

Jan. 13, 1942.

W. A. WILDHACK
RESPIRATORY APPARATUS

2,269,500

Filed Dec. 2, 1939

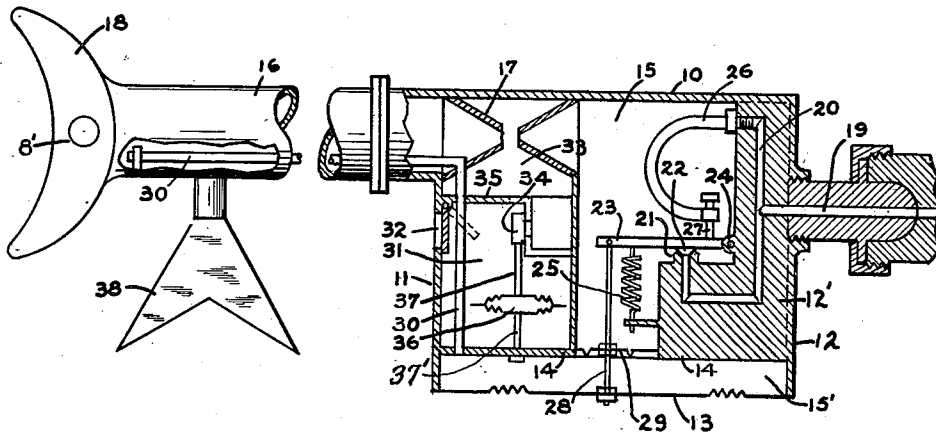


Fig. 1

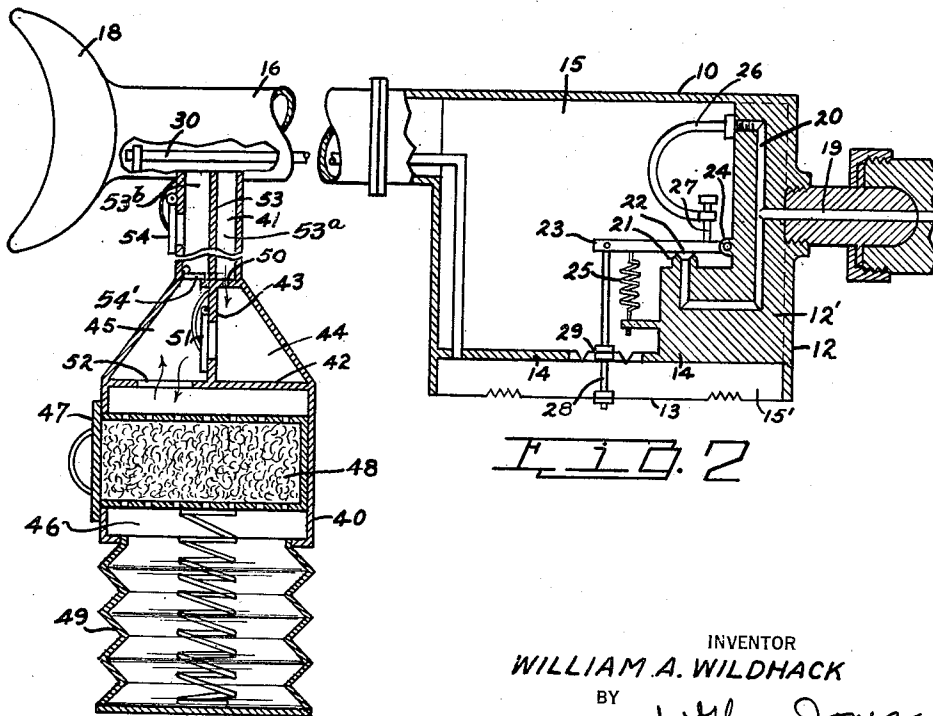


Fig. 2

INVENTOR
WILLIAM A. WILDHACK
BY

Wesley Jones
ATTORNEY

UNITED STATES PATENT OFFICE

2,269,500

RESPIRATORY APPARATUS

William A. Wildhack, Arlington, Va.

