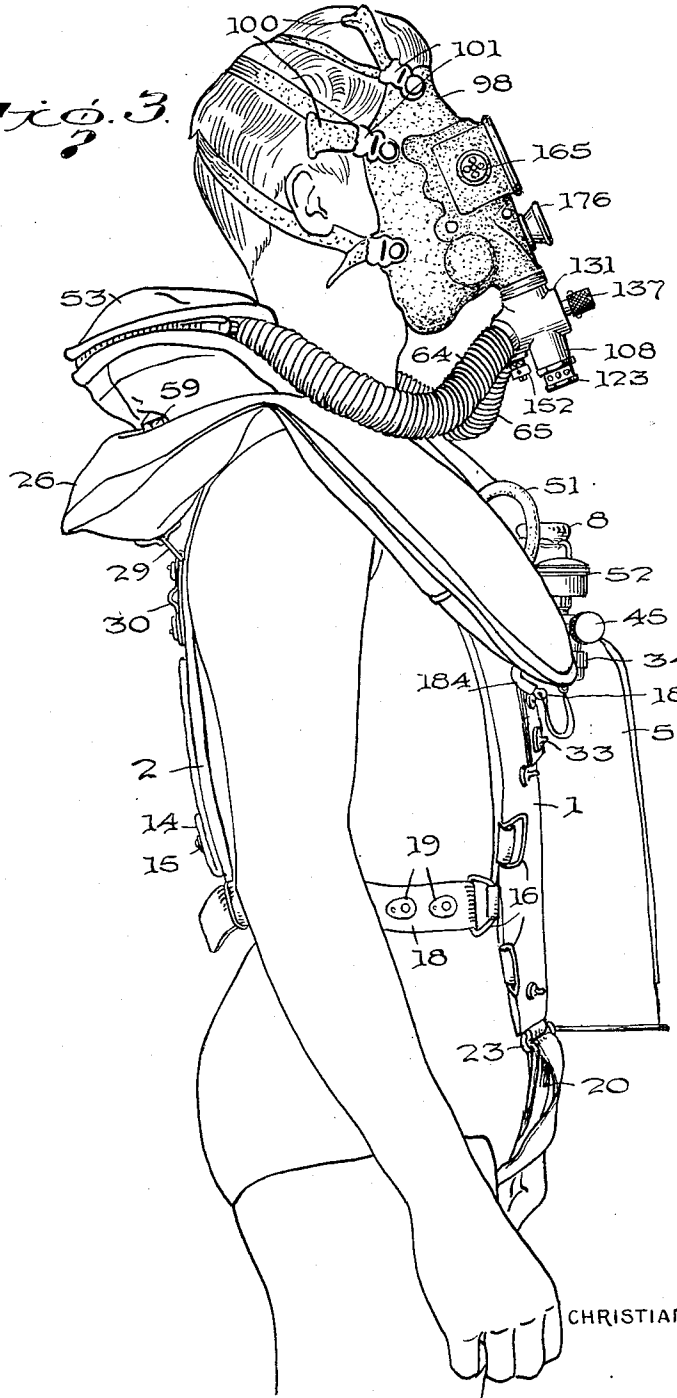
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Dec. 14, 1948. C. J. LAMBERTSEN 2,456,130

BREATHING APPARATUS

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Fig. 3.



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BREATHING APPARATUS

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Fig. 4.

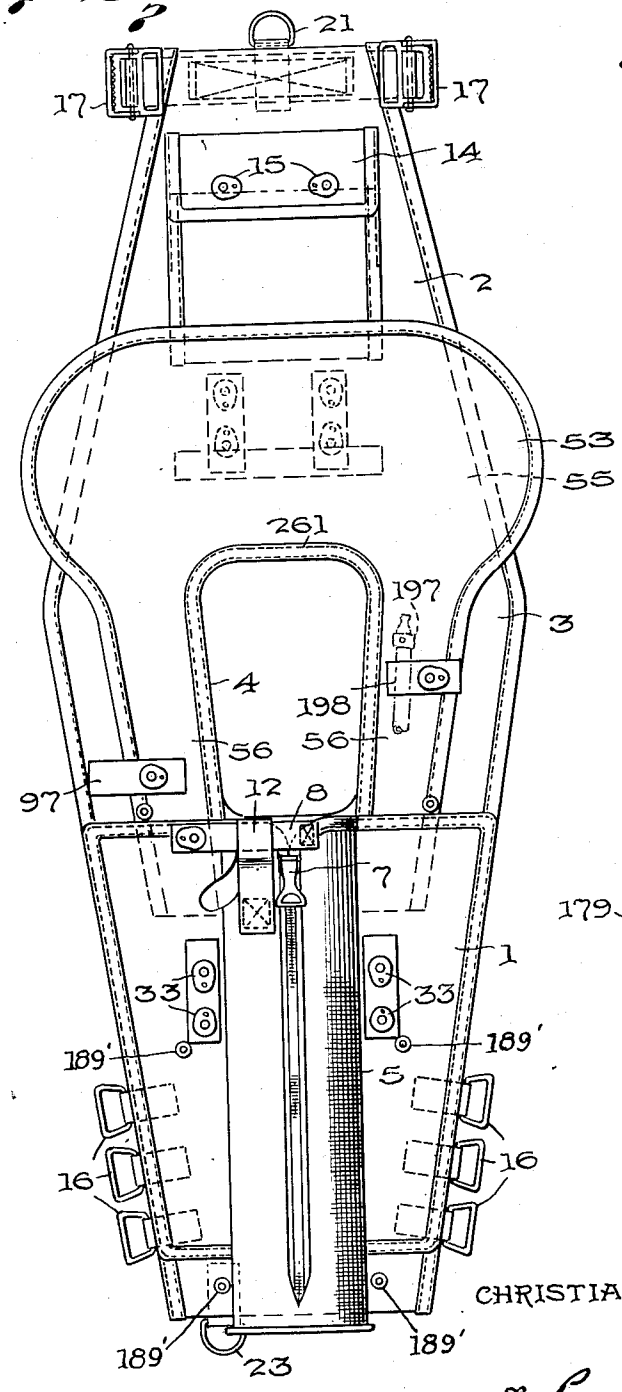
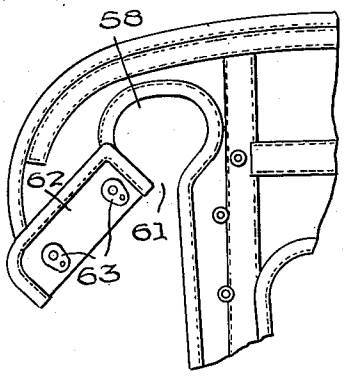


Fig. 7.



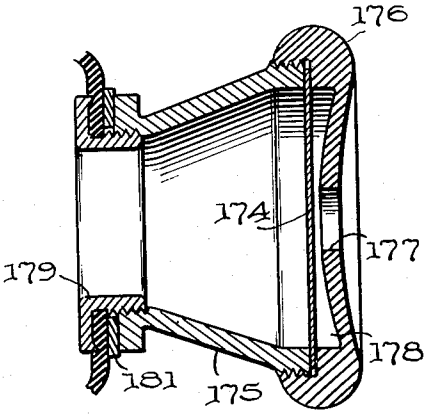


Fig. 12.

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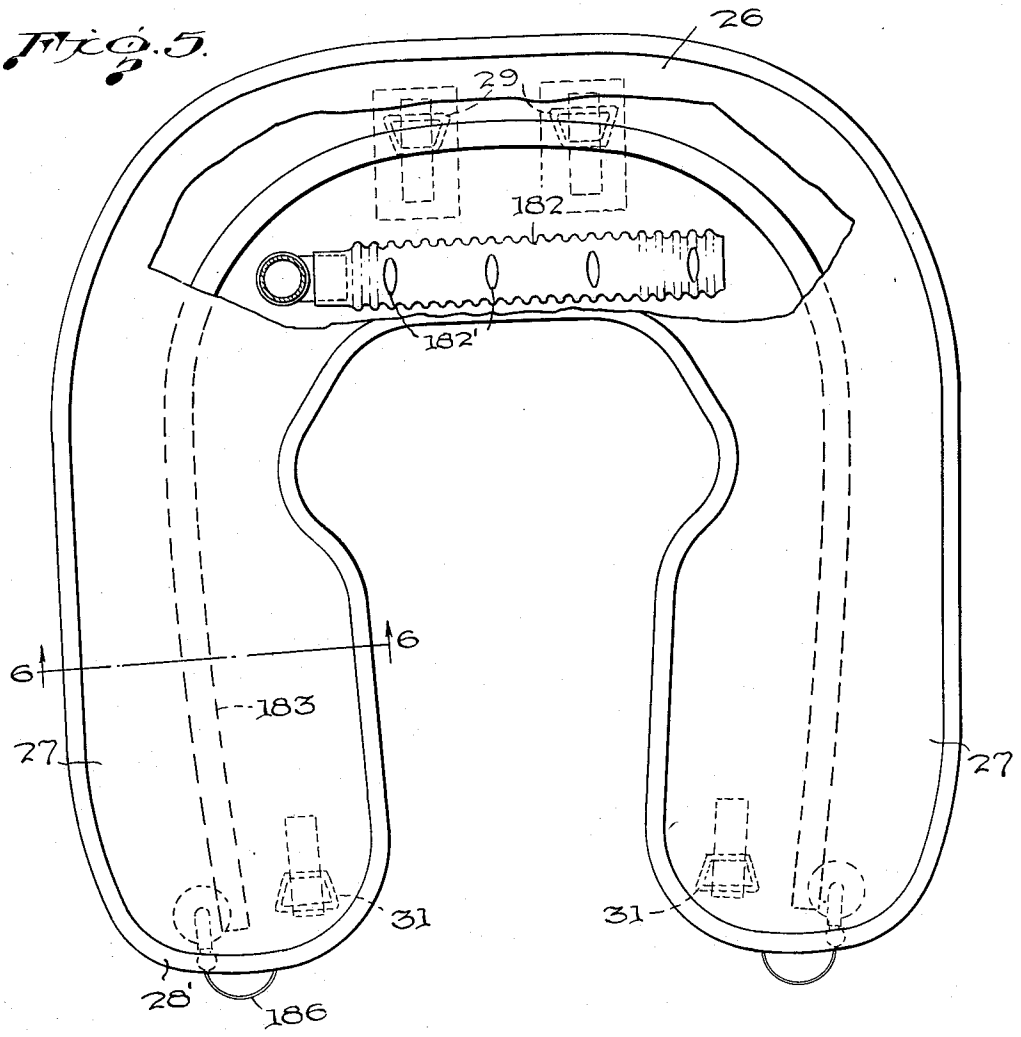
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Dec. 14, 1948. C. J. LAMBERTSEN 2,456,130

BREATHING APPARATUS

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Fig. 5.



