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DIFFERENTIAL PRESSURE GAS SUPPLYING APPARATUS

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2 Sheets-Sheet 1

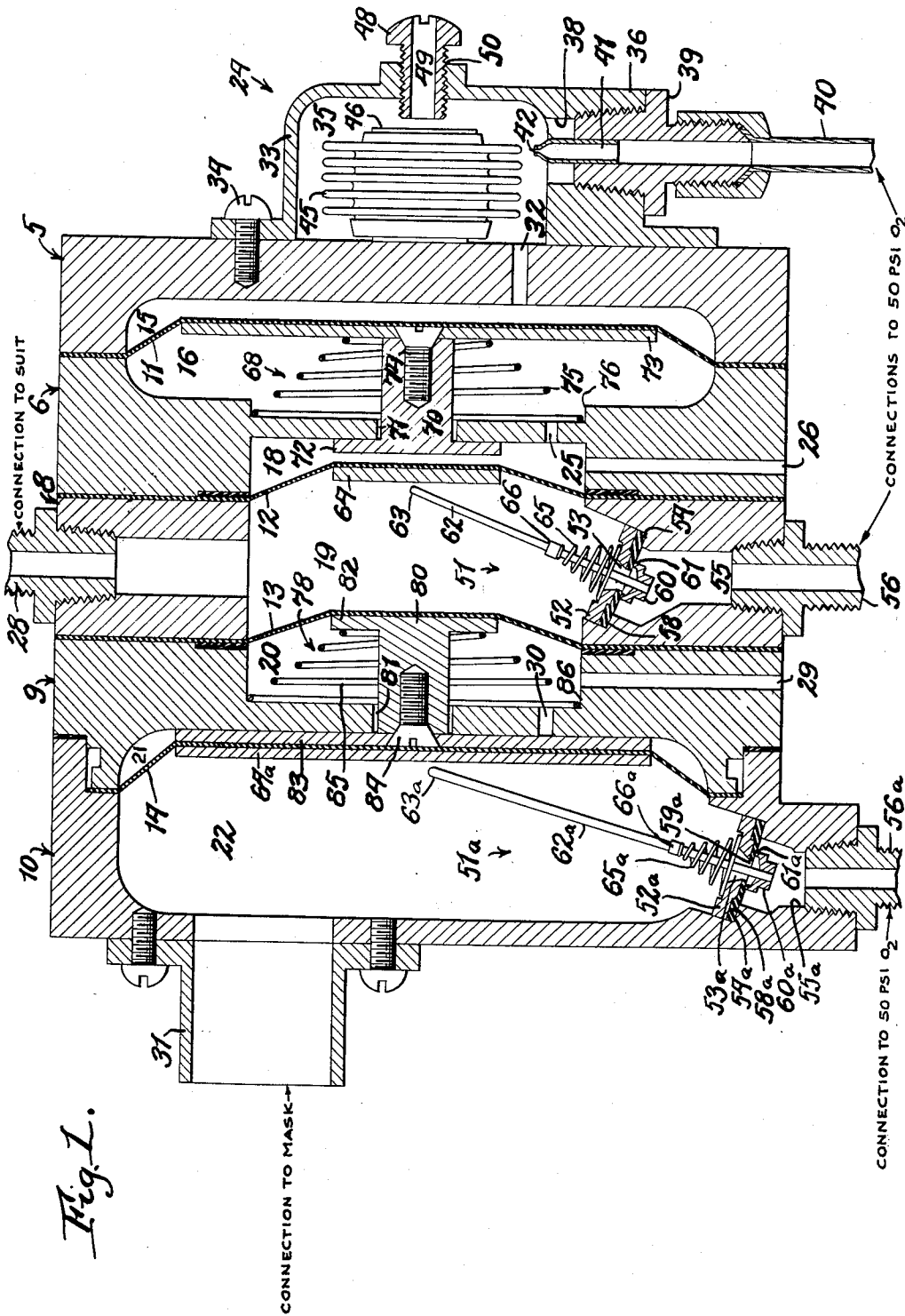


Fig. 1.

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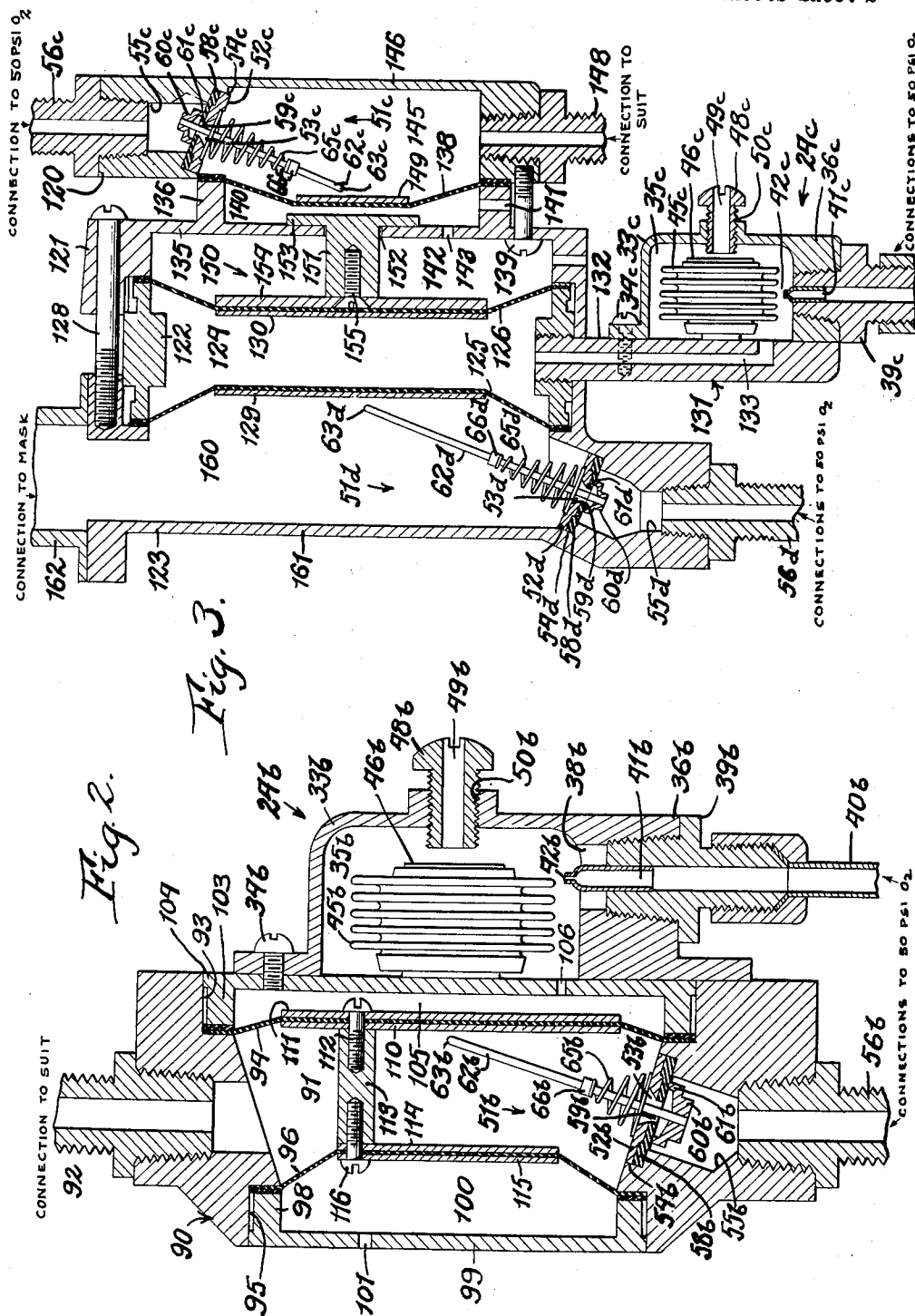
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DIFFERENTIAL PRESSURE GAS SUPPLYING APPARATUS