Application December 2, 1939, Serial No. 307,240

17 Claims. (Cl. 128—191)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

The present invention relates to respiratory apparatus such as is employed for high altitude flying, in submarine working and diving, and for medicinal and physiological purposes, wherein a respirant or other gas is delivered to the user or patient in predetermined quantities and at regulable pressures.

One of the main difficulties encountered in the design and use of the usual breathing apparatus is the necessity for the user to overcome by lung action the resistance to the flow of the circulating air. In order to avoid undue fatigue from breathing against this resistance, the pressure drop in the apparatus must be made low by using breathing tubes of large diameter.

One of the objects of the present invention is the provision of an improved apparatus, of the character described, wherein certain disadvantages previously encountered are avoided and which embodies in its construction a valve operable by differential pressure developed at a respiratory zone located remote thereto for controlling the high pressure supply of respirant with less breathing effort than was formerly required.

Another object of the invention is the provision of a respiratory device which may be used in a demand or intermittent type of apparatus and which may also be employed in a rebreathing or regenerator type of apparatus, achieving greater flexibility and convenience, by permitting the use of a relatively long conduit leading from the supply container and control valve to a respiratory zone at which point in the system a face mask, breathing bag, regenerator and the like may be located and in which these instrumentalities may be freely moved relative to the supply container when located remote thereto.

A further object of the invention is the provision of means for humidifying the air or other respirant so as to prevent irritation of the nasal and oral passages and lungs of the user.

A still further object of the invention is the provision in certain cases of a respiratory device in which means are provided for admitting controllable amounts of atmospheric air into the system for the purpose of diluting the respirant gas.

With these and other objects in view, as well as other advantages that may be incident to the use of the improvements, the invention consists in the parts and combinations thereof herein-after set forth and claimed, with the understanding that the several necessary elements constituting the same may be varied in proportion and arrangement without departing from the nature

and scope of the invention, as defined in the appended claims.

In order to make the invention more clearly understood, there are shown in the accompanying drawing, means for carrying the invention into practical use, without limiting the improvements in their useful application to the particular constructions, which, for the purpose of explanation, have been made the subject of illustration.

In the accompanying drawing:

Fig. 1 is a view partly in side elevation and partly in longitudinal section showing diagrammatically a respiratory apparatus of the demand or intermittent type embodying the invention, and

Fig. 2 is a similar view of an apparatus of the rebreather or regenerator type constructed in accordance with the invention.

Referring to the drawing, and particularly to Fig. 1 thereof, the improved respiratory apparatus is shown as comprising in its essentials, a casing 10 having end walls 11 and 12 and a flexible bottom wall or diaphragm 13. A partition 14 is provided interiorly of the casing 10 which extends parallel to the bottom wall 13 in spaced relation thereto, forming an upper receiving and delivering chamber 15 and a lower control chamber 15'. A flexible conduit 16 communicates at one end with the chamber 15 and at its other end with a mask 18 located at a remote point and adapted to fit over the face of the user. The mask 18 may be provided with a one-way outlet valve 18' if so desired.

A respiratory gas, such as oxygen, is admitted into the chamber 15 from a high pressure source of supply, through an inlet pipe 19 which communicates with a branch duct 20 formed in an enlargement or boss 12' of the end wall 12 of the casing. One end of the branch duct 20 terminates in a valve seat 21, communication through which is controlled by a valve member 22 carried by a lever 23 which is pivoted on the boss 12', as indicated at 24. This valve is urged toward its seated or closed position by a spring 25 and also by an expansible and contractible element, such as a Bourdon tube 26 or the like, which communicates at one end with the branch duct 20. The other end of the Bourdon tube 26 is provided with an adjusting screw 27 which bears against the lever 23 with a force sufficient to balance the pressure in the supply tank.