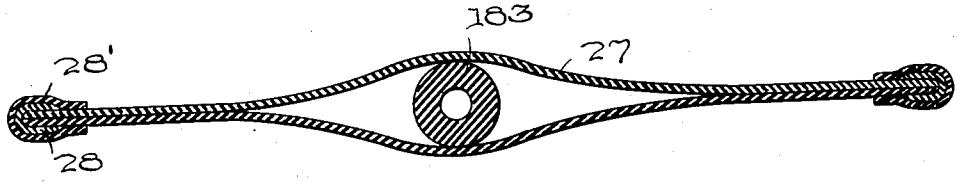


Fig. 6.

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Dec. 14, 1948. C. J. LAMBERTSEN 2,456,130

BREATHING APPARATUS

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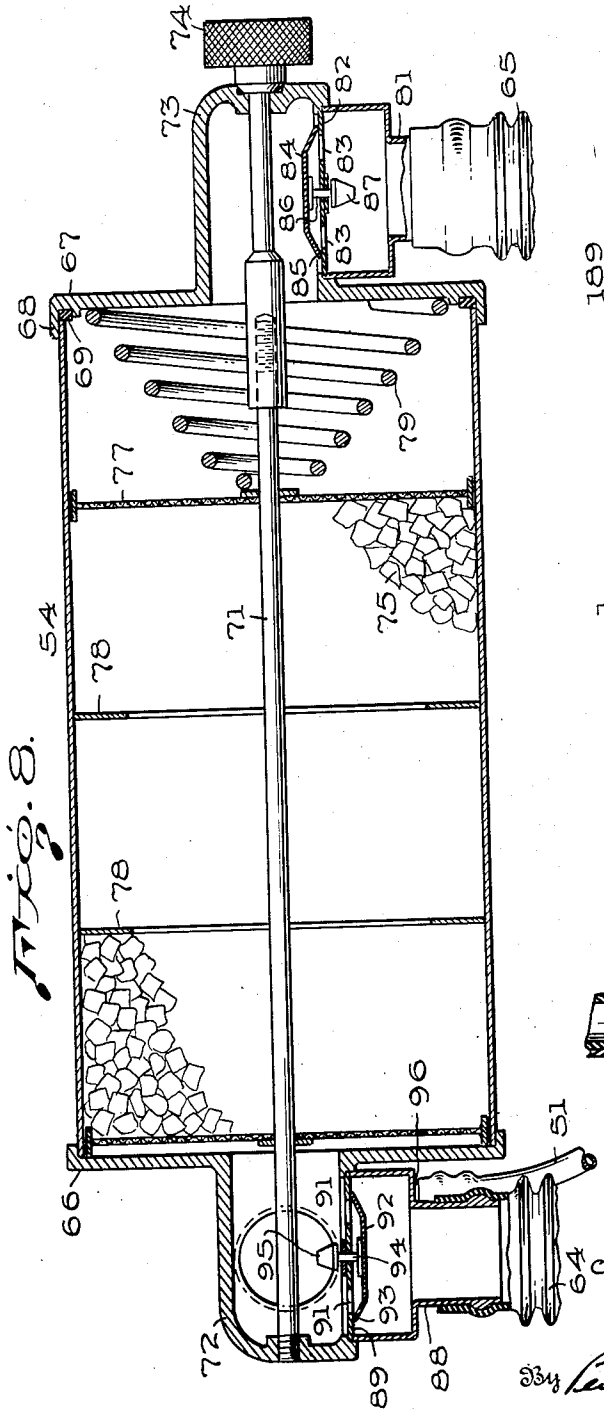


Fig. 8.

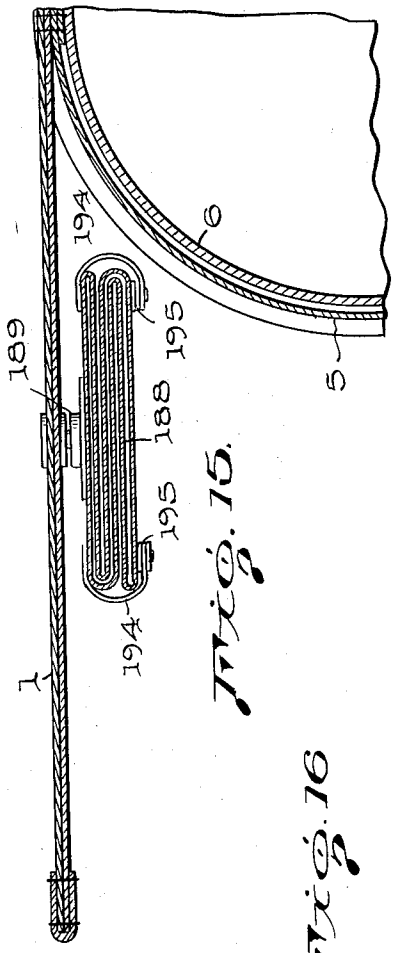


Fig. 15.

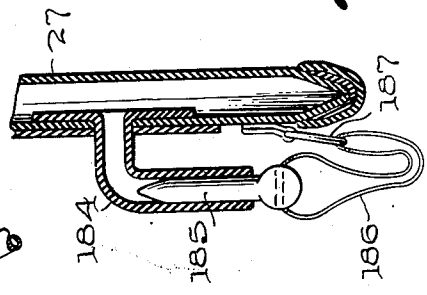


Fig. 16

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BREATHING APPARATUS

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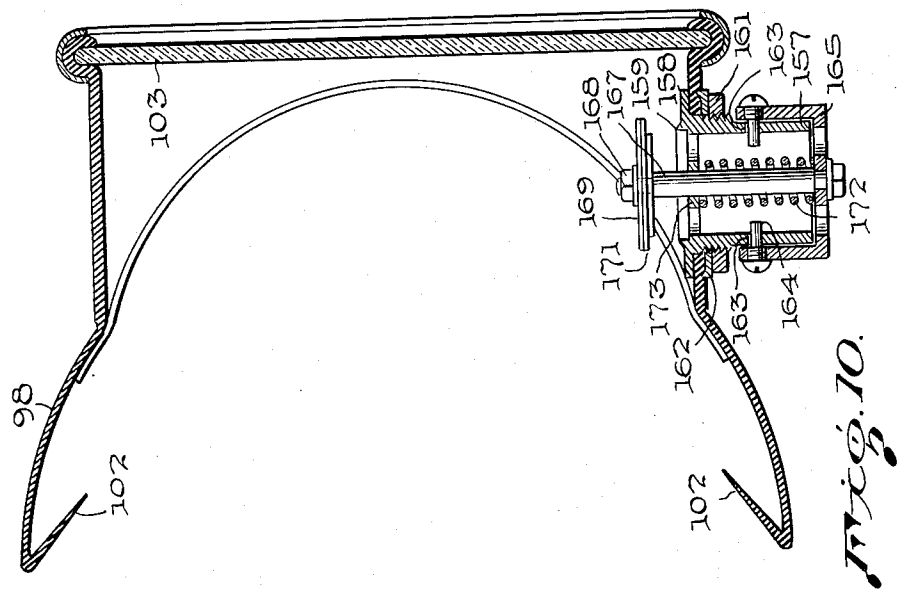


Fig. 10.

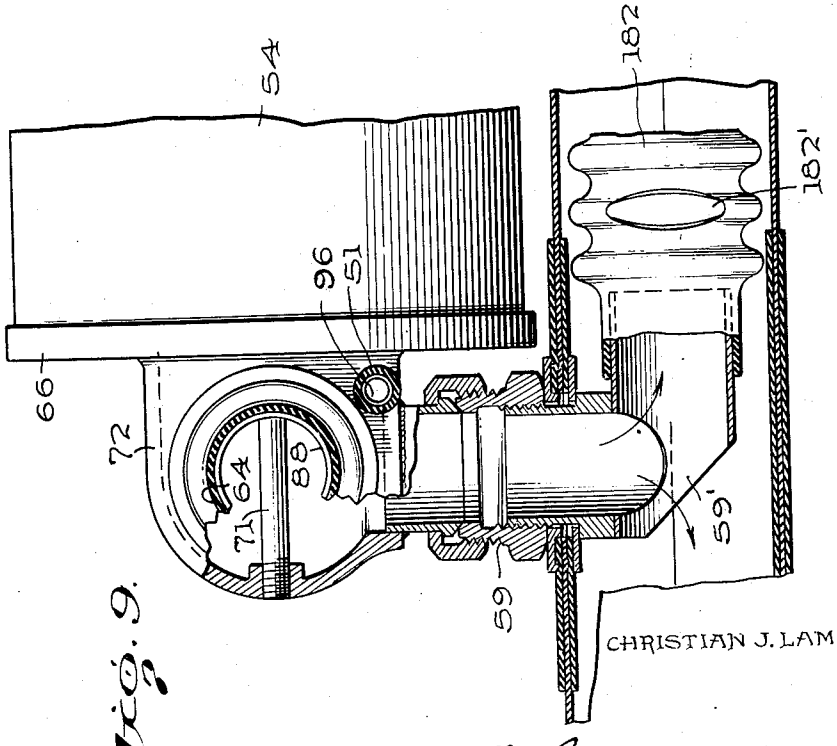


Fig. 9.

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Dec. 14, 1948. C. J. LAMBERTSEN 2,456,130

BREATHING APPARATUS

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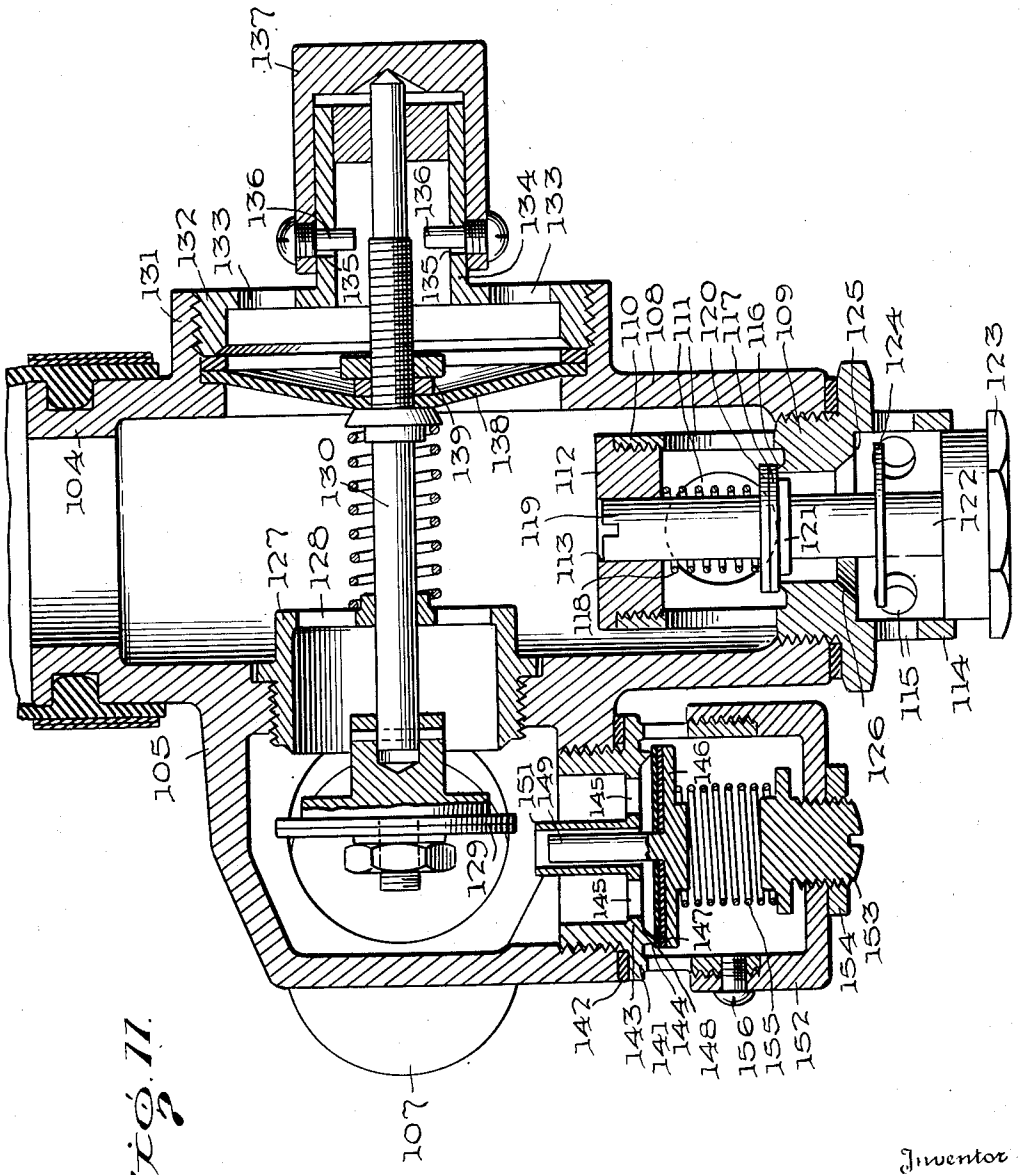