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19 Claims. (Cl. 137-64)

This invention relates to a differential pressure gas supplying apparatus and more particularly to such apparatus designed for use by high altitude aviators for maintaining the suit pressure in a so called partial pressure suit also known as a Henry suit. In the preferred form of the invention the apparatus also supplies oxygen for respiration at a predetermined minimum pressure and also applies this minimum pressure to the exterior of the respiratory organs through a so called belly bladder.

In flying at high altitudes, the pressure of 3.4 p. s. i. a. (pounds per square inch absolute) represents a critical value below which the aviator cannot go without pressure protection for his body since below this 3.4 p. s. i. a. a person's blood will boil at normal temperatures. 3.4 p. s. i. a. corresponds to an altitude of about 35,000 feet. This protection can be provided by a pressurized cabin for the airplane or by a so called full pressure suit or capsule which is in the form of a gas tight bag or capsule maintained at a minimum pressure of 3.4 p. s. i. a. This protection, in the practice of the present invention can also be provided by a so-called partial pressure or Henry suit. Such a partial pressure suit is in the form of a restraining garment having an inflatable bladder over the aviator's stomach area in which the pressure can be the same as in the mask from which the aviator withdraws oxygen for respiration, i. e. 3.4 p. s. i. a. The remainder of the suit, particularly around the arms and legs, include cords which alternately loop around the body and an inflatable tube. Increasing the gas pressure within the tube draws the body loop more tightly about the body so as to increase the restraining pressure. No restraining pressure is required until an altitude is reached which corresponds to 3.4 p. s. i. a. Above this altitude a suit pressure in the tubes of the suit is required which corresponds to a differential between the 3.4 p. s. i. a. minimum pressure and the ambient pressure. Thus the suit pressure should be the minimum pressure of 3.4 p. s. i. a. plus about four times the difference between this 3.4 p. s. i. a. and any lower ambient pressure, the specific apparatus herein-after described being calculated to provide a suit pressure, at lower than 3.4 p. s. i. a. ambient pressures, equal to five times this pressure of 3.4 p. s. i. a. less four times the lower ambient pressure.

It is also desirable to provide apparatus which in addition to providing suit pressure at a differential between such constant minimum pressure and ambient pressure also supplies gas at such constant minimum pressure for application to the belly bladder protecting the external parts of the respiratory organs of the user and also to supply such gas in the form of oxygen at such constant minimum pressure for inhalation by the user.

Also while no harm results from applying suit pressure before mask and belly bladder pressure, harm can result from applying mask and belly bladder pressure before suit pressure. Accordingly where both mask pressure and suit pressure is applied by the apparatus it is important

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to provide apparatus insuring that there is no mask or belly bladder pressure without suit pressure.

It is accordingly an object of the present invention to provide a differential pressure gas supplying apparatus which supplies gas at a constant predetermined minimum pressure of, say 3.4 p. s. i. a. and at a predetermined differential between this minimum pressure and ambient pressure, say, at a pressure equal to five times this minimum pressure less four times any lower ambient pressure.

Another object is to provide such apparatus which can be used, in aviation, for supplying suit pressure alone or suit pressure in combination with oxygen for inhalation by the user.

Another object, where both suit pressure and oxygen for respiration is supplied, is to provide apparatus in which the supply of oxygen under pressure for inhalation is a function of supplying suit pressure so that with no suit pressure there can be no mask or inhalation oxygen pressure.

Another object is to provide such apparatus which is rugged and sturdy and reliable in operation and at the same time is very sensitive in its response.

Other objects and advantages of the invention will be apparent from the following description and drawings in which:

Fig. 1 is a central longitudinal section through one form of apparatus embodying the present invention and adapted to supply oxygen to a mask at a constant minimum pressure which can also be maintained in the belly bladder and which also provides a suit pressure at a differential between ambient and this constant minimum pressure when this constant minimum pressure becomes greater than ambient pressure.

Fig. 2 is a view similar to Fig. 1 and showing a modification in which oxygen for breathing is not provided.

Fig. 3 is a view similar to Fig. 1 and showing a modified form of the invention which functions to produce the same results as the apparatus shown in Fig. 1.

FIG. 1

In the form of the invention shown in Fig. 1, the numerals 5, 6, 8, 9 and 10 represent a succession of sections of a casing or housing which can be of cylindrical form and with the circular sections having the central parts of their opposing faces recessed to provide a succession of diaphragm chambers within the casing. These chambers are completed by diaphragms indicated generally at 11, 12, 13 and 14, the marginal part of the diaphragm 11 being clamped between the marginal opposing faces of the casing sections 5, 6; the marginal part of the diaphragm 12 being clamped between the marginal opposing faces of the casing sections 6, 8; the marginal part of the diaphragm 13 being clamped between the marginal opposing faces of the casing sections 8, 9; and the marginal part of the diaphragm 14 being clamped between the marginal opposing faces of the casing sections 9, 10. The succession of casing sections 5, 6, 8, 9 and 10 with their so intercalated diaphragms 11, 12, 13 and 14 can be fastened together in any suitable manner.

A constant pressure chamber 15 is defined by the end casing section 5 and the diaphragm 11. An ambient air pressure chamber 16 is defined by the casing section 6 and the diaphragm 11. An ambient air pressure chamber 18 is defined by the casing section 6 and the diaphragm 12. A suit pressure chamber 19 is defined by the casing section 8 and the two diaphragms 12, 13. An ambient air pressure chamber 20 is defined by the casing section 9 and the diaphragm 13. An ambient air pressure chamber 21 is defined by the casing section 9 and the diaphragm 14. A mask pressure chamber 22 is

defined by the end casing section 10 and the diaphragm 14.