The valve 22 is opened in order to admit gas from the high pressure supply container, when necessary, by means of a rod 28 connected at one

end to the flexible wall 13 and at its other end with the lever 23. The rod 28, where it passes through the partition 14, is fixed to a flexible diaphragm 29 provided in the partition, thus permitting of its free movement with the flexing of the wall 13 and at the same time preventing leakage between the chambers 15 and 15'. The wall 13 is flexed, in order to actuate the valve 22, by differential pressure effected by the respiration of the user through the medium of a breather tube 30 which extends through the conduit 16, one end terminating adjacent to the mask 18 and the other end thereof communicating with the control chamber 15'. Thus, when the user inhales, the pressure within the control chamber 15' is reduced and the wall 13 is flexed inwardly. This moves the rod 28 upwardly, opening the valve 22 against the combined force of the spring 25 and the expansible element 26 so as to admit gas from the high pressure supply into the chamber 15 and thence through the conduit 16 to the mask 18.

The difference in pressure between the two ends of the conduit 16 depends on the rate of flow of the respirant and may in practical cases amount to several inches of water pressure. The difference in pressure between the ends of the tube 30 is, on the contrary, unaffected by this flow and, except for transient variations due to the movement of the diaphragm 13, is zero. The suction which must be developed by breathing effort is thus essentially only that necessary to open the valve 22, which in practice may be made as small as one-half inch of water, or less. Breathing fatigue is thus greatly reduced.

The oxygen thus supplied to the mask 18, is at times diluted with air from the outer atmosphere in amounts determined by the conditions under which the apparatus is employed. This diluting air is admitted from a chamber 31 located within the casing 10 which communicates with the outer atmosphere through a flap valve 32 provided in the wall 11 and with a chamber 33 through a valve 34 provided in the upper wall 35 of the chamber 31. The valve 34 is opened and closed with changes in the ambient pressure by means of an adjustably positioned aneroid capsule 36 connected therewith by a rod 37. The adjustment may be effected by means of a rod 37' secured to the capsule and threaded into the wall 14. If desired a Venturi tube or injector 17 may be employed to facilitate the introduction and metering of the air admitted into the system. By means of this construction when the wearer of the mask 18 inhales, he not only draws in a limited amount of oxygen, as previously described, but also a controllable quantity of air, the proportions being regulated by preliminary adjustments of the parts and by the pressure of the atmosphere, as in high altitude flying. In the latter case, as the ambient pressure decreases with an increase in altitude, the capsule 36 expands and gradually moves the valve 34 toward its closed position, thus restricting the admission of atmospheric air. Studies of the physiology of respiration have shown that for each altitude there is a minimum concentration of oxygen which must be provided in the air breathed, if normal oxygenation of the blood is to be maintained. This necessary concentration of oxygen for various altitudes are approximately: 20% at sea level, 27.5% at 10,000 feet, 50% at 20,000 feet, 60% at 25,000 feet, 80% at 30,000 feet, and 100% at 34,000 feet. It is a characteristic of the jet and Venturi structure shown that the proportion

of air drawn in to the oxygen delivered may be made nearly independent of the rate of delivery of oxygen, over the range of rates encountered in practice. The performance of the apparatus is thus not dependent on the variable respiratory characteristics of the user. The proportion of air drawn in is regulated only by the opening of the valve 34.

The diluter operation described is not dependent on the tube 30, which may, in some embodiments of the invention, be terminated at the outlet of the casing 10. In this case, the jet and Venturi 17 may also be omitted, the correct proportioning of admitted air being attained by empirical adjustment of the valves 32 and 34, and of the spring 25, to obtain air flow and oxygen delivery characteristics varying in like manner with the suction applied. The use of the jet and Venturi is, however, preferred.