Fig. 11.

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BREATHING APPARATUS

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Fig. 13.

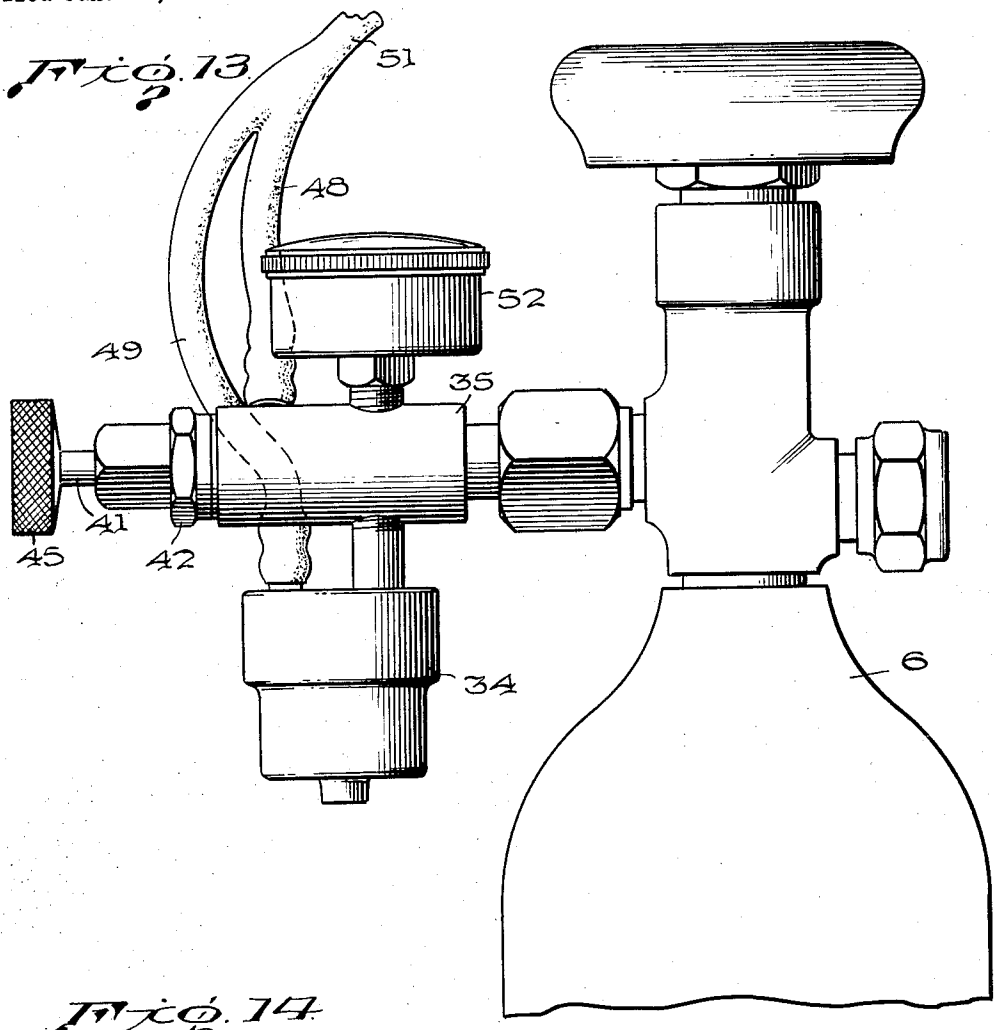
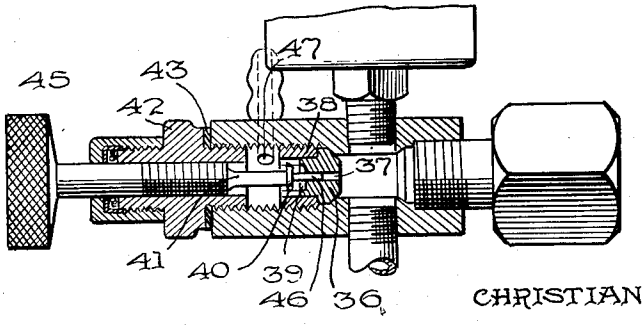


Fig. 14.



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Patented Dec. 14, 1948 2,456,130

UNITED STATES PATENT OFFICE

2,456,130

BREATHING APPARATUS

Christian J. Lambertsen, Scotch Plains, N. J.

Application January 31, 1945, Serial No. 575,386

17 Claims. (Cl. 128—142)

1

This invention relates to a wholly self-contained breathing apparatus for use under water, in atmospheres of noxious gases, or where the normal amount of oxygen in the air is insufficient. It will be particularly described in connection with breathing apparatus for use under water. However, it is to be understood that such breathing apparatus, or modifications thereof, readily are adapted for use in mines or other places where toxic or poisonous gases may exist; by firemen or others in smoke-filled places to prevent being overcome by the smoke; and by aviators or others in rarified atmospheres where the normal amount of oxygen in the air is insufficient. In general it is adapted for use at any place where a surrounding atmosphere satisfactory and adequate for breathing does not exist.

The present invention is an improvement on the type of breathing apparatus described and claimed in my Patents Nos. 2,348,074 dated May 2, 1944, and 2,362,643 dated November 14, 1944, particularly the latter.

Prior to the inventions disclosed in my aforesaid patents the usual diver's paraphernalia included a suit and a heavy helmet which was donned by the diver. Oxygen or air was supplied to the diver's outfit from a source at the surface of the water. Such paraphernalia, although it had been used for a great many years, was known to have many disadvantages. It required a crew of one or more at the source of supply of the oxygen or air at the surface to see, among other things, that everything operated satisfactorily and that oxygen or air constantly was supplied to the diver. The outfit was cumbersome and interfered with the diver performing the desired tasks. As the outfit was connected by tubing to the source of oxygen or air at the surface, there always was danger of damage to the tubing or of its becoming entangled with an object under water, or otherwise. Further, such tubing seriously circumscribed the movement of the diver from his place of descent.

In my aforesaid patents I have disclosed and claimed a wholly self-contained breathing apparatus which may be worn by a diver and render him wholly independent of any fixed source of supply of oxygen, or air, thereby eliminating the necessity of his wearing the cumbersome suit and helmet theretofore used.

The apparatus described in my later patent includes a closed breathing system having means for supplying a regulatable amount of oxygen thereto and means for removing carbon dioxide from the exhaled gases before they pass to a

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breathing bag to be reinhaled. Means also are provided whereby on each exhalation an amount of the exhaled gases equal to the amount of oxygen admitted to the closed breathing system, less the amount consumed by the body, is exhausted from the system. With such an apparatus the diver is free to move about under water to any extent which he may desire. Also, as he does not wear the former cumbersome suit and helmet he is much freer to go about performing his intended tasks.

While the basic and underlying principles of my former devices and particularly that disclosed in my later patent have been proven sound and practical in actual use, and such devices have been found to be a decided improvement over the former type of diver's outfits described above, such use has shown the need for further improvements with respect to certain features thereof.

In accordance with my present invention the amount of oxygen normally and continuously fed into the breathing system is merely the amount required by a diver when at rest, and manually regulatable means are provided for supplying such additional amounts of oxygen as he may need when he is working or engaging in other energy-consuming activities. Thus, a substantial saving of oxygen results as it is not necessary to constantly supply the maximum that may be needed and exhaust the remainder from the system when a less amount is being consumed.

The strap harness of my aforesaid later patent has been found, in some respects, not to be as satisfactory as it might be. Hence, a feature of my present invention is to provide a vest-like harness which will be more comfortable for a person to wear and which more adequately will support the source of oxygen and other component parts of the respiratory system. Such vest-like harness is made of relatively heavy canvas so as to withstand hard wear and yet provide the flexibility necessary to permit rolling or folding when not in use.

Another important feature of the present invention is the provision of a full-face mask which will maintain a water-tight seal with the wearer's face; which will enable the wearer to see better under water; and which is provided with means to enable the breathing of atmospheric air therethrough when the wearer is not under water, thereby preventing the necessity, at such times, of removing the mask to conserve the supply of oxygen.

The present invention also contemplates the provision of a mask shut-off valve which may be

used to close the respiratory system just below the mask. Such a valve has a twofold function. It prevents entrance of water into the respiratory system if the mask must be removed in or under water, and it enables the breathing bag to be inflated with air or oxygen for use as an emergency flotation bladder.

In my aforesaid later patent, the breathing bag is carried at the back of the wearer and covered with a perforated metal casing for protection. The bag is so positioned that when the wearer is in an upright position the lowermost portion of the bag is approximately at the nipple line whereby the hydrostatic pressure on the lowermost portion of the breathing bag, and consequently the pressure in the entire respiratory system, including the lungs, is equal to the mean hydrostatic pressure on the outside of the chest wall, and consequently, to the mean pressure which is exerted through the chest wall onto the exterior of the lungs. However if the wearer, with such an apparatus, finds it necessary to stoop over, or work in a head-down position the difference between the pressure in the respiratory system and the pressure on the exterior of the lungs is such that appreciable exertion is necessary in order to exhale. According to the present invention a breathing bag is provided which will cause the pressure in the respiratory system to substantially equal that on the exterior of the lungs in any position which the wearer may assume. Thus, he may assume any position which his particular tasks may require without the necessity of exerting himself either to inhale or exhale.