The pressure in the constant pressure chamber 15 is maintained at a constant pressure of, say, 3.4 p. s. i. a. by a regulating device indicated generally at 24. Ambient air pressure is maintained in the ambient air pressure chamber 16 by a bore or passage 25 providing communication between the chambers 16 and 18. Ambient air pressure is maintained in the ambient air pressure chamber 18 (and through 25 in 16) by a bore or passage 26 extending through the rim of the casing section 6 to the exterior thereof. Suit pressure is maintained in the suit pressure chamber 19 by a connection 28 to the suit of the aviator. Ambient air pressure is maintained in the ambient air pressure chamber 20 by a bore or passage 29 extending through the rim of the casing section 9 to the exterior thereof. Ambient air pressure is maintained in the ambient air pressure chamber 21 by a bore 30 through the casing section 9 and establishing communication between the chambers 20, 21. Mask pressure is established in the mask pressure chamber 22 by a connection 31 to the mask of the aviator.

It will particularly be noted that the diaphragms 12, 13 have substantially the same effective area but that the diaphragms 11, 14 are of larger effective area, the area of each of the diaphragms 11, 14 being preferably five times the effective area of either of the diaphragms 12, 13.

The constant pressure regulator 24 is preferably constructed as follows:

The numeral 32 represents a passage or hole in the casing section 5 and establishing continuous communication between the constant pressure chamber 15 and the interior chamber 35 of the pressure regulator 24. Chamber 35 is enclosed by a cup-shaped housing 33 having its rim secured, as by screws 34, to the exterior end face of the end casing section 5 to provide a chamber 35 communicating with the passage 32. One side of this cup-shaped housing 33 is thickened to provide a boss 36 having a through bore 38 in which a fitting 39 is screwed. This fitting connects with a, say, 50 p. s. i. g. (pounds per square inch gage) oxygen line 40 and a plug or restriction 41 in the fitting 39 provides a constant size orifice 42 which permits, say, 20 cubic centimeters per minute to flow from the 50 p. s. i. g. oxygen line 40 into the chamber 35. This chamber 35 is in constant communication with the constant pressure chamber 15 through a bore or passage 32.

A sealed bellows member or aneroid 45 is arranged in the chamber 35. This aneroid has a corrugated tubular wall enclosed by end heads one of which is secured to the end face of the end casing section 5 while the opposite end head, designated at 46, forms a valve head arranged to seat against the end of a tubular adjusting stem 48. This tubular adjusting stem is in the form of a screw having an axial through bore 49 and screwed into a threaded hole 50 in the cup-shaped casing 33 and which hole aligns with the axis of expansion of the aneroid 45.

Oxygen under a pressure of, say, 50 p. s. i. g. is also supplied under control of a demand valve indicated generally at 51 to the suit pressure chamber 19. This demand valve is shown as comprising a metal valve seat disk 52 which is provided with a coaxial conical through opening 53 and can be press fitted into a recess 54 in one side of the suit pressure chamber 19. The metal valve seat 52 is interposed between the suit pressure chamber and an oxygen supply bore or conduit 55 into the outer end of which is screwed the fitting 56 of a supply of oxygen under, say, 50 p. s. i. g. pressure. The metal valve disk 52 is provided on its side facing the bore 55 with a rubber facing or disk 58.

The valve head is in the form of a cup 60 with an axially extending rim 61 seated on the rubber facing 58. In the valve head 60 is anchored a valve stem or rod 62 which projects through the openings 59 and 53, and

has its rounded head 63 arranged in close proximity to the center of a metal disk 64 mounted centrally on the diaphragm 12.

It will be noted that the axis of the entire demand valve 51 is tipped with reference to the plane of the diaphragm plate 64. The movable parts of the demand valve are preferably yieldingly held in this tipped position, which is mean to the valve seat disk 52 and its rubber facing 58, by a spiral compression return spring 65, the small end of which bears against a small collar 66 press fitted on the rod 62 while its large end bears against the valve seat disk 52.

Oxygen under the same assumed pressure of 50 p. s. i. g. is also supplied under control of a demand valve indicated generally at 51a to the mask pressure chamber 22. The oxygen is supplied to this demand valve through a screw fitting 56a at the end of the oxygen supply line and screwed into a bore or conduit 55a in the end casing section 10. Except for size and location, the demand valve 51a is identical with the demand valve 51 and hence the same reference numerals have been used and distinguished by the suffix "a" and the description of this second demand valve is not repeated. Its rounded end 63a is arranged in close proximity to the center of a metal disk 64a mounted centrally on the diaphragm 14.

The numeral 68 represents a motion transmitting device or relay for transmitting motion from the large diaphragm 11 to the small diaphragm 12, this relay operating (when the larger diaphragm is moved to the left by the constant pressure assumed to be 3.4 p. s. i. a. in the chamber 15 preponderating over the ambient air pressure in the chamber 16) to first engage and then move the diaphragm 12 to the left thereby to move the stem 62 of the demand valve 51 to the left so as to cock its valve head 60 on the rubber facing 58 of the valve seat 52 and permit the flow of 50 p. s. i. g. oxygen from the inlet fitting 56 and bore 55 past the cocked valve head 60 and through the openings 59 and 53 into the suit pressure chamber 19.

This motion transmitting device or relay 68 is shown as comprising a stem 70 arranged in an oversize hole 71 at the center of the casing 6 and having, within the ambient air pressure chamber 18, a disk-like head 72 adapted to engage that face of the diaphragm 12 which encloses the chamber 18. A larger disk or head 73 is secured to the stem 70 by means of a screw 74, or in any other suitable manner. The larger disk or end head 73 is held in engagement with that face of the diaphragm 11 which encloses the ambient air pressure chamber 16 by a spiral compression spring 75. The large end of the spiral compression spring is seated in a recess 76 in the casing section 6 and its small end bears against the end head or disk 73 of the relay or motion transmitting device 68.

A generally similar relay or motion transmitting device 78 is operatively interposed between the diaphragms 13 and 14. This motion transmitting device 78 is generally similar to the motion transmitting device 68 and is shown as comprising a stem 80 arranged in an oversize hole 81 at the center of the casing section 9 and having, within the ambient air pressure chamber 20, a disk-like head 82 adapted to engage that face of the diaphragm 13 which encloses the chamber 20. A larger disk or head 83 is secured to the stem 80 by means of a screw 84 or in any other suitable manner. The smaller disk or end head 82 is held in engagement with that face of the diaphragm 13 which encloses the ambient air pressure chamber 20 by a spiral compression spring 78. The large end of the spiral compression spring is seated in a recess 86 in the casing section 9 and its small end bears against the end head or disk 82 of the relay or motion transmitting device 78.

Operation.—Fig. 1

With the form of the invention shown in Fig. 1, oxygen is supplied to the mask of the aviator in response to his demand. Thus the medium pressure oxygen from the

supply line fitting 56a to the bore 55a presses against the cup-shaped valve head 60a and holds its rim 61a firmly against the rubber facing 58a of the valve seat disk 52a. Accordingly the stem or rod 62a of this valve is held in a position perpendicular to this valve seat disk. In this position the rounded end 63a of this valve rod or stem is held in closely spaced relation to the center of the metal plate 64a on the diaphragm 14 on the side of this diaphragm enclosing the mask pressure chamber 22.