In the use of apparatus not of the regenerative or rebreather type, discomfort is often experienced due to the drying and irritation of the mouth and nasal passages by the dry respirant supplied to the mask. To overcome this inconvenience, and to promote economy of the oxygen or other gas, in cases where substantially pure undiluted respirant is supplied, there may be provided a breather bag 38. This bag is fixed to and communicates with the conduit 16 adjacent to the mask 18 and has a volume considerably less than the normal lung capacity of the user, such as $\frac{1}{4}$ to $\frac{1}{2}$ liter. During exhalation, the first part of the exhaled air, which is humid, and high in content of the previously inhaled respirant and comparatively low in CO_2 content, is collected in the bag 38. The remainder of the exhaled gases are exhausted to the outside air through the relief valve 18' located in the mask or adjacent thereto. Subsequent inhalation of a mixture of this air from the bag and fresh respirant from the supply into the lungs provides a satisfactorily humid atmosphere, and may slightly reduce the quantity of respirant supplied. The presence of a small amount of CO_2 in the rebreathed air has the physiological effect of causing an increase in the pulmonary ventilation, so that using too large a breathing bag results in an actual decrease in economy. The use of the small bag permits a desirable combination of humidity and respirant and insures adequate inspiration since in the event of shallow breathing the CO_2 content in the bag increases and induces deeper breathing.

The breathing effort in the present device is much less than in that in other types due principally to the use of the tube 30 to control directly the suction operating the valve 22. It will be noted that the gas pressure acting on the valve 22 and tending to open the valve is balanced by the pressure in the elastic distensible member 26 tending to close the valve. The spring 25 also tends to hold the valve closed. The areas on which the gas pressure acts and the location of the points of application on the valve arm 23 are so chosen that the net closing force, for small or zero opening of the valve, is substantially that exerted by the spring and is thus independent of the supply pressure. The screw 27 may be adjusted, if desired, to place the distensible member 26 under compression so as to always exert a closing force upon the valve 22 that is greater than that of the gas pressure alone. In such cases, the spring 25 can be omitted.

In Fig. 2 there is shown a respiratory apparatus of the regenerator or rebreather type. In

this particular device the diluting instrumentalities including the chamber 31, valves 32 and 34 and aneroid capsule 36 and also the Venturi tube or injector 17 are omitted. The mechanism for controlling the flow of respiratory gas is, however, identical to that hereinabove described in connection with the apparatus shown in Fig. 1. Also, the breathing bag 38 shown in Fig. 1 is omitted and replaced by a regenerator comprising a casing 40 of light weight material which is communicably connected with the conduit 16 adjacent to the mask 18 by a pipe 41. The interior of the casing 40 is divided by a horizontal wall 42 and vertical partition 43 into an inlet chamber 44, an outlet chamber 45 and a regenerative chamber 46, the latter having a removable receptacle 47 slidably mounted therein. This receptacle is provided with perforated upper and lower walls and is adapted to contain a renewable absorbent 48, such as soda lime, lye, or other basic material or chemical capable of removing the CO₂ content of the exhaled air or removing the CO₂ with liberation of oxygen, as will presently be described. The lower portion of the casing 40 opens into an expansible and collapsible container or bellows 49 which is adapted to receive the exhaled air after passing through the absorbent 48. The pipe 41 is divided longitudinally by a wall or partition 53 so as to form an outlet passage 53^a and an inlet passage 53^b.

When the user of the apparatus exhales, the air passes from the mask 18 through the conduit 16, thence through the passage 53^a in the pipe 41 and a port 50 at the bottom thereof into the inlet chamber 44 of the casing 40. From this chamber the exhaled air passes through a one-way valve 51 in the vertical partition 43 into the outlet chamber 45 and thence through a port 52 in the horizontal wall 42 into the regenerative chamber 46, and thence through the absorbent 48 into the container 49 which expands so as to accommodate the same. Upon the succeeding inhalation the air from the chamber 49 passes again through the absorbent 48 in the regenerating chamber 46, and port 52 into the outlet chamber 45. From here the purified air passes through a valve 54 into the inlet passage 53^b and thence into the conduit 16 and thence to the mask. When inhalation occurs after the bellows 49 is collapsed, the breathing suction increases slightly in the mask 18, and therefore also in the control chamber 15', actuating valve 22 and allowing respirant gas to be forced through the chamber 15 and the conduit 16 to the user. When the flow of gas thus delivered exceeds the user's demand, the pressure at the mask 18, in the tube 30, and in the control chamber 15' increases, closing valve 22. If desired, a spring loaded one-way outlet valve 54 may be provided in the pipe 41 to permit air to escape to the outer atmosphere if the pressure within the apparatus becomes too great.