In actual use it has been found that an appreciable amount of water will collect in a closed breathing system used under water due to condensation. In order that such water may be removed, a water drain valve is provided. Such valve is so constructed as to permit water or oxygen to be discharged from the system while preventing the entrance of water thereto.

In order to prevent over-distention or rupture of the breathing bag or any part of the respiratory system when the mask shut-off valve is closed, or when the breathing bag is inflated for emergency flotation, I provide a pressure relief, or pop-off valve which will open when the internal pressure of the breathing system exceeds the equivalent of 50 inches of water, or any other pressure for which the valve may be set.

Still further features of my invention include, inter alia, the provision of a cannister for the absorbent for exhaled carbon dioxide which more efficiently and more effectively will absorb the carbon dioxide from the exhaled gases before they are returned to the breathing bag for rebreathing; and the provision of means for preventing collapsing of the breathing bag in a manner such as would prevent free flow of the gases to and from it, and possibly cause suffocation.

The invention will be further described in connection with the accompanying drawings. However, it is to be understood that such further illustration and explanation is by way of exemplification and the invention is not limited thereby, except to the extent set forth in the appended claims.

In the drawings:

Fig. 1 is a front elevation showing the breathing apparatus of the present invention in place on a wearer;

Fig. 2 is a rear elevation;

Fig. 3 is a side elevation with the emergency inflation bladders removed;

Fig. 4 is a plan view of the vest-like harness and attached carrier pocket for the carbon dioxide absorber removed from the wearer and straightened out longitudinally;

Fig. 5 is a plan view of the breathing bag with parts broken away to show the means for preventing collapsing of the bag and shutting off the free passage of gas through the interconnecting passage between it and the balance of the respiratory system;

Fig. 6 is a sectional view on line 6—6 of Fig. 5;

Fig. 7 is an inverted plan view of one end of the carrier pocket for the carbon dioxide absorber;

Fig. 8 is a longitudinal sectional view through the carbon dioxide absorber showing portions of the inhalation and exhalation tube attached thereto;

Fig. 9 is a sectional view showing the manner in which the carbon dioxide absorber is attached to the breathing bag;

Fig. 10 is a horizontal sectional view through the mask and associated parts;

Fig. 11 is an enlarged sectional view through a housing member carried at the lower end of the mask showing various valves carried thereby;

Fig. 12 is an enlarged sectional view through the speaking diaphragm;

Fig. 13 is an enlarged elevational view of the pressure reducing and regulating valve, the supplemental supply valve, and the pressure gauge;

Fig. 14 is a longitudinal sectional view through the supplemental oxygen supply valve, showing associated parts in elevation;

Fig. 15 is an enlarged sectional view on line 18—18 of Fig. 1, showing how the emergency inflation bladders are secured in folded position onto the front vest section of the harness, and

Fig. 16 is a detail sectional view, showing the means for draining the anterior ends of the breathing bag.

Referring now to the drawings, the harness for supporting the component parts of the respiratory system and its oxygen supply is vest-like in nature and includes a front section 1, a rear section 2, and relatively wide shoulder sections 3. The front and rear sections are of such width as to substantially cover the front and back, respectively, of the torso of the wearer, and each section tapers inwardly and downwardly from the shoulders. The upper edges of the front and rear sections, together with the inner edges of the shoulder sections define an elongated neck opening 4 which enables the harness to be placed over one's head when the breathing device is to be donned.

The vest-like supporting harness may be made of any suitable material, but I prefer to make it of heavy canvas as such material is sufficiently strong to withstand wear and provide the necessary support for the oxygen supply and the several parts comprising the respiratory system, to be described, while at the same time being sufficiently flexible to permit rolling or folding when the breathing apparatus is not being used.

The rear section 2 terminates at about waist level, but the front section 1 extends substantially below the waist in order to provide the necessary length for a vertically-extending pocket 5 for receiving an oxygen cylinder 6. To permit ready insertion and removal of oxygen cylinders to and from the pocket, it has a vertically-extending opening running substantially the entire length thereof which is closed by a slide fastener 7. A strap 8 is stitched or otherwise permanently se-

cured at one end 9 of the upper portion of one side of the oxygen cylinder pocket, above the slide fastener. The strap is adapted to be passed beneath the valve handle 8', which regulates the flow of oxygen from the cylinder, and through a loop 12 formed at the upper edge of the other side of the pocket and to be secured to the front vest section by means of a snap fastener. When the strap 8 is thus fastened it maintains the oxygen cylinder in proper place within the pocket 5, even if the slide fastener should be opened accidentally.

A rectangular pocket is sewed onto the lower portion of the rear vest section 2 to receive lead or other ballast plates when used to adjust for the gross difference in the buoyancy of divers. As shown in Fig. 2 the pocket opens downwardly and is closed by a flap 14 which is fastened to the pocket by a pair of snap fasteners 15, preferably of the "Lift-the-dot" type. Such fasteners are a well known type and have a dot at one side of the outer face of the female member, and in order to unsnap the fastener it is necessary to lift that side of such member. By arranging the fasteners so that the dots of both of them are on the inner side the pocket readily and quickly may be opened by inserting a finger under the flap between the fasteners and pulling outwardly, whereupon the flap is unsnapped and the ballast plates fall out. Such an arrangement is desirable as it enables the pocket to be opened and the ballast plates dropped with a minimum of time and effort for emergency flotation.

Three pairs of large brass rings 16 are attached at different levels to the opposite sides of the lower portion of the front section 1, and a single buckle is attached to each side of the lower edge of the back section 2. One end of each of a pair of web side straps or belts 18 are passed through one of the pairs of rings 16 and folded back upon itself and secured by means of a pair of "Lift-the-dot" fasteners 19, thereby detachably fixing those ends of the side straps to the front section 2. The other ends of the straps or belts 18 are passed around the sides of the wearer and secured by the buckle 17 to the rear vest section 2, thus holding the sides of the front and rear vest sections snuggly against the body of the wearer. The free ends of the strap 18, after being passed through the buckle 17 may be knotted to prevent their accidentally slipping back through the buckles. The bottoms of the front and rear sections are held in proper position on the wearer by a crotch strap 20, having one end secured to a small brass ring 21 at the center of the lower edge of the back section by a "Lift-the-dot" fastener 22. The other end of the crotch strap 20, after being passed through the crotch and along the right groin is passed through a small brass ring 23 attached to the lower right side of the lower edge of the front vest section. After being passed through the ring 23 the free end of the crotch strap is folded back upon itself and secured by a pair of "Lift-the-dot" fasteners 24.

The side straps or belts 18 and the crotch strap 20 provide readily detachable means for comfortably and firmly holding the supporting harness in place on the torso of the wearer. The provision of the three pairs of rings at the lower sides of the front section enable the necessary adjustment for differences in torso length to be made.

As a safety feature, that is, to enable the harness to be removed in a hurry in an emergency, the fasteners 19 and 24 are so positioned that the dots thereof are at the sides towards the free ends of the straps. Thus, it is only necessary to jerk the free ends of those straps outwardly in order to unfasten them and enable the harness to be taken off.

The respiratory system is an independent closed-circuit, rebreathing one and comprises a breathing bag which acts as a storage chamber for oxygen from the cylinder 6 and the recycled exhaled gases, a carbon dioxide absorber, a breathing mask, conduits for conducting carbon-dioxide-free gases from the breathing bag to the mask and the exhaled gases from the mask to the carbon dioxide absorber from which they pass, after removal of carbon dioxide, into the breathing bag, and from there into an inhalation tube leading to the breathing mask, and the necessary valves.

At this point it may be stated that on any inhalation, even though one is breathing pure oxygen, the body will absorb and utilize only so much oxygen, the amount depending to a large extent upon the energy-consuming activities in which the person at that moment is engaging. In a closed-circuit breathing system, the system initially is purged of most of the gases then in it for the purpose of removing nitrogen and other gases present in atmospheric air. It is then filled with oxygen and the breathing is of substantially pure oxygen. Any oxygen which is inhaled and not absorbed and utilized by the body is exhaled on the next exhalation and passes back into the system for subsequent rebreathing. Hence, such a closed system is sometimes referred to as a "rebreathing" system. As a substantial amount of the oxygen inhaled is formed into carbon dioxide by the body and subsequently exhaled, means must be provided for absorbing the carbon dioxide from the exhaled gases before they are cycled for rebreathing, as carbon dioxide is quite toxic to the human system, even in small amounts.

The breathing bag is of generally horseshoe or U-shape and includes a posterior base section 26 which lies across the wearer's shoulders, as shown in Fig. 2, and right and left sections 27 which pass over the shoulders and terminate at the front of the body at the mean level of the lungs.

The shape of the breathing bag and the manner in which it is positioned on the wearer is important because the pressure in the entire respiratory system, including the lungs, at any time, will equal the hydrostatic pressure on the lowermost portion of the breathing bag. If the lowermost portion of the breathing bag is at the mean level of the lungs the pressure in the entire respiratory system will equal the exterior pressure on the lungs, and vice-versa, and it will require no extra exertion on the part of the wearer either to inhale or exhale. On the other hand, if the pressure in the respiratory system should be greater than the exterior pressure on the lungs as for example, when the lowermost portion of the breathing bag is at a level below the mean level of the lungs, the wearer would have to exert himself in order to exhale, as he would have to "push" the air from his lungs into a chamber of greater pressure. Likewise, if the pressure within the respiratory system were less than the exterior pressure on the lungs, as, for example, when the lowermost portion of the breathing bag is at a level above the mean level of the lungs, the wearer would have to exert himself to inhale, as he then would have to "pull" the inhaled gases into the lungs which would be

under a greater pressure. Any such exertion unnecessarily tires a person, particularly one working, or engaging in other energy-consuming tasks, and should be avoided.

While it might seem that the difference in hydrostatic pressure caused by a few inches of water would be negligible, such is not the case, and in actual tests it has been found that a differential of as little as three inches of hydrostatic pressure is sufficient to noticeably tire a person engaged in other energy-consuming tasks. With a breathing bag shaped and position on the wearer as described above, some part of the breathing bag will be the lowermost part thereof and at the mean level of the lungs regardless of what position the wearer may assume, thus, he may work in an erect position, while lying on his back or on either side, or even in a head-down position, which sometimes is necessary, and the pressure in the entire respiratory system always will equal the mean pressure on the outside of the lungs.

The breathing bag may comprise a casing formed from flat sheets of cotton canvas twill rubberized on both sides to render it gas-tight and double sealed at the edges by means of an inner U-shape rubber seal **28** and a similarly shaped outer, overlying rubber seal **28'** formed of tough, abrasive-resistant rubber. Of course, if desired the breathing bag could be formed of some non-rubberized material and a rubber bladder or the like inserted therein. By forming the breathing bag from flat upper and lower pieces of rubberized canvas, as above described, it assumes a somewhat flat position on the body of the wearer when in use.