When the user of the mask inhales, the pressure in the mask is reduced and through the connection 31 to the mask the pressure in the mask pressure chamber 22 is reduced. Since ambient air pressure is impressed on the side of the diaphragm 14 forming the ambient air pressure chamber 21, this reduction in pressure in the chamber 22 moves the diaphragm 14 to the left and causes its plate 64a to contact and tip the stem 62a of the demand valve 51 laterally to the left. This tips the cup-shaped valve head 60a laterally and hence separates one side of the rim 61a of the valve head from the rubber facing 58a and permits the moderate pressure oxygen to escape through the valve openings 59a, 53a into the mask pressure chamber 22. This oxygen is inhaled by the user.

After the inhalation is complete, the pressure in the mask pressure chamber 22 rises, through the admission of moderate pressure oxygen past the demand valve 51a as above described, to the value of the pressure exerted against the side of the diaphragm 14 remote from the mask pressure chamber 22. When this counter-pressure against the diaphragm 14 is exceeded by the rising pressure of oxygen in the mask pressure chamber 22, the diaphragm 14 moves to the right. This moves the metal plate 64a out of contact with the free end 63a of the valve stem 62a and permits the valve parts to assume the closed position shown. In this position the valve head 60a is held firmly closed by the static pressure of the oxygen supply until the user again inhales to repeat the cycle just described.

At the altitude at which the aneroid 45 becomes operative, and at all higher altitudes, this aneroid maintains a constant pressure in the chamber 35 and hence, through the opening 32, in the constant pressure chamber 15. It will be assumed that this constant pressure is 3.4 p. s. i. a. this being close to the lowest limit which can be safely applied to the outside of the human body. This constant pressure is determined by the internal pressure in the enclosed or sealed aneroid 45 and the setting of the drilled screw 48.

Thus oxygen is supplied at the assumed 50 p. s. i. g. pressure through the fitting 39 to the restricted orifice 42. This orifice is proportioned to admit, say, 20 cubic centimeters per minute to the chamber 35. When the pressure being built up in the constant pressure chamber 35 exceeds the internal pressure of the aneroid 45 it contracts this aneroid axially until its end 46 moves away from the end of the adjusting tube or screw 48. When this occurs the oxygen escapes through the bore 49 of the screw 48 until the pressure in the chamber 35 falls to such value as to permit the internal pressure in the aneroid 45 to expand the aneroid axially and engage the screw end 48 to again seal the escape passage 49. The constant pressure so maintained in the chamber 35, through the passage 32 is maintained in the constant pressure chamber 15 and is impressed against the right hand side of the diaphragm 11.

When the airplane reaches an altitude of about 35,000 feet the ambient pressure drops to the 3.4 p. s. i. a. Accordingly at any altitude above this 35,000 feet, the diaphragm 11 is positioned to the left since constant pressure of 3.4 p. s. i. a. is maintained in the chamber 15 at one side of this diaphragm while the ambient pressure in the chamber 16 on the other side of this diaphragm is below this value. With the continued movement of the diaphragm 11 to the left, the relay or motion transmitting device 68, comprising the end plates 72, 73 connected by the stem 70, is moved to the left to contact and move to the left

the diaphragm 12. This continues until the plate 64 on this diaphragm 12 engages and moves to the left the free end 63 of the stem 62 of the demand valve 51. This tips the cup-shaped valve head 60 laterally and hence separates one side of the rim 61 of the valve head from the rubber facing 58 and permits the moderate pressure oxygen to escape through the valve openings 59, 53 into the suit pressure chamber 19.

When the suit pressure in the chamber 19 rises, through such admission of moderate pressure oxygen past the demand valve 51, to a sufficient value, the diaphragm 12 is moved by this rising pressure in the chamber 19 to the right until it releases the free end 63 of the demand valve 51 and permits this moderate pressure oxygen to cut off the further admission of moderate pressure oxygen from the fitting 56 to the suit pressure chamber 19.

The demand valve 51 so closes when the suit pressure in the chamber 19 builds up to a predetermined differential between the constant pressure of 3.4 p. s. i. a. maintained in the constant pressure chamber 15 and the ambient pressure maintained in the ambient pressure chambers 16 and 18. This differential is determined by the relative effective sizes of the diaphragms 11 and 12, as measured by the areas of their plates 73 and 64 respectively plus a portion of the unsupported areas of these diaphragms between these plate and the surrounding casing. It will be seen that the suit pressure maintained in the suit pressure chamber 19 by the demand valve 51 equals five times the constant pressure of 3.4 p. s. i. a. maintained in the chamber 15 less four times the ambient pressure maintained in the ambient pressure chambers 16, 18. Since the demand valve can only be effective after the ambient pressure drops below 3.4 p. s. i. a., this formula is only effective when ambient pressure is below the constant pressure maintained in chamber 15. It will be seen that this equation of suit pressure (chamber 19) being equal to five times the constant pressure (chamber 15) less four times the ambient pressure (chambers 16 and 18) is derived from the fact that the constant pressure (chamber 15) is impressed on the full area of the diaphragm 11, the effective pressure area of which is assumed to have a unit value of five whereas the ambient pressure (chamber 16) impressed on the opposite side of this diaphragm 11 having such effective unit area of five is countered by the ambient pressure (chamber 18) impressed against the diaphragm 12 having an effective unit area of one.

So long as the airplane is at an altitude less than 35,000 feet with an ambient pressure greater than 3.4 p. s. i. a. the demand valve 51a is opened and closed only in response to the respiratory demand of the user as first above described. When, however, this altitude is exceeded, the constant 3.4 p. s. i. a. pressure maintained in chamber 15 preponderates over the ambient air pressure in chambers 16, 18 to move the diaphragm 11, 12 to the left and to tip and open the demand valve 51. The rising pressure in the suit pressure chamber 19 caused by so opening the demand valve 51 effects a movement to the left of diaphragm 13. Through the relay comprising the plates 82, 83 and their connecting pin 80, this moves the diaphragm 14 to the left to tip and open the demand valve 51a. This demand valve admits moderate pressure oxygen to the mask pressure chamber 22, regardless of the respiratory demand, so as to maintain a minimum pressure of 3.4 p. s. i. a. in this mask pressure chamber 22.