By suitably adjusting the several springs, the pressure exerted by the Bourdon tube 26, and the relative sizes of the diaphragms 29 and 13, the valve 22 may be caused to remain open until the pressure in the chambers 15 or 15', or both, is built up to a point somewhat above atmospheric before the valve is closed. This will insure that if the apparatus is employed in a poisonous atmosphere any leakage will be in an outward direction; and that the pressure in the chamber 15 will not become excessive.

A diaphragm or any other type of elastic distensible member can be used in place of the Bour-

don tube if so desired to urge the valve 22 closed and it may act directly on the valve arm 23 or indirectly through links or levers. By the use of a balanced valve, the delivery rate may be made great enough to supply the breathing demand even at very low supply pressures, thus economizing in the respirant gas by utilizing practically the entire supply. This also has the advantage of reducing the tendency for ice to form and the clogging of the valve by particles of foreign matter.

If desired, the force available to open the valve 22 may be increased by using a plurality of collapsible chambers acting in parallel on the valve, as well as by increasing the size of the single diaphragm 13 shown.

It will be understood that the above description and accompanying drawing comprehend only the general and preferred embodiment of the invention and that various changes in construction, proportion and arrangement of the parts may be made within the scope of the appended claims without sacrificing any of the advantages of the invention.

The invention described herein may be manufactured and/or used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

I claim:

1. A respiratory apparatus comprising a casing having a receiving chamber therein adapted to be communicably connected with a source of respirant gas under pressure; a breathing conduit communicating with said chamber and extending to a respiratory zone located remote thereto; valve means for controlling communication between said chamber and said source; a collapsible control chamber sealed from the atmosphere and from said receiving chamber; a control tube communicating with the interior of said control chamber and extending to a point adjacent to said respiratory zone for effecting a reduction of pressure in said control chamber and the collapse thereof upon a reduction of pressure at said respiratory zone; and means operable when said control chamber is thus collapsed for opening said valve means to admit gas to said receiving chamber.

2. A respiratory apparatus comprising a casing having a receiving chamber therein adapted to be communicably connected with a source of respirant gas under pressure; a breathing conduit communicating with said chamber and extending to a respiratory zone located remote thereto; valve means for controlling communication between said chamber and said source; a collapsible control chamber seal from the atmosphere and from said receiving chamber; a control tube communicating with the interior of said control chamber and extending along said conduit to a point adjacent to said respiratory zone for effecting a reduction of pressure in said control chamber and the collapse thereof upon a reduction of pressure at said respiratory zone; and means operable when said control chamber is thus collapsed for opening said valve means.

3. A respiratory apparatus comprising a casing having a receiving chamber therein adapted to be communicably connected with a source of respirant gas under pressure; a breathing conduit communicating with said chamber and extending to a respiratory zone located remote thereto; valve means for controlling communication between said chamber and said source; a

pressure responsive device sealed from the outer atmosphere and from said receiving chamber for actuating said valve; a control tube communicating with the interior of said pressure responsive device and with said respiratory zone for effecting a reduction of pressure in said pressure responsive device and the movement thereof upon a reduction of pressure at said respiratory zone, thus to open said valve; and means responsive to the pressure of the atmosphere for admitting air into said casing for mixture with the respirant gas.

4. A respiratory apparatus comprising a casing having a receiving chamber therein adapted to be communicably connected with a source of respirant gas under pressure; a conduit communicating with said chamber and extending to a respiratory zone located remote thereto; valve means for controlling communication between said chamber and said source; a collapsible control chamber; a tube communicating with said control chamber and extending to a point adjacent to said respiratory zone for effecting a reduction of pressure in said control chamber and the collapse thereof upon a reduction of pressure at said respiratory zone; means operable when said control chamber is thus collapsed for opening said valve means; and means responsive to the pressure of the atmosphere for admitting air into said casing for mixture with the respirant gas.