The breathing bag is secured to the vest-like sections **1** and **2** by appropriate fastening means. For that purpose the underside of the posterior base **26** has a pair of brass rings **29** attached thereto at opposite sides of the center of the bag. A pair of anchoring straps **30** of web material have one end permanently attached to the back section **2**. The free ends of the straps **30** are passed through the rings **29** and folded back upon themselves and secured by a pair of "Lift-the-dot" fasteners to firmly anchor the breathing back at the back. The space between the female portions of the fasteners attached to the free end of the strap **30** is sufficiently greater than the space between the cooperating male portions of the fasteners attached to the straps that when the respective parts are in cooperative engagement a pucker will be formed between them. The fasteners are so positioned that the dots face each other. Hence, by inserting one's finger in the pucker and pulling outwardly both fasteners simultaneously will be unsnapped.

The front ends of the leg sections **27** of the breathing bag are secured to the front vest-like section by anterior brass rings **31** and web straps **32** secured by "Lift-the-dot" fasteners **33**, similarly to the manner in which the posterior base section **26** is secured to the back section **2**.

Oxygen from the oxygen cylinder **6** passes to the respiratory system through an adjustable pressure-reducing and regulating valve **34** connected to the lower side of the inlet end of a casing **35**, and through a supplemental manually-regulatable valve formed in the other end of the casing.

The type of adjustable pressure-reducing and regulating valve which is used forms no part of the present invention. It may be of the single or multiple stage type, as desired.

Regardless of the type of pressure reducing and regulating valve which is used, it will be set to furnish a steady flow of 500 c. c. of oxygen per minute, which is sufficient for the normal requirements of the wearer when he is at rest. The manually-regulatable supplemental valve is provided so that the wearer may regulate the supplemental supply of oxygen in accordance with his needs at any time when he is working, or otherwise consuming more oxygen than when at rest. Hence, means are provided for furnishing an adequate supply of oxygen to the wearer without furnishing at all times an amount equal to the maximum possible need and permitting the excess over that consumed to be exhausted, unused, from the system.

Should the wearer at anytime fail to open the supplemental valve when his activities are such that he requires more than the minimum amount of oxygen, he still will receive a life-sustaining amount through the valve **34** and there will be no danger of suffocation. His failure to open the supplemental valve soon will be brought to his attention by the natural tendency to pant in order to draw a greater amount of oxygen into his lungs. He then will open the supplemental valve to cause it to furnish whatever supplemental oxygen is necessary. Likewise, should the wearer be rendered unconscious, a life sustaining amount of oxygen will continue to be supplied to him through the valve **34**.

The outer end of the casing **35** forms the housing of the manually-operable supplemental valve. A valve seat member **36** having an axial, cylindrical bore **37** is secured within the casing by key members **38**. The outer side of the seat member **36** is formed with a tapered seat **39** to receive a similarly tapered shoulder **40** on a valve stem **41**. The valve stem **41** is longitudinally adjustable by means of a threaded engagement with a bushing **42** secured in the outer end of the casing **35**. A packing washer **43** between the bushing **42** and the end of the casing and a packing gland **44** at the outer end of the bushing ensure a gas-tight connection. A knurled thumb nut **45** on the outer end of the valve stem enables the desired adjustment readily to be made. A cylindrical needle section **46** extends inwardly at the inner end of the valve stem, beyond the tapered shoulder **40**, and is received within the cylindrical bore **37**. The needle section **46** is of only slightly less diameter than the diameter of the bore **37**. Therefore, the amount of supplemental oxygen which is permitted to pass can be very finely and accurately adjusted. When the thumb nut is screwed inwardly the tapered shoulder **40** is caused to seat in the tapered seat **39** and close the valve against the passage of oxygen, thereby leaving the pressure reducing and regulating valve as the sole metering device for feeding oxygen to the respiratory system.

Oxygen passing through the supplemental oxygen supply valve leaves the casing **35** through an outlet **47** and passes through a strong latex tube **48** to be admixed with oxygen from the low pressure side of the pressure reducing and regulating valve **34** passing through a similar tube **49**. Oxygen from the tubes **48** and **49** passes through a latex tube **51** into the respiratory system, as will be described.

All things considered, it has been found most practical to use an oxygen cylinder containing oxygen under a pressure of 2,000 pounds per square inch and in amount to provide an ample supply for six hours' breathing, when at rest.

However, the amount of oxygen consumed by the body, and consequently, the time the diver may remain under water is a function of the physical exertion of the diver, as is indicated by the following table, based upon the use of an oxygen cylinder of the size above referred to.

Degree of work	Oxygen Consumption	Possible Diving Time
	Cubic centimeters per min.	*Hours*
Rest	500	6
Moderate work	900	3
Hard work	2,200	1½

In order that the diver at all times may be apprised of the amount of oxygen remaining in the cylinder **6** a pressure gauge **52** is attached to the high pressure side of the valve casing **35** and registers the pressure or amount of oxygen remaining in the oxygen cylinder. To enable the diver more readily to know the amount of oxygen remaining in the cylinder, the gauge is not calibrated to indicate the pressure in pounds per square inch, but is calibrated to indicate the extent to which the cylinder **6** is full of oxygen, similar to the manner in which the ordinary gasoline gauge for an automobile is calibrated to indicate whether the gasoline tank is "full" or "empty," or contains an amount of gasoline somewhere between those extremes. For ease of reading, the pressure gauge is so positioned that the dial thereof faces towards the face of the wearer, and is provided with luminous markings and with a luminous indicating needle.

A canvas carrier **53** for a cannister **54** containing a carbon dioxide absorbent includes a main, transversely-extending pocket section **55** which is sewed to the rear vest section **2** along the upper edge **261** thereof only, and forwardly extending sections **56** which lie against and are sewed to the shoulder sections **3** of the vest-like harness.

The pocket section **55** of the carrier has an opening extending the full length thereof to give ready access to the cannister **54** for the purpose of removing spent or exhausted absorbent and for refilling the cannister with a fresh supply thereof. The opening preferably is closed by a slide fastener **57**.

When the breathing apparatus is in use, the main pocket section **55** of the carrier overlies the posterior base **26** of the breathing bag and is positioned at the back of the wearer's neck.

In order that this cannister **54** within the carrier may be connected to the breathing bag, the under side of the main pocket section **55** has a substantially circular opening **58** therethrough for the passage of a brass union **59** which connects the cannister to the breathing bag and forms an interconnecting passage for gases. To permit entrance of the union **59** into the opening **58**, the latter, as shown in Fig. 7, has an entrance neck **61** extending to the inner edge of the under side of the carrier pocket **55**, which is closed by a flap-like portion **62** of said under side. The flap-like portion **62** is fastened to the main portion of the underside of the carrier pocket by a pair of "Lift-the-dot" fasteners **63**.

If desired the carrier **54** may be reinforced by tapes or the like sewed to the inside thereof.

The carbon dioxide absorber is connected with the breathing mask by means of a pair of corrugated, flexible rubber breathing tubes. The tubes are of such construction to permit unrestricted

movement of the head in any direction. One of the breathing tubes **64** is an inhalation tube and extends from the right-hand end of the cannister **55** over the right shoulder to the mask. The other breathing tube **65** is an exhalation tube and extends from the breathing mask over the left shoulder to the left hand end of the cannister.

The structure of the carbon dioxide absorber is shown in Fig. 8. It comprises the cylindrical cannister **55**, one end **66** of which permanently is closed, while the other end is closed by a removable lid **67** having a flange **68** which forms a slip fit with the open end of the cannister. A packing ring **69** secured in a recess in the inner face of the lid **67** near the periphery thereof forms a gas-tight connection when the lid is pressed against the open end of the cannister.

In order to press the removable lid **67** tightly against the packing **69** to make a gas-tight joint, an axially extending rod **71** has one end screwed into an axial extension **72** of the end **66**, while the other end of the rod extends through a similar axial extension **73** of the removable lid **67**. A knurled thumb nut **74** threads onto the free end of the rod **71**. When the thumb nut **74** is screwed against the outer portion of the extension **73** the lid **67** is pressed tightly against the open end of the cannister to form a gas-tight connection.

The cannister is filled with soda lime **75** (a mixture of 60% granular calcium hydroxide coated with 5% sodium hydroxide, and 35% inert material), "Baralyme" (a granular mixture of 80% calcium hydroxide and 20% barium hydroxide), or other suitable material which has the property of selectively absorbing carbon dioxide from other gases. The absorbent is retained between removable wire mesh screens **76** and **77**, which retain the absorbent in place while permitting the exhaled gases to pass therethrough.

Gas passing through a body of absorbent has a tendency to form channels along the side wall of the surrounding container. In order to prevent such channelling and to insure proper circulation of the exhaled gases through the absorbent, two removable baffle rings **78** are inserted in the body of an absorbent during the filling operation. Such baffle rings prevent free circulation of the gases longitudinally of the cannister along the side wall thereof and divert the gases passing through the cannister into the center of the body of absorbent material. A large conical spring **79** between the end screen **77** and the removable lid exerts a constant pressure against the end of the body of absorbent and further prevents channelling of grating which would occur if the absorbent were loosely packed in the cannister.

The cannister is of such size as to contain an amount of carbon dioxide absorbent sufficient to absorb the carbon dioxide formed by the body when utilizing an amount of oxygen equal approximately to one and one-half times that contained in the oxygen cylinder **6**. However, it is preferred that the absorbent be replaced every time the oxygen in a cylinder **6** is consumed. Thus an ample excess of absorbent is provided to insure complete and satisfactory absorption of all carbon dioxide passing therethrough. That is important because it has been found that more than 1% of carbon dioxide in gases which are breathed has a deleterious effect upon the human system.

The cannister **55** is of such dimensions that the ratio of its diameter to its length is such as

to give maximum absorption of carbon dioxide to minimum resistance to the passage of exhaled gases through the absorbent contained therein.

The corrugated rubber exhalation tube 65 is connected to the extension 73 of the removable lid 67 by means of a short connector 81 secured thereto. The exhalation tube slips over the connector and is secured to it by appropriate clamping means. A metal partition plate 82 is clamped between the inner end of the connector 81 and the extension 73 of the lid. The plate is provided with perforations 83 for the passage of exhaled gases into the carbon dioxide absorber. Backward flow of gases from the absorber into the exhaling tube is prevented by a cupped rubber disk valve 84 at the inner side of the partition plate 82. The edges 85 of the valve 84 normally bear against the partition radially outwardly beyond the perforations 83. A stem 86 connected to the center of the valve passes through an opening in the center of the partition plate 82 and has a cut-off tail 87 at the outer side of the plate 82 to hold the valve in its normal position, shown in Fig. 8.

The edge 85 of the valve 84 bears against the plate 82 with such light pressure that the pressure created in the exhalation tube due to normal exhalation is sufficient to lift it and permit the passage of the exhaled gases thereunder and into the carbon dioxide absorber. However, a pressure on the other side of the valve, even though slight, presses the valve tighter against the plate 82 to form a better seal against the return flow of gases from the absorber into the exhalation tube.