It will be seen that at all times the demand valve 51a maintains a minimum mask pressure in the mask pressure chamber 22 of 3.4 p. s. i. a. due to the ratio of the sizes of the various diaphragm plates and to the fact that this 3.4 p. s. i. a. is assumed to be maintained in the constant pressure chamber 15. Thus the effective area of the diaphragm 14 is five times the effective size of the diaphragm 13 whereas the effective area of the diaphragm 11 is five times the effective size of the diaphragm 12.

and ambient pressure is between the pairs of diaphragms 11, 12 and 13, 14 with a constant pressure against the far side of the diaphragm 11 and a regulated suit pressure between the diaphragms 12, 13. With the ratio of sizes assumed it will be apparent that while the suit pressure in the suit pressure chamber 19 will be five times the assumed constant pressure of 3.4 p. s. i. a. (chamber 15) less four times the ambient pressure (chambers 16, 18) this suit pressure will also be five times the mask pressure (chamber 22) less four times the ambient pressure (chambers 21, 20). Accordingly, when ambient pressure is below the constant pressure in chamber 15, the mask pressure (chamber 22) will always equal the pressure in this chamber 15 and since this latter is assumed to be 3.4 p. s. i. a., a minimum constant pressure of 3.4 p. s. i. a. will always be maintained in the mask pressure chamber 22 so that a supply of oxygen is always available at this minimum pressure for inhalation. Of course, the pressure in the mask pressure chamber 22 goes below this minimum pressure of 3.4 p. s. i. a. each time the user inhales, this reduction in pressure serving to move the diaphragm 14 to open the demand valve 51a and admit the required amount of oxygen to supply each inhalation demand of the user.

FIG. 2

In the form of the invention shown in Fig. 2, the numeral 90 represents a casing or housing which can be of cylindrical form the interior chamber 91 of which is a suit pressure chamber. From this chamber 91, suit pressure is maintained by a connection 92 in the assumed partial pressure suit (not shown) of the aviator. The casing 90 is open-ended and at one end is provided with an enlarged recess 93 around the chamber 91 in which the marginal part of a diaphragm 94 is placed. At its other side this casing 90 is provided with an enlarged recess 95 around the chamber 91 and in this enlarged recess is fitted the marginal part of a diaphragm 96. The marginal part of the diaphragm 96 can be held in the recess 95 by the axially extending rim 98 of a cover or cap 99 which can be press fitted in the recess 95 thereby to form an ambient air pressure chamber 100 between this cover or cap 99 and the diaphragm 96. Ambient air pressure is maintained in the ambient air pressure chamber 100 by a vent 101 through the cap or cover 99.

The marginal part of the diaphragm 94 can be held in the recess 93 by the axially extending rim 103 of a cover or cap 104 which can be press fitted in the recess 93 thereby to form a constant pressure chamber 105 between this cover or cap 104 and the diaphragm 94. A constant pressure of, say, 3.4 p. s. i. a. is maintained in this chamber 105, through a passage or hole 106 in the cover or cap 104, by a regulating device indicated generally at 24b. This regulating device is identical to the regulating device 24 in the form of the invention shown in Fig. 1 and accordingly the same reference numerals have been employed and distinguished by the suffix "b." Also the description of the construction and parts of the regulating device 24b is not repeated, reference being made to the description of the regulating device 24.

Oxygen under an assumed pressure, of say, 50 p. s. i. g. is supplied under control of a demand valve indicated generally at 51b to the suit pressure chamber 91. The oxygen is supplied to this demand valve through a screw fitting 56b at the end of the supply line and screwed into a bore or conduit 55b in one side of the casing 90. The demand valve 51b is identical with the demand valve 51 in the form of the invention shown in Fig. 1 and hence the same reference numerals have been used and distinguished by the suffix "b" and the description of this demand valve 51b is not repeated.

The rounding end 63b of the stem 62b of this demand valve 51b is arranged in close proximity to the center of a disk 110 secured to the corresponding face of the diaphragm 94. A similar disk 111 is secured to the opposite

face of this diaphragm 94 and these disks are fastened by one or more screws 112 which extend through these disks and the diaphragm 94 and anchor in one or more spacers 113 arranged in the suit pressure chamber 91. The opposite end of each of the spacers 113 bears against a disk 114 which engages the corresponding face of the diaphragm 96. A disk 115 is disposed against the opposite face of this diaphragm 96 and these disks 114, 115 are fastened by a screw 116 which extends through these disks and the diaphragm 96 and anchor in the corresponding spacer 113. It will be seen that by the connection of the diaphragms 94, 96 through the connector or spacer 113 these diaphragms are compelled to move together. It is an important feature of the invention that the effective unit area of the diaphragm 94 as measured by the area of either disk 110 or 111 is five whereas the effective area of the diaphragm 96 as measured by the area of either disk 114 or 115 is four.

It will be noted that in this form of the invention oxygen is not supplied for breathing.

Operation.—Fig. 2

A constant pressure is maintained in the chamber 35b and hence, through the opening 106, in the constant pressure chamber 105. It will be assumed that this constant pressure is 3.4 p. s. i. a. As with the form of the invention shown in Fig. 1, this constant pressure is determined by the internal pressure in the enclosed or sealed aneroid 45b and the setting of the drilled screw 48b.

The oxygen at, say 50 p. s. i. g., supplied through the fitting 39b to the restricted orifice 42b is passed by this orifice at say 20 cubic centimeters per minute to the chamber 35b. When the pressure being built up in this constant pressure chamber 35b exceeds the internal pressure of the aneroid 45b it contracts this aneroid axially until its end 46b moves away from the adjusting tube or screw 48b. When this occurs the oxygen escapes through the bore 49b of the screw 48b until the pressure in the chamber 35b falls to such value as to permit the internal pressure in the aneroid 45b to expand the aneroid axially and engage the screw end 48b to again seal the escape passage 49b. The constant pressure so maintained in the chamber 35b, through the passage 106, is maintained in the constant pressure chamber 105 and is impressed against the right hand side of the diaphragm 94.

When the airplane reaches an altitude of about 35,000 feet the ambient pressure drops to the assumed 3.4 p. s. i. a. Then for any altitude above 35,000 feet the diaphragms 94, 96 move to the left since a constant pressure of 3.4 p. s. i. a. is maintained in the chamber 105 at one side of the diaphragm 94 while the ambient pressure in the chamber 100 on the other side of the diaphragm 96 is reducing below this value. With the continued movement of the diaphragms 94, 96 to the left, the plate 110 on the diaphragm 94 engages and moves to the left the free end 63b of the stem 62b of the demand valve 51b. This tips the cup-shaped head 60b laterally and hence separates one side of the rim 61b of the valve head from the rubber facing 58b and permits the medium pressure oxygen to escape through the valve openings 59b, 53b into the suit pressure chamber 91.

When the suit pressure in the chamber 91 rises, through such admission of moderate pressure oxygen past the demand valve 51b, to a sufficient value, the diaphragm 94, 96 are moved by this rising pressure in the chamber 91 to the right until the diaphragm 94 releases the free end 63b of the demand valve 51b and permits this demand valve to close and cut off further admission of moderate pressure oxygen to the suit pressure chamber 91.

The demand valve 51b so closes when the suit pressure in the chamber 91 builds up to a predetermined differential between the constant pressure of 3.4 p. s. i. a. maintained in the constant pressure chamber 105 and the ambient pressure maintained in the ambient pressure chamber 100. This differential is determined by the rela-

tive effective sizes of the diaphragm 94 and 96. It will be seen that the suit pressure maintained in the suit pressure chamber 91 by the demand valve 51b equals five times the constant pressure maintained in the chamber 105 less four times the ambient pressure maintained in the ambient pressure chamber 100. Since the demand valve 51b can only be effective after the ambient pressure drops below 3.4 p. s. i. a., this formula is only effective when ambient pressure is below the constant pressure maintained in chamber 105. It will be seen that this equation of suit pressure (chamber 91) being equal to five times the constant pressure (chamber 105) less four times the ambient pressure (chamber 100) is derived from the fact that the constant pressure (chamber 105) is impressed on the full area of the diaphragm 94, the effective pressure area of which is assumed to have a unit value of five whereas the ambient pressure (chamber 100) is impressed as a counter against the diaphragm 96 having an effective unit area of four.