5. A respiratory apparatus comprising a casing having a receiving chamber therein adapted to be communicably connected with a source of respirant gas under pressure; a conduit communicating with said chamber and extending to a respiratory zone located remote thereto; valve means for controlling communication between said chamber and said source; a collapsible control chamber; a tube communicating with said control chamber and extending to a point adjacent to said respiratory zone for effecting a reduction of pressure in said control chamber and the collapse thereof upon a reduction of pressure at said respiratory zone; means operable when said control chamber is thus collapsed for opening said valve means; a valve for admitting air into said casing for mixture with the respirant gas; and an aneroid capsule responsive to atmospheric pressure for controlling said valve.

6. A respiratory apparatus comprising a casing having a receiving chamber therein adapted to be communicably connected with a source of respirant gas under pressure and with a respiratory zone; valve means for controlling communication between said chamber and said source; a collapsible and expansible control chamber sealed from the atmosphere and from said receiving chamber and communicating separately with said respiratory zone through a control tube extending from a position adjacent the respiratory zone to the interior of the control chamber; and means operable by the collapse of said control chamber for opening said valve means to admit gas to said receiving chamber.

7. A respiratory apparatus comprising a casing having a receiving chamber therein adapted to be communicably connected with a source of respirant gas under pressure and with a respiratory zone; valve means for controlling communication between said chamber and said source; a collapsible and expansible control chamber sealed from the atmosphere and from said receiving chamber and communicating separately with said respiratory zone through a control tube extending from

a position adjacent the respiratory zone to the interior of the control chamber; means operable by the collapse of said control chamber upon the inhalation of the user for opening said valve means to admit gas to said receiving chamber; and means for humidifying the air prior to its inhalation.

8. A respiratory apparatus comprising a casing having a receiving chamber therein adapted to be communicably connected with a source of respirant gas under pressure and with a respiratory zone; valve means for controlling communication between said chamber and said source; a collapsible and expansible control chamber sealed from the atmosphere and from said receiving chamber and communicating separately with said respiratory zone through a control tube extending from a position adjacent the respiratory zone to the interior of the control chamber; means operable by the collapse of said control chamber upon the inhalation of the user for opening said valve means to admit gas to said receiving chamber; an expansible storage chamber communicating with said respiratory zone for receiving exhaled air; and means for absorbing the carbon dioxide content in the exhaled air.

9. A respiratory apparatus comprising a casing having a receiving chamber therein adapted to be communicably connected with a source of respirant gas under pressure and with a respiratory zone; valve means for controlling communication between said chamber and said source; a collapsible and expansible control chamber sealed from the atmosphere and from said receiving chamber and communicating separately with said respiratory zone through a control tube extending from a position adjacent the respiratory zone to the interior of the control chamber; means operable by the collapse of said control chamber upon the inhalation of the user for opening said valve means to admit gas to said receiving chamber; and means for absorbing the carbon dioxide content in the exhaled air.

10. A respiratory apparatus comprising a casing having a receiving chamber therein adapted to be communicably connected with a source of respirant gas under pressure and with a respiratory zone; valve means for controlling communication between said chamber and said source; a collapsible and expansible control chamber sealed from the atmosphere and from said receiving chamber and communicating separately with said respiratory zone through a control tube extending from a position adjacent the respiratory zone to the interior of the control chamber; means operable by the collapse of said control chamber upon the inhalation of the user for opening said valve means to admit gas to said receiving chamber; and means including an expansible and contractible storage chamber communicating separately with said respiratory zone; and means for absorbing the carbon dioxide content of the air exhaled by the user.

11. A respiratory apparatus comprising a casing having a receiving chamber therein adapted to be communicably connected with a source of respirant gas under pressure and with a respiratory zone; valve means for controlling communication between said chamber and said source; a collapsible and expansible control chamber sealed from the atmosphere and from said receiving chamber and communicating separately with said respiratory zone through a control tube extending from a position adjacent the respiratory zone to the interior of the control chamber; means oper-

able by the collapse of said control chamber upon the inhalation of the user for opening said valve means to admit gas to said receiving chamber; and an expansible chamber having a volume substantially less than the normal tidal breathing volume of the user communicably connected with the apparatus for storing a limited amount of the first part of the air exhaled by the user for subsequent inhalation thereby.