At the other end of the carbon dioxide absorber the inhalation tube 64 is connected to the extension 72 by a connector 88. A perforated partition plate 89 is clamped between the inner end of the connector 88 and the extension 72 of the closed end 66 of the cannister. The partition plate 89 is formed with perforations 91 for the passage of purified gases from the closed end of the carbon dioxide absorber and from the breathing bag into the inhalation tube 64. Backward flow of gases from the inhalation tube into the closed end of the cannister is prevented by a cupped rubber disk valve 92, the edge 93 of which normally bears against the outer face of the partition plate, radially outwardly beyond the perforations 91. A stem 94 connected to the center of the valve 92 passes through an opening in the center of the partition plate 89 and has a cut-off tail 95 at the inner side of the partition plate to hold the valve in its normal position. The edge of the valve 94 like the edge 85 of the valve 84 bears against the partition plate 88 with such light pressure that the suction created by normal inhalation through the tube 64 is sufficient to cause the edge 93 to be lifted from the partition plate 89 sufficiently to permit flow of purified gases from the extension 72 into the inhalation tube.

The connector 88 has an inlet extension 96 to which the oxygen tube 51, which receives oxygen from the pressure reducing and regulating valve 34 and the supplemental oxygen valve, is connected, in order to continuously introduce into the respiratory system an amount of oxygen equal to the requirements of the wearer. The oxygen tube 51 between the valve 34 and the connector 88, is held against the right shoulder section 3, in an out-of-the-way position beneath the breathing bag, by a strap loop 97 having a free end detachably secured by a "Lift-the-dot" fastener.

As shown in Fig. 1, the mask 98 is of the full-face type. It is secured in place on the wearer's face by a mask harness including a rubber section 99 which lies flat against the back of the head and has three straps 100 extending forwardly from each side thereof, with their free ends attached adjacent the edges of the mask by buckles 101. By appropriately adjusting the several straps the mask can be caused to fit snugly against the wearer's face.

As stated above, since the pressure in the entire respiratory system, including the mask, at all times equals the hydrostatic pressure against the lowermost portion of the breathing bag, which is approximately a foot and a half below the level of the upper portion of the mask, the pressure within the mask exceeds the hydrostatic pressure against the outside of the mask by an amount equal to the pressure of approximately a foot and a half of water. Such pressure differential tends to cause an escape of gas from beneath the mask, which, if not prevented, would result in a loss and waste of oxygen.

In order to prevent the escape of gas from around the edges of the mask, a sealing flap 102 extends inwardly around the entire edge of the mask. The sealing flap is pressed against the wearer's face by the gas pressure within the mask being exerted against the inner side thereof, thus effectively sealing the edges of the mask against the escape of gases.

More efficient, and a wider range of visibility from within the mask is obtained by the provision of a single lens 103 of non-breakable plastic which extends at least the full width of both eyes.

As a person's eyes are not constructed to permit one to look side-walled, only one eye may be focused on any object at any one time when a pair of mask lenses positioned at an angle to each other are provided, due to the angle at which the rays strike the two lenses and are refracted to the two eyes. By the use of a single wide mask lens, both eyes always may focus on any object, thereby giving the wearer the proper perspective and preventing double vision.

The lens may be of the single or double type as desired. If spaced lenses are used there will be less danger of cloudiness or fogging on the inside of the lens due to the difference between inside and outside temperatures.

The lower portion of the mask is sealed with a gas-tight connection to an extension 104 extending from the top of a housing 105. The housing 105 has lateral extensions 106 and 107 to which the inhalation and exhalation tubes 64 and 65, respectively, are attached. A downwardly-directed extension 108 of the housing forms a collecting sump for water of condensation which collects in the respiratory system when worn in a relatively cold surrounding medium, such as the water in which divers must work, and which may be discharged through a water-drain valve. The housing 105 also carries a mask shut-off valve and a pressure relief valve, for purposes which will be described.

The water-drain valve is shown in detail in Fig. 11. It comprises a valve body 109 which is screwed into the lower end of the extension 108. The valve body has an inwardly extending cylindrical portion 110 extending upwardly into the extension 108 so that a trap or sump for water is formed between it and the inner wall of the extension. The cylindrical portion 110 is provided with spaced openings 111 through which water from the sump may pass to drain from the valve

when it is opened. A guide plate 112 having a central opening 113 for the valve stem is threaded into the inner end of the cylindrical portion 110.

The outer end of the valve body is formed with a cylindrical, open-ended extension 114 having spaced openings 115 for the drainage of water. The valve body is formed with a valve seat 116 against which the valve head 117 normally is seated under the influence of a coiled spring 118 interposed between it and the inner side of the guide plate 112. The valve stem is in two sections. One section 119 has a plate 120 permanently fixed thereto, against which the resilient valve member 117 is clamped by a nut 121. The outer end 122 of the valve stem screws onto a threaded extension of the inner end of the section 119. A push button or plate 123 is formed integrally with the outer section 122 of the valve stem and has a sliding fit with the inside of the open end of the cylindrical extension 114. A resilient rubber flap-disk 124 is secured to an intermediate portion of the outer section 122 of the valve stem.

Normally the position of the parts of the water-drain valve are as shown in Fig. 11, with the valve closed and the inner end of the section 119 of the valve stem extending into the guide opening 113 of the guide plate 112. Whenever it is desired to open the valve for the purpose of draining water from the system the push button or plate is pressed inwardly to lift the valve 117 from the seat 116, against the pressure of the spring 118. Simultaneously with the opening of the valve 117 the outer portion of the rubber flap-disk 124 bears against a shoulder 125 of the valve body 109 and an intermediate portion of the flap-disk bears against a shoulder 125 of the valve body 109, and an intermediate portion of the flap-disk bears against the conical seat 126 of the valve body. The disk 124 is of relatively thin rubber and does not bear against the shoulder 125 with sufficient pressure to prevent passage of water downwardly through the valve and through the discharge openings 113. However, the flap-disk will prevent water from the outside passing into the extension 103 while water of condensation is being drained therefrom, or, if the valve should be maintained open after all of such water has been drained from the sump within the extension, as any tendency of outside water to pass through the valve will cause the flap-disk to be pressed tightly against the seat 126 and form an effective seal against the entrance of such water.

An important feature of the invention is the means whereby the mask may be shut off from the remainder of the respiratory system when it is desired to take off the mask under water, when it is desired to open the atmospheric air-breathing valve, to be described, to permit the breathing of atmospheric air, or when it is desired to inflate the breathing bag for emergency flotation.

The mask shut-off valve is shown in detail in Fig. 11. It comprises a valve seat 127 threaded into an opening in the housing 105 through which gases inhaled through the inhalation tube 64, and gases exhaled into the exhalation tube 65 pass. Openings 128 in the base portion of the valve member normally permit the passage of such gases. The valve head 129 is secured at the inner end of a valve stem 130 which passes outwardly through an extension 131 formed on the front of the housing 105. A closure member 132 having openings 133 is threaded into the open end of the extension 131. The closure member has an outwardly directed neck portion 134 having bayonet slots 135 for engagement by studs 136 fixed to a knurled handle 137 to which the outer end of the valve rod 130 is secured.

A rubber diaphragm 138 is clamped by a nut 139 to an intermediate portion of the valve rod 130. The peripheral edge portion of the diaphragm is clamped against a shoulder of the extension 131 by the closure 132 to make a water-tight seal.

In normal operation of the respiratory system the knurled nut 137 is maintained in its inner position so that the valve head 129 is lifted from its seat for the free passage of gases from the inhalation tube 64 into the mask, and for the passage of exhaled gases from the mask to the exhalation tube for return to the respiratory system for recycling after purification. However, if the mask is to be taken off under water or atmospheric air is to be breathed, or if the breathing bag is to be inflated for emergency flotation the thumb nut 137 is turned to release the studs 136 from the bayonet slots, whereupon the valve rod is moved outwardly and the valve 129 closed. The diaphragm 138 being of rubber not only provides an effective water seal but also provides the necessary resiliency to permit the necessary longitudinal movement of the valve rod 130 when the valve is moved from open to closed position, and vice-versa. When the valve is in its closed position the diaphragm is in its normal unstrained position, but when the valve 129 is opened the diaphragm assumes a conical position as shown in full lines in Fig. 11. When the studs 136 are released from the bayonet slots the valve 129 is forced closed and maintained in that position by the pressure of the gases in the respiratory system.

A pressure relief or pop-off valve is positioned just behind the water-drain valve in order to prevent over distention or rupture of the breathing system when the mask shut-off valve is closed. As shown in Fig. 11 it comprises a valve body 141 having an inner threaded end which is screwed into an opening in the bottom of the housing 105 at the rear thereof. A packing gasket 142 insures a water-tight seal between the body 141 and the housing. A brass partition 143 having a sharp valve seat 144 is secured across the valve body 141 and is provided with spaced openings 145 for the passage of gases from the respiratory system when the valve is open. The valve head comprises a backing member 146 having a rubber disk 147 vulcanized or otherwise permanently secured thereto and a thin rubber flap-disk 148 which is secured to the disk 147 at the central portion only so that the outer portions are free. The valve head has a stem 149 attached thereto which is guided in an extension sleeve 151 of the partition 143. A cap member 152 is threaded onto the outer end of the valve body 141 and has a central threaded opening for the reception of a fine-adjustment plug 153 which is secured in adjusted position by a lock nut 154. A spring 155 interposed between adjustment plugs normally maintains the valve in its closed position and seals the respiratory system against escape of gases through the valve.

The pressure relief or pop-off valve is normally set to open when the internal pressure of the breathing system exceeds that of the surrounding medium by the equivalent of 50 inches of water so that when the pressure within the breathing system exceeds that amount the valve will be opened to permit the escape of excess oxygen from the system.

The pressure at which the relief valve will open can be very accurately adjusted. The threaded connection between the cap 162 and the valve body 141 provides a rough adjustment. After that adjustment is made the cap is locked to the valve body by a set screw 156. Thereafter the adjustment plug is screwed inwardly or outwardly to give an accurate adjustment of the pressure at which the valve will open.

The provision of the loose thin rubber flap 148 prevents the flow of water into the respiratory system while any excess oxygen is escaping therefrom. Even though the pressure within the breathing system normally would be greater than the surrounding hydrostatic pressure of the water when gas is being discharged through the pressure relief valve, it has been found, not withstanding, that frequently there is a tendency for water to enter the system. However any tendency of water to flow into the respiratory system through the valve immediately exerts a pressure on the outer of the thin disks 148 to seal the valve against such passage of water at that point.