FIG. 3

In the form of the invention shown in Fig. 3 the numerals 120, 121, 122 and 123 represent a succession of sections of a casing or housing each of which can be of cylindrical form. The section 122 defines a constant pressure chamber 124 which is completed by a pair of diaphragms 125 and 126 the marginal parts of which are disposed against the axially facing faces at the rim of the casing section 122. The marginal part of the diaphragm 125 is held against the casing section 122 by the end casing section 123 and the marginal part of the diaphragm 126 is held against the casing section 122 by the casing section 121. The casing sections 121, 123 are secured together to hold the marginal parts of the diaphragms 125, 126 in compressive relation with the casing section 122 by a plurality of screws 128.

A circular plate 129 is secured to the diaphragm 125 centrally on its side opposite the constant pressure chamber 124. Similarly a disk or plate 130 is secured centrally to that face of the diaphragm 126 which forms the constant pressure chamber 124. Preferably the diaphragms 125 and 126 and the disks 129 and 130 are of the same effective size.

The pressure in the constant pressure chamber 124 is maintained at a constant pressure of, say, 3.4 p. s. i. a. by a regulating device indicated generally at 24c and which is constructed generally similarly to the pressure regulating device, Fig. 1. The numeral 131 represents a fitting having an externally threaded neck screwed into a threaded hole through one side of the casing section 122 so that this neck is in communication with the constant pressure chamber 124. The fitting 131 enlarges and is formed to provide a circular flat face 132 at one side. A passage 133 extends from this flat face 132 through the neck 131 to the constant pressure chamber 124.

To this flat face 132 is secured the constant pressure regulating device 24c. Since this constant pressure regulating device 24c is identical to the constant pressure regulating device 24 in the form of the invention shown in Fig. 1, the description is not repeated, the corresponding parts of the constant pressure regulating device 24c being distinguished by the suffix "c."

The casing section 121 is provided with an end wall 135 from the central part of which a rim 136 projects axially outward. The marginal part of a diaphragm 138 is arranged against the axially facing end of this rim 136 and is held thereagainst by the casing section 120. The rim 136 of the casing section 121 and the casing section 120 are held in compressive relation with the marginal part of the diaphragm 138 by one or more screws 139 which secure the casing sections 120, 121 to each other. The diaphragm 138 forms with the wall 135 of the casing section 121 an ambient air pressure chamber 140. Ambient air pressure is maintained in this ambient air pressure chamber 140 by a vent 141 through the rim of the casing

section 121. Ambient air pressure is also maintained in the chamber 142 between the diaphragm 126 and the wall 135 by an opening 143 in this wall 135 and establishing communication between the chambers 140 and 142.

The chamber 145 between the diaphragm 138 and the end wall 146 of the casing section 120 is a suit pressure chamber. Suit pressure is maintained in this suit pressure chamber 145 by a connection 148 to the suit of the aviator.

Oxygen under a pressure of, say, 50 p. s. i. is supplied under control of a demand valve indicated generally at 51c to the suit pressure chamber 145. The oxygen is supplied to this demand valve through a screw fitting 56c at the end of the oxygen supply line and screwed into a bore or conduit 55c in the end casing section 120. The demand valve 51c is identical with the demand valve 51 of the form of the invention shown in Fig. 1 and hence the same reference numerals have been used and distinguished by the suffix "c" and the description of this demand valve 51c is not repeated. The rounding end 63c of its stem 62c is arranged in close proximity to the center of a metal disk 149 secured to the diaphragm 138.

The numeral 150 represents a motion transmitting device or relay from the large diaphragm 126 to the small diaphragm 138, this relay operating (when the larger diaphragm is moved to the right by the constant pressure assumed to be 3.4 p. s. i. a. in the chamber 124 preponderating over the ambient air pressure in the chamber 142) to first engage and then move the diaphragm 138 to the right thereby to move the stem 62c of the demand valve 51c to the right so as to cock its valve head 60c on the rubber facing 58c of the valve seat or disk 52c and permit the flow of 50 p. s. i. g. oxygen from the inlet fitting 56c and bore 55c past the cocked valve head 60c and through the openings 59c and 53c into the suit pressure chamber 145.

This motion transmitting device or relay 150 is shown as comprising a stem 151 arranged in an oversize hole 152 at the center of the wall 135 and having, within the ambient air pressure chamber 140 a disk-like head 153 adapted to engage that face of the diaphragm 138 which encloses the chamber 140. A larger disk or head 154 is secured to the stem 151 by means of a screw 155, or in any other suitable manner. The larger disk or head 154 engages with that face of the diaphragm 126 which encloses the ambient air pressure chamber 142.

A mask pressure chamber 160 is formed between the diaphragm 125 and the end wall 161 of the casing section 123. Mask pressure is maintained in the mask pressure chamber 160 by a connection 162 to the mask of the aviator. Oxygen under the same assumed pressure of 50 p. s. i. is also supplied under control of a demand valve indicated generally at 51d to the mask pressure chamber 160. The oxygen is supplied to this demand valve through a screw fitting 56d at the end of the oxygen supply line and screwed into a bore or conduit 55d in the end casing section 123. This demand valve 51d is substantially identical with the demand valve 51 of the form of the invention shown in Fig. 1 and hence the same reference numerals have been used and distinguished by the suffix "d" and the description of this second demand valve is not repeated. The rounding end 63d of its stem 62d is arranged in close proximity to the center of the metal disk 129.

Operation.—Fig. 3

In the operation of the form of the invention shown in Fig. 3, a constant pressure is being maintained in the chamber 124. Thus oxygen is supplied at the, say, assumed 50 p. s. i. g. pressure through the fitting 39c to the restricted orifice 42c. This orifice is proportioned to admit, say, 20 cubic centimeters per minute to the chamber 35c. When the pressure being built up in the constant pressure chamber 35c exceeds the internal pres-

sure of the aneroid 45c it contracts this aneroid axially until its end 46c moves away from the end of the adjusting tube or screw 48c. When this occurs the oxygen escapes through the bore 49c of the screw 48c until the pressure in the chamber 35c falls to such value as to permit the internal pressure in the aneroid 45c to expand the aneroid axially and engage the screw end 48c to again seal the escape passage 49c. The constant pressure so maintained in the chamber 35c, through the passage 133, is maintained in the constant pressure chamber 124 and is impressed against the opposing faces of the diaphragms 125, 126. As with the other forms of the invention it will be assumed that a pressure of 3.4 p. s. i. a. is maintained in the constant pressure chamber 124.