12. A respiratory apparatus comprising a casing having a receiving chamber therein adapted to be communicably connected with a source of respirant gas under pressure and with a respiratory zone; valve means for controlling communication between said chamber and said source; a collapsible and expansible control chamber sealed from the atmosphere and from said receiving chamber and communicating separately with said respiratory zone through a control tube extending from a position adjacent the respiratory zone to the interior of the control chamber; means operable by the collapse of said control chamber for opening said valve means to admit gas to said receiving chamber; means for admitting atmospheric air into said apparatus; and a second expansible chamber having a volume substantially less than the normal tidal breathing volume of the user communicably connected with the apparatus for storing a limited amount of the first part of the air exhaled by the user for subsequent inhalation thereby.

13. A respiratory apparatus comprising a casing having a receiving chamber therein adapted to be communicably connected with a source of respirant gas under pressure; a breathing conduit communicating with said chamber and extension to a respiratory zone located remote thereto; valve means for controlling communication between said chamber and said source; a pressure responsive device sealed from the outer atmosphere and from said receiving chamber for actuating said valve; a control tube communicating with the interior of said pressure responsive device and with said respiratory zone for effecting a reduction of pressure in said pressure responsive device and the movement thereof upon a reduction of pressure at said respiratory zone, thus to open said valve; and means for admitting air from the outer atmosphere into said casing for mixture with the respirant gas substantially in proportion to the amount of respirant gas delivered.

14. A respiratory apparatus comprising a casing having a receiving chamber therein communicably connected with a source of respirant gas under pressure; a breathing conduit communicating with said chamber and extending to a respiratory zone located remote thereto; valve means for controlling communication between said chamber and said source; pressure responsive means sealed from the outer atmosphere and

from said receiving chamber and communicating separately with said respiratory zone through a control tube extending from a position adjacent the respiratory zone to the interior of the control chamber for operating said valve means in response to breathing suction, and means for admitting air from the outer atmosphere into said apparatus substantially in proportion to the amount of respirant gas delivered.

15. A respiratory apparatus comprising a casing having a receiving chamber therein communicably connected with a source of respirant gas under pressure; a conduit communicating with said chamber and extending to a respiratory zone located remote thereto; valve means for controlling communication between said chamber and said source; pressure responsive means sealed from the outer atmosphere and from said receiving chamber and communicating separately with said respiratory zone through a control tube extending from a position adjacent the respiratory zone to the interior of the control chamber for operating said valve means in response to breathing suction, and means responsive to the pressure of the atmosphere for admitting air from the outer atmosphere into said apparatus.

16. A respiratory apparatus comprising a casing having a receiving chamber therein communicably connected with a source of respirant gas under pressure; a conduit communicating with said chamber and extending to a respiratory zone located remote thereto; an injector in said conduit for drawing air from the outer atmosphere into said conduit; valve means for controlling communication between said chamber and said source; a control chamber sealed from the outer atmosphere and from said receiving chamber; and a control tube extending from the interior of said control chamber to said conduit at a point between said injector and said respiratory zone for operating said valve means in response to breathing suction.

17. A respiratory apparatus comprising a casing having a receiving chamber therein communicably connected with a source of respirant gas under pressure; a conduit communicating with said chamber and extending to a respiratory zone located remote thereto; an injector in said conduit for drawing air from the outer atmosphere into said conduit; valve means for controlling communication between said chamber and said source; a control chamber sealed from the outer atmosphere and from said receiving chamber; a control tube extending from the interior of said control chamber to said conduit at a point between said injector and said respiratory zone for operating said valve means in response to breathing suction, and means responsive to the pressure of the atmosphere for admitting air from the outer atmosphere into said apparatus.

WILLIAM A. WILDHACK.