In order to permit the breathing of atmospheric air rather than the oxygen in the breathing system, and thereby conserve the supply of oxygen, when one is not submerged in water nor in an atmosphere of noxious gases the mask is provided with an atmospheric-air breathing valve. As shown in Fig. 10 this valve comprises a collar 167 having an inner, outwardly directed flange 168 which is provided with a valve seat 169 at its inner periphery. The collar is secured in water-tight engagement with the mask by a clamping nut 161 and a clamping plate 162. The outer portion of the collar 167 is provided with diametrically opposite bayonet slots 163 for the reception of studs 164 carried by the inner end of a knurled thumb cap 165 having openings 166 for the passage of atmospheric air into the mask when the valve is open. A valve stem 167 is attached to the thumb cap 165 by a nut 168. The inner end of the valve stem carries a valve head 169 having a rubber, lead or other resilient surface 171 which is adapted to seat on the valve seat 169 when the valve is closed. A spring 172 interposed between the cap 165 and a spider 173 extending across the outer end of the collar 167 normally maintains the valve closed against the escape of gases from the breathing system, and the passage of water or surrounding gases thereinto. When it is desired to breath atmospheric air rather than the oxygen in the breathing system it is only necessary to push the cap 165 inwardly and rotate it sufficiently to bring the studs 164 into the offset portions of the bayonet slots, whereupon the valve is locked in its open position for the passage of atmospheric air into the mask. Of course, it will be understood that when the atmospheric air-breathing valve is open the mask shut-off valve will be closed to prevent the escape of oxygen from the breathing system.

I have found that under proper conditions water can be used as a medium for the propagation of sound waves. In order that the wearer of the present breathing apparatus may carry on a normal conversation with co-workers or others while under water the mask is provided opposite the wearer's mouth with voice-transmitting means. As shown in Fig. 12 such voice-transmitting means comprises a diaphragm 174 of suitable corrosion resistant metal, or the like which is clamped between an outwardly diverging brass mouth piece 175 and a metal, Bakelite or other resinous cap 176. The Bakelite cap is provided with a central aperture or opening 177 which permits water to flow into and fill the space 178 between the diaphragm 174 and the cap. The opening 177 also provides the necessary space for the passage of sound waves transmitted through the diaphragm 174. A clamping collar 179 firmly clamps the mask against a packing gasket 181 interposed between the mask and the base of the mouth piece 175 to form a water-tight seal.

It has been found that with a special diaphragm constructed and positioned as described above one's normal voice will carry through water for a distance of at least 75 yards, thereby readily enabling conversation to be carried on between workers under water.

A corrugated rubber tube 182 having openings 182' spaced about its periphery is secured within the posterior base section 28 of the breathing bag by attachment to an angular extension 59' of the brass union 59. The tube 182 prevents the bottom layer of the bag from collapsing against the bottom of the brass union 59 and preventing the free passage of gases in the respiratory system to and from the breathing bag. Thus it is impossible to trap oxygen in the breathing bag, as otherwise might happen when the diver lies on his right side. A relatively thick-walled latex rubber tube 183 likewise is secured within the breathing bag and extends from the forward end of one leg section thereof through the posterior base section and to the forward end of the other leg section of the breathing bag. If the opposite walls of the leg sections 27 should tend to collapse, as, for example, where they pass over the wearer's shoulders, a substantially V-shaped space will be formed at each side of the tube, as shown in Fig. 6 so that the gases within the respiratory system are free to flow to and from the anterior portions of both leg sections. If the tube 183 or other similar means for preventing the shutting off of the anterior ends of the leg sections from the base section of the breathing bag were not provided, it might happen that the walls of the leg sections might collapse against one another over the shoulders or elsewhere and form a closed pocket at their ends, with the result that the pressure in the respiratory system would not equal the exterior pressure on the lungs.

Means previously have been described for withdrawing water of condensation which collects in the sump or trap in the extension 188. In order to permit draining of any water from the breathing bag which may form as the result of condensation therein, or which may remain after a washing of the bag, a relatively rigid rubber outlet tube 184 is vulcanized or otherwise secured adjacent the lower end of each leg section 27 of the breathing bag. The outlet tubes 184 normally are closed by a plug 185 attached by means of a flexible cord 186 to anterior anchoring rings 187 secured to the leg section 27, in order to prevent their loss.

A pair of emergency inflation bladders 188 are secured to the front vest section at opposite sides of the pocket 5 for the oxygen cylinder by means of "Lift-the-dot" fasteners 189 which cooperate with male fastening members 189' secured to the front section 1. The inflation bladders 188 are connected for the free passage of gas from one to another by a connecting tube 191. Cylinders of compressed carbon-dioxide 192 are attached to the lower portion of each of the emergency infla-

tion bladders 188. A string with a pull-ring 193 extends from the trigger of each of the carbon-dioxide cylinders so that either one or both of them may be discharged to inflate the bladder. As shown in Fig. 15 each of the bladders, when in position on the front of the vest, are folded in three folds flat upon themselves and held in such folded position by means of straps 194 and readily releasable snap fasteners 195.

An oral inflation tube 196 extends from the upper end of the left emergency inflation bladder 188. The end of the tube normally is closed by a rotary valve 197. The inflation tube is of sufficient length to reach to the wearer's mouth, so that if an emergency flotation is to be made and the carbon dioxide cartridges 192 are empty the valve 197 may be opened and the end of the tube inserted in the wearer's mouth for oral flotation. The free end of the tube 196 is held in an out-of-the-way position beneath the left leg of the breathing bag by a strap loop 198 attached to the left shoulder section 3. To permit ready release of the tube the loop has a free end which is detachably secured by a "Lift-the-dot" fastener.

When the breathing apparatus is to be used, a cylinder of oxygen is inserted in the pocket 5 and connected to the respiratory system, as previously described. The breathing bag is then deflated as much as can be by pressing the opposite sides thereof together. The harness is then placed over the wearer's head and the front and back sections strapped to his torso, as described above, and the mask placed on his face and adjusted into close-fitting position by the mask harness straps 100. With the oxygen cylinder valve and the atmospheric-air breathing valve of the mask closed, and the mask shut-off valve open, the wearer inhales deeply to draw into his lungs as much of the residual air in the system as possible. The mask shut-off valve is then closed and the atmospheric breathing air valve opened, after which the wearer exhales to exhaust the previously inhaled gas to the atmosphere. After repeating that cycle of operations a few times, substantially all of the residual air remaining in the respiratory system can be exhausted. That is important, because if the nitrogen of the air initially in the breathing system were not purged, it would cause suffocation of the wearer should he fail to open the oxygen supply valve, or should the amount of oxygen in the cylinder be exhausted without the wearer noting that fact.

After the respiratory system has been purged of residual air, the mask shut-off valve is again closed and the atmospheric-air valve opened to permit the breathing of atmospheric air, while the oxygen-supply valve is opened and the respiratory system initially filled with oxygen, passing through the pressure-reducing and regulating valve 34. Thereafter, as much as possible of the atmospheric air within the lungs is exhausted as above described, whereupon the atmospheric air breathing valve is closed and the mask shut-off valve opened to thereafter permit breathing of the oxygen from the system.

On each inhalation the wearer will draw into his lungs a supply of substantially pure oxygen from the inhalation tube 64. As the valve 84 between the exhalation tube 65 and the carbon dioxide absorber prevents flow of gas from the carbon dioxide absorber into the exhalation tube 65, there will be relatively little, if any flow of gas, during an inhalation, from the exhalation tube into the breathing mask. When the inhaled gases subsequently are exhaled, they will pass from the mask through the exhalation tube 65, past the valve 84 and into the carbon dioxide absorber. Flow of the exhalated gases back into the inhalation tube is prevented by the valve 92 at the closed end of the carbon dioxide absorber, it being understood, of course, that with the valve 92 closed during an exhalation, the gases in the inhalation tube would have to be compressed in order for exhaled gases to pass into that tube, while such is not the case with respect to the passing of the inhalation gases in the exhalation tube.

The exhaled gases pass through the soda-lime or other absorbent in the cannister 54 and into the extension 72 at the closed end thereof, from which they pass through the interconnecting union 59 into the breathing bag which acts as a storage chamber for the purified gases until the next inhalation, when fresh oxygen, introduced into the connector 81 from the pressure-reducing and regulating valve, or from that valve and the supplemental supply valve, and a portion of the recycled and purified gases from the breathing bag pass through the inhalation tube 64 to the mask. The use of the breathing bag to act as a storage chamber for purified gases to be recycled is necessary due to the fact that there is a dwell or pause between an exhalation and the subsequent inhalation.

With the apparatus applied to a diver and the system working as just described, he is then free to descend in water to the desired depth to perform all desired tasks, and may move about freely to whatever extent may be necessary for that purpose. As the pressure in the entire respiratory system is equal to the pressure exerted through the chest wall onto the exterior of his lungs, he encounters no difficulty whatever either in inhaling or exhaling, regardless of what position he may assume.

As previously indicated the pressure-reducing and regulating valve 34 is set to constantly and continuously introduce into the respiratory system an amount of oxygen equivalent to that normally consumed by an adult when at rest. When the diver begins performing energy-consuming tasks, he opens the supplemental oxygen supply valve to the extent necessary to furnish to the respiratory system such additional amounts of oxygen as are required.

The diver may go about performing the desired tasks until they are completed, or until the supply of oxygen in the cylinder 6 is exhausted. Ordinarily just before the supply of oxygen is exhausted, he will swim to the surface.

If a diver is working at a depth of 60 feet, the pressure in the respiratory system, including the diver's lungs, will be at approximately three atmospheres. Hence, in order to reduce the pressure in the diver's lungs to correspond to the hydrostatic pressure exerted on the exterior of them through the chest wall, it will be necessary, as he ascends to the surface, to reduce the pressure in the respiratory system to the extent of two atmospheres. That can be done by intermittently opening the water-drain valve at the bottom of the extension 108 as he ascends to exhaust some of the gas from the respiratory system.

If at any time it is necessary to make an emergency flotation in a hurry, the ballast plate pocket 13 on the back vest section may be opened, as previously described, to permit the ballast plates to drop out. Also, the diver may pull one or both of the rings 193 to release the trigger of one or both of the carbon dioxide cartridges 192 to inflate the emergency flotation bladders

188. If for any reason the carbon dioxide cartridges should be empty, the emergency flotation bladders can be inflated through the oral tube 186, as previously described. When the diver reaches the surface, if he is not picked up immediately, he may close the discharge valve at the top of the oxygen cylinder, close the mask shut-off valve, and open the atmospheric-air breathing valve, so that while floating on the water, atmospheric air may be breathed through the mask.

I claim:

1. A harness for a breathing apparatus comprising vest-like front and rear sections of such size and shape as substantially to cover the front and back of the torso above the waist and connecting shoulder sections, means for securing said harness on the body, and a ballast-carrying pocket carried by said harness on the outside thereof and secured thereto in an inverted position, the opening to said pocket being at the lower side, and a flap for closing said pocket.

2. A harness for a breathing apparatus comprising vest-like front and rear sections of such size and shape as substantially to cover the front and back of the torso above the waist and connecting shoulder sections, means for securing said harness on the body, a ballast-carrying pocket carried by said harness on the outside thereof and secured thereto in an inverted position, the opening to said pocket being at the lower side, a flap for closing said pocket, and spaced means for releasably securing the flap to the pocket, said spaced means being releasable by an outward pull exerted on the flap at a point between them.