As with the form of the invention shown in Fig. 1, oxygen is supplied to the mask of the aviator in response to his demand, but only in response to an inhalation that reduces the pressure in the mask pressure chamber 160 below the pressure in chamber 124. Thus, the medium pressure oxygen from the supply line fitting 56d presses against the cup-shaped valve head 60d and holds its rim 61d firmly against the rubber facing 58d of the valve seat disk 52d. Accordingly the stem or rod 62d of this valve is held in a position perpendicularly to this valve seat disk. In this position the rounded end 63d of this valve rod or stem is held in closely spaced relation to the center of the metal plate 129 of the diaphragm 125 on the side of this diaphragm enclosing the mask pressure chamber 160. When the user of the mask, through the connection 162, inhales to reduce the pressure in this chamber 160 below 3.4 p. s. i. a. this reduction in pressure in the chamber 160 moves the diaphragm 125 to the left and causes its plate 129 to contact and tip the stem 62d of the demand valve laterally to the left. This tips the cup-shaped valve head 60d laterally and hence separates one side of the rim 61d of the valve head from the rubber facing 58d and permits the moderate pressure oxygen to escape through the valve openings 59d, 53d into the mask pressure chamber 160. This oxygen is inhaled by the user.

After the inhalation is complete, the pressure in the mask pressure chamber 160 rises, through the admission of moderate pressure oxygen past the demand valve 51d as above described, to the value, namely 3.4 p. s. i. a., of the pressure exerted against the side of the diaphragm 125 remote from the mask pressure chamber 160. When this counter-pressure against the diaphragm 125 is exceeded by the rising pressure of oxygen in the mask pressure chamber 160, the diaphragm 125 moves to the right. This moves the metal plate 129 out of contact with the free end 63d of the valve stem 62d and permits the valve parts to assume the closed position shown. In this position the valve head 60d is held firmly closed by the pressure of the oxygen supply until the user again inhales to repeat the cycle just described.

When the airplane reaches an altitude of about 35,000 feet the ambient pressure drops to 3.4 p. s. i. a. Then for any altitude above 35,000 feet the diaphragm 126 moves to the right since a constant pressure of 3.4 p. s. i. a. is maintained in the chamber 124 at one side of this diaphragm while the ambient pressure in the chamber 142 on the other side of this diaphragm is reducing below this value. With the continued movement of the diaphragm 126 to the right, the relay or motion transmitting device 150, comprising the end plates 153, 154 connected by the stem 151, is moved to the right to contact and move to the right the diaphragm 138. This continues until the plate 149 on this diaphragm 138 engages and moves the free end of the stem 61c of the demand valve 51c. This tips the cup-shaped valve head 60c laterally and hence separates one side of the rim 61c of the valve head from the rubber facing 58c and permits the moderate pressure oxygen to escape through the valve openings 59c, 53c into the suit pressure chamber 145. When the suit pressure in the chamber 145

rises, through such admission of moderate pressure oxygen past the demand valve 51c, to a sufficient value, the diaphragm 138 is moved by this rising pressure in the chamber 145 to the left until it releases the free end 63c of the demand valve 51c and permits this demand valve to close and cut off the further admission of moderate pressure oxygen from the fitting 56c to the suit pressure chamber 145.

The demand valve 51c so closes when the suit pressure in the chamber 145 builds up to a predetermined differential between the constant pressure of 3.4 p. s. i. a. maintained in the constant pressure chamber 124 and the ambient pressure maintained in the ambient pressure chambers 142 and 140. This differential is determined by the relative effective sizes of the diaphragms 126 and 138. It will be seen that the suit pressure maintained in the suit pressure chamber 145 by the demand valve 51c equals five times the constant pressure of 3.4 p. s. i. a. maintained in the chamber 124 less four times the ambient pressure maintained in the ambient pressure chambers 142, 140. Since the demand valve can only be effective after the ambient pressure drops below 3.4 p. s. i. a., this formula is only effective when ambient pressure is below the constant pressure maintained in chamber 124. It will be seen that this equation of suit pressure (chamber 145) being equal to five times the constant pressure (chamber 124) less four times the ambient pressure (chambers 142, 140) is derived from the fact that the constant pressure (chamber 124) is impressed on the full area of the diaphragm 126, the effective pressure area of which is assumed to have a unit value of five whereas the ambient pressure (chamber 142) impressed on the disk 154 which is on the opposite side of this diaphragm 126 is countered by the ambient pressure (chamber 140) impressed against the diaphragm 138 having an effective unit area of one. As with the form of the invention shown in Fig. 1 it will be seen that the apparatus shown in Fig. 3 insures that both mask pressure and suit pressure are supplied at the same time. Thus in the event of failure of the constant pressure maintaining device 24c to maintain the assumed 3.4 p. s. i. a. in the chamber 124, neither of the demand valves 51c or 51d will be operative. Similarly in the event of failure of the moderate pressure oxygen supply, again it will be seen that neither of these demand valves will be operative. Accordingly it is impossible to have mask pressure without suit pressure.

From the foregoing it will be seen that the present invention provides a simple and effective differential pressure gas supplying apparatus which accomplishes the various objectives set forth. It will also be seen that the invention can be widely varied as to its details of construction and the invention is therefore not to be construed as limited to the particular embodiment shown and described but is to be accorded the full range of the equivalents comprehended by the accompanying claims.

What is claimed is:

1. A differential pressure gas supplying apparatus for maintaining the suit pressure of an aviator flying at high altitudes at a differential between ambient pressure and the critical minimum pressure at which one's blood would boil at normal temperatures, comprising a hollow casing, an internal movable wall across the interior of said casing dividing said casing into two chambers and moved essentially in response to the pressure differential in said chambers, means arranged to maintain a constant pressure approximately said critical minimum pressure in one of said chambers, means arranged to maintain ambient pressure in the other of said chambers, and means responsive to the movement of said movable wall in response to a differential in said pressures and arranged to produce said suit pressure.

2. A differential pressure gas supplying apparatus for maintaining the suit pressure of an aviator flying at high altitudes at a differential between ambient pressure and

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the critical minimum pressure at which one's blood would boil at normal temperature, comprising a hollow casing, an internal movable wall across the interior of said casing dividing said casing into two chambers and moved essentially in response to the pressure differential in said chambers means arranged to maintain a constant pressure approximately said critical minimum pressure in one of said chambers, means arranged to maintain ambient pressure in the other of said chambers, and means arranged to produce said suit pressure, said last means being responsive to the movement of said movable wall in a direction to contract said ambient pressure chamber under a preponderating pressure in said constant pressure chamber.

