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