3. Breathing apparatus comprising a harness adapted to be secured to the body, a breathing bag including a posterior portion adapted to lie across the back and anterior portions adapted to extend over the shoulders, a breathing mask, a container for material for selectively removing carbon dioxide from exhaled gases, means for securing said container in a position to overlie the posterior portion of the breathing bag, means connecting one end of said container with the breathing bag, means including an inhalation conduit connecting the breathing bag to the breathing mask for the passage of gases to be inhaled, an exhalation tube connecting the breathing mask with the other end of said container, a source of oxygen carried by the harness, means for conducting oxygen from said source to the inhalation conduit, and a perforated and corrugated tube within the breathing bag and underlying said container, said tube spacing the walls of the breathing bag and preventing collapsing of the posterior portion thereof.

4. Breathing apparatus comprising a harness adapted to be secured to the body, a breathing bag including a posterior portion adapted to lie across the back and anterior portions adapted to extend over the shoulders, a breathing mask, a container for material for selectively removing carbon dioxide from exhaled gases, means for securing said container in a position to overlie the posterior portion of the breathing bag, means connecting one end of said container with the breathing bag, means including an inhalation conduit connecting the breathing bag to the breathing mask for the passage of gases to be inhaled, an exhalation tube connecting the breathing mask with the other end of said container, a source of oxygen carried by the harness, means for conducting oxygen from said source to the respiratory system, a perforated and corrugated tube within the posterior portion of the breathing bag and underlying said container, said tube spacing the walls of the breathing bag and preventing complete collapsing of said posterior portion thereof and means within those parts of said anterior portions of the breathing bag which are adapted to overlie the shoulders for preventing complete collapsing of them.

5. Breathing apparatus comprising a harness including front and rear sections and connecting shoulder sections, means for securing said harness to the body, a breathing bag secured to said harness, a breathing mask, a container for material for selectively removing carbon dioxide from exhaled gases, means for connecting one end of said container to the breathing bag, means including an inhalation conduit connecting the breathing bag to the breathing mask for the passage of gas to be inhaled, an exhalation tube connecting the breathing mask to the other end of said conduit, a source of oxygen carried by the front section of the harness, means for conducting oxygen from said source to the inhalation conduit, and a cover member for said container, said cover member including a pocket secured at its upper edge across the top of the back section of the harness and having its lower edge free of the back section said cover member having forwardly extending portions secured to the shoulder sections, the front section of the harness which carries the source of oxygen connecting to the same shoulder sections to which the forwardly-extending portions of said cover member are secured, whereby the weight of said container at the back of the harness and the weight of the source of oxygen at the front of the harness at least in part counterbalance one another when the breathing apparatus is secured to the body.

6. Breathing apparatus comprising a harness adapted to be secured to the body and including front and rear sections and connecting shoulder sections, a breathing bag carried by said harness, a breathing mask, a container for material for selectively removing carbon dioxide from exhaled gases positioned to extend across the top of the back section of the harness, means connecting one end of said container with the breathing bag, means including an inhalation conduit connecting the breathing bag to the breathing mask for the passage of gas to be inhaled, an exhalation tube connecting the breathing mask with the other end of said container, a source of oxygen carried by the front section of the harness, means for conducting oxygen from said source to the inhalation conduit, a cover member having a pocket for said container and forwardly extending portions secured to the shoulder sections of the harness, said cover member extending horizontally of the rear section of the harness and having its upper edge secured to said upper rear section and having its lower edge free thereof, said cover member having an opening to receive the connecting means between said container and the breathing bag, and a closure for the outer portion of said opening after the pocket of said cover has been placed about the container with said connecting means extending through said opening in the cover member, the front section of the harness which carries the source of oxygen connecting to the same shoulder sections to which the forwardly-extending portions of said cover member are secured, whereby the weight of said container at the back of the harness and the weight of the source of oxygen at the front

of the harness at least in part counterbalance one another when the breathing apparatus is secured to the body.

7. In breathing apparatus comprising a respiratory system including a breathing mask, a source of oxygen and means for conducting oxygen from said source to the breathing mask; the improvement which comprises valve means carried by the mask for exhausting water of condensation accumulating therein, manually-operable means for opening said valve, and means carried by a portion of said manually-operable means and operable simultaneously therewith for mechanically preventing fluid from surrounding fluid medium from passing into the mask when said valve is open.

8. Breathing apparatus comprising a breathing mask, a housing connected to said breathing mask, said housing having a main chamber in communication with the breathing mask and an auxiliary chamber into which oxygen is admitted for breathing and from which exhaled gases are exhausted, an oxygen inlet tube connected to said auxiliary chamber, means for conducting exhausted gases from said auxiliary chamber, a passage for gas between said main and auxiliary chambers, and a manually-operable valve for controlling the flow of gas through said passage, said manually-operable valve when closed sealing the apparatus against escape of oxygen when the breathing mask is not in place on the face of a person.

9. Breathing apparatus comprising a breathing mask, a housing connected to said breathing mask, said housing having a main chamber in communication with the breathing mask and an auxiliary chamber into which oxygen is admitted for breathing and from which exhaled gases are exhausted, an oxygen inlet tube connected to said auxiliary chamber, means for conducting exhausted gases from said auxiliary chamber, a passage for gas between said main and auxiliary chambers, a valve for controlling the flow of gas through said passage, a valve stem extending from said valve through an opposite wall of said housing, and manually-engageable means on the outer end of said valve stem for operating said valve, said manually-operable valve when closed sealing the apparatus against escape of oxygen when the breathing mask is not in place on the face of a person.

10. Breathing apparatus comprising a breathing mask, a housing connected to said breathing mask, said housing having a main chamber in communication with the breathing mask and an auxiliary chamber into which oxygen is admitted for breathing and from which exhaled gases are exhausted, an oxygen inlet tube connected to said auxiliary chamber, means for conducting exhausted gases from said auxiliary chamber, a passage for gas between said main and auxiliary chambers, a valve for controlling the flow of gases through said passage, a valve stem extending from said valve through an opposite wall of said housing, manually-engageable means on the outer end of said valve stem for operating said valve to move it from open to closed position and vice versa, and means for holding said valve in its full open or full closed position, said manually-operable valve when closed sealing the apparatus against escape of oxygen when the breathing mask is not in place on the face of a person.

11. Breathing apparatus comprising a breathing mask, a housing connected to said breathing mask, said housing having a main chamber in communication with the breathing mask and an auxiliary chamber into which oxygen is admitted and from which exhaled gases are exhausted, an oxygen inlet tube connected to said auxiliary chamber, means for conducting exhausted gases from said auxiliary chamber, a passage for gas between said main and auxiliary chambers, a valve for controlling the flow of gas through said passage, a valve stem extending from said valve through an opposite wall of said housing, manually-engageable means on the outer end of said valve stem for operating said valve to move it from open to closed position and vice versa, means resiliently urging said valve to one of its said positions, and means for holding said valve in the other of its said positions against the force of said resilient means, said manually-operable valve when closed sealing the apparatus against escape of oxygen when the breathing mask is not in place on the face of a person.

12. Breathing apparatus comprising a breathing mask, a housing connected to said breathing mask, said housing having a main chamber in communication with the breathing mask and an auxiliary chamber into which oxygen is admitted and from which exhaled gases are exhausted, an oxygen inlet tube connected to said auxiliary chamber, means for conducting exhausted gases from said auxiliary chamber, a passage for gas between said main and auxiliary chambers, a valve for controlling the flow of gas through said passage, a valve stem extending from said valve through an opening in the opposite wall of said housing, manually-engageable means on the outer end of said valve stem for operating said valve to move it from open to closed position and vice versa, and a flexible gas impervious diaphragm connected in gas-tight relation to said valve stem and to the portion of the housing surrounding the opening therein through which said valve stem passes, whereby a gas-tight connection is made between said handle and the housing.

13. Breathing apparatus comprising a breathing mask, a housing connected to said breathing mask, said housing having a main chamber in communication with the breathing mask and an auxiliary chamber into which oxygen is admitted and from which exhaled gases are exhausted, an oxygen inlet tube connected to said auxiliary chamber, means for conducting exhausted gases from said auxiliary chamber, a passage for gas between said main and auxiliary chambers, a valve for controlling the flow of gas through said passage, a valve stem extending from said valve through an opening in the opposite wall of said housing, manually-engageable means on the outer end of said valve stem for operating said valve to move it from open to closed position and vice versa, and a rubber diaphragm connected in gas-tight relation to said valve stem and to the portion of the housing surrounding the opening therein through which said valve stem passes, whereby a gas-tight connection is made between said handle and the housing.

14. Breathing apparatus comprising a breathing bag, a breathing mask, a housing connected to said breathing mask, said housing having a main chamber in communication with the breathing mask and an auxiliary chamber, a passage for gas between said main and auxiliary chambers, a conduit for gases to be inhaled connecting said breathing bag with said auxiliary chamber, a conduit for exhaled gases connecting said auxiliary chamber with the breathing bag,

and a manually-operable valve for controlling the flow of gas through said passage, said manually-operable valve when closed sealing the apparatus against escape of oxygen when the breathing mask is not in place on the face of a person.

15. Breathing apparatus comprising a breathing mask, a housing connected to the breathing mask, an oxygen inlet tube connected to said housing, means for exhausting exhaled gases from said housing, a valve for draining water from said housing, said valve including an inwardly facing valve seat surrounding a drain passage, a valve body normally held on said seat, a valve stem connected to said valve body and extending through said drain passage to a position external of said housing, a manually-operable actuating member on the outer end of said valve stem, and a relatively thin flexible diaphragm connected to the valve stem and extending outwardly therefrom at a position to be brought, mechanically, into position with an outer portion of the valve surrounding said drain passage simultaneously with the inward movement of the valve to lift the valve body from the valve seat to drain water from said housing, whereby reverse flow of the surrounding medium through said drain passage is prevented.

16. A harness for a breathing apparatus including vest-like front and rear sections of such size and shape as substantially to cover the front and back of the torso above the waist, shoulder sections connecting the front and back sections at each side, means for securing said front and back sections onto the body, and a container cover secured at its upper edge to the upper portion of the rear vest-like section and extending horizontally thereof and having its lower edge free of the rear vest-like section, said container cover having extensions extending along said shoulder sections and connected thereto, whereby the weight of a container in said cover is supported mainly from the shoulders.

17. Breathing apparatus comprising a breathing bag, a breathing mask, a housing connected to said breathing mask, said housing having a main chamber in communication with the breathing mask and an auxiliary chamber from which oxygen is inhaled and into which exhaled

gases pass and from which they are exhausted, a passageway for gas between said main and auxiliary chambers, means for conducting oxygen to be inhaled from said breathing bag to said auxiliary chamber, means for removing carbon dioxide from exhaled gases, means for conducting exhaled gases to said carbon dioxide-removing means, means for conducting exhaled gases from which carbon dioxide has been removed from said carbon dioxide-removing means to said breathing bag, and a manually-operable valve for controlling the flow of gas through said passageway, said valve, when closed, and when the mask is not on the face of a person, preventing the escape of oxygen from said auxiliary chamber.

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