3. Apparatus as set forth in claim 2 wherein said movable wall is in the form of a flexible diaphragm.

4. A differential pressure gas supplying apparatus for maintaining the suit pressure of an aviator flying at high altitudes at a differential between ambient pressure and the critical minimum pressure at which one's blood would boil at normal temperature, comprising a hollow casing, at least two internal movable walls across the interior of said casing dividing said casing into at least three chambers and moved essentially in response to the pressure differential in said chambers, means arranged to maintain a constant pressure approximating said critical minimum pressure in one of said chambers, means arranged to maintain ambient pressure in another of said chambers, a demand valve arranged to admit gas under pressure to the third of said chambers to produce said suit pressure, and means arranged to open and close said demand valve in response to the joint movement of said movable walls.

5. Apparatus as set forth in claim 4 wherein said constant pressure chamber is an end chamber, wherein said ambient pressure chamber is the other end chamber, wherein said third of said chambers is between said end chambers, and wherein said means arranged to open and close said demand valve in response to the joint movement of said movable walls includes means connecting said internal movable walls to move in unison and a disk mounted on the movable wall separating the constant pressure chamber from said third of said chambers, said last movable wall being of greater effective area than the movable wall separating said ambient pressure chamber from said third of said chambers.

6. A differential pressure gas supplying apparatus for maintaining the suit pressure of an aviator flying at high altitudes at a differential between ambient pressure and the critical minimum pressure at which one's blood would boil at normal temperature, comprising a hollow casing, a pair of internal movable walls across the interior of said casing dividing said casing into three chambers and moved essentially in response to the pressure differential in said chambers, means arranged to maintain a constant pressure approximating said critical minimum pressure in one of said chambers, means arranged to maintain ambient pressure in another of said chambers, a demand valve arranged to admit gas under pressure to the third of said chambers to produce said suit pressure, a motion transmitting device arranged to transmit movement from the movable wall forming the constant pressure chamber to the movable wall forming the other two chambers, and means responsive to the movement of one of said movable walls and arranged to open and close said demand valve.

7. Apparatus as set forth in claim 6 wherein a third internal movable wall also moved essentially in response to the pressure differential in the chambers formed thereby is arranged across the interior of said casing to provide a fourth chamber, said four chambers being arranged in succession, wherein said third chamber is an end suit pressure chamber and said demand valve is actuated through motion derived from the movable wall forming this end suit pressure chamber, wherein said ambient pressure chamber is next to said end suit pressure chamber, wherein said constant pressure chamber is next to said ambient pressure chamber, wherein the movable wall between said ambient pressure chamber and constant pres-

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sure chamber is of larger effective size than the movable wall between said ambient pressure chamber and said suit pressure chamber, wherein said motion transmitting device is arranged to transmit motion from said larger movable wall between said ambient pressure chamber and said constant pressure chamber and said smaller movable wall between said ambient pressure chamber and said suit pressure chamber, wherein a second demand valve is provided for maintaining mask pressure in the end chamber opposite said end suit pressure chamber, and wherein means are arranged to actuate said second demand valve through motion derived from the movable wall between said constant pressure chamber and said mask pressure chamber.

8. Apparatus as set forth in claim 7 wherein said movable walls are in the form of flexible diaphragms.

9. Apparatus as set forth in claim 6 wherein said movable wall forming said constant pressure chamber has an effective area which is of a greater effective size than said movable wall forming the other two chambers.

10. Apparatus as set forth in claim 9 wherein said movable walls each is in the form of a flexible diaphragm.

11. Apparatus as set forth in claim 9 wherein said demand valve is opened on movement of said movable walls in a direction to contract said ambient pressure chamber.

12. Apparatus for supplying gas under differential pressure to the suit and mask of an aviator, comprising a hollow casing, three internal movable walls across the interior of said casing and dividing said casing into four chambers, means arranged to maintain a constant pressure in one of said chambers, means arranged to maintain ambient pressure in another of said chambers, means responsive to the movement of a movable wall between the constant pressure and ambient pressure chambers and arranged to maintain a suit pressure in still another of said chambers, and means responsive to movement of a movable wall forming the last of said four chambers and arranged to maintain a minimum mask pressure in said last of said chambers.

13. Apparatus as set forth in claim 12 wherein a motion transmitting device is interposed between said movable wall between said constant pressure and ambient pressure chambers and the other movable wall forming said ambient pressure chamber and wherein said means arranged to maintain a suit pressure includes a demand valve moved by said last wall.

14. Apparatus as set forth in claim 13 wherein each of said movable walls includes a rigid portion and wherein said movable wall between said constant pressure and ambient pressure chambers is of larger effective area than said other movable wall forming said ambient pressure chamber.

15. A differential pressure gas supplying apparatus for maintaining the suit pressure of an aviator flying at high altitudes at a differential between ambient pressure and the critical minimum pressure at which one's blood would boil at normal temperature, comprising a hollow casing, two internal movable walls across the interior of said casing dividing said casing into three chambers and moved essentially in response to the pressure differential in said chambers, means arranged to maintain a constant pressure approximating said critical minimum pressure in the first of said chambers, means arranged to maintain ambient pressure in the chamber formed by both of said movable walls, a demand valve arranged to admit gas under pressure to the third of said chambers to produce said suit pressure, and means arranged to open and close said demand valve in response to joint movement of said movable walls.

16. Apparatus as set forth in claim 15 wherein a motion transmitting device is interposed between said walls and is arranged to transmit movement from the wall between said constant pressure and ambient pressure chambers to the wall between said ambient pressure chamber and said third of said chambers.

17. Apparatus as set forth in claim 16 wherein said wall between said constant pressure chamber and said

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ambient pressure chamber is of larger effective area than said wall between said ambient pressure chamber and said third of said chambers.

18. Apparatus for supplying gas under differential pressure to the suit and mask of an aviator, comprising a hollow casing, four successive internal movable walls across the interior of said casing and dividing said casing into a succession of chambers, means arranged to maintain a constant pressure in one end chamber of said casing, means arranged to maintain ambient pressure in the next succeeding of said chambers, a demand valve for maintaining suit pressure in the next succeeding chamber by controlling the admission of gas under pressure thereto, means arranged to actuate said demand valve through motion derived from the movable wall between said ambient pressure chamber and said suit pressure chamber, said last movable wall being of smaller effective size than the movable wall between said ambient pressure chamber and said constant pressure chamber, a motion transmitting device arranged to transmit movement from said last movable wall to said smaller movable wall between said ambient pressure chamber and said suit pressure chamber, means arranged to maintain ambient pressure in the succeeding chamber on the side of said suit pressure chamber remote from said first ambient pressure chamber, a second demand valve for maintaining mask pressure in the next succeeding of said chambers and which is the

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end chamber opposite said one end chamber in which constant pressure is maintained, means arranged to actuate said second demand valve through motion derived from the movable wall between said second ambient pressure chamber and said mask pressure chamber, said last movable wall bearing a disk of greater effective size than the movable wall between said second ambient pressure chamber and said suit pressure chamber, and a motion transmitting device arranged to transmit movement from said larger movable wall between said second ambient pressure chamber and said mask pressure chamber to said smaller movable wall between said second ambient pressure chamber and said suit pressure chamber.

19. Apparatus as set forth in claim 18 wherein said movable walls are in the form of flexible diaphragms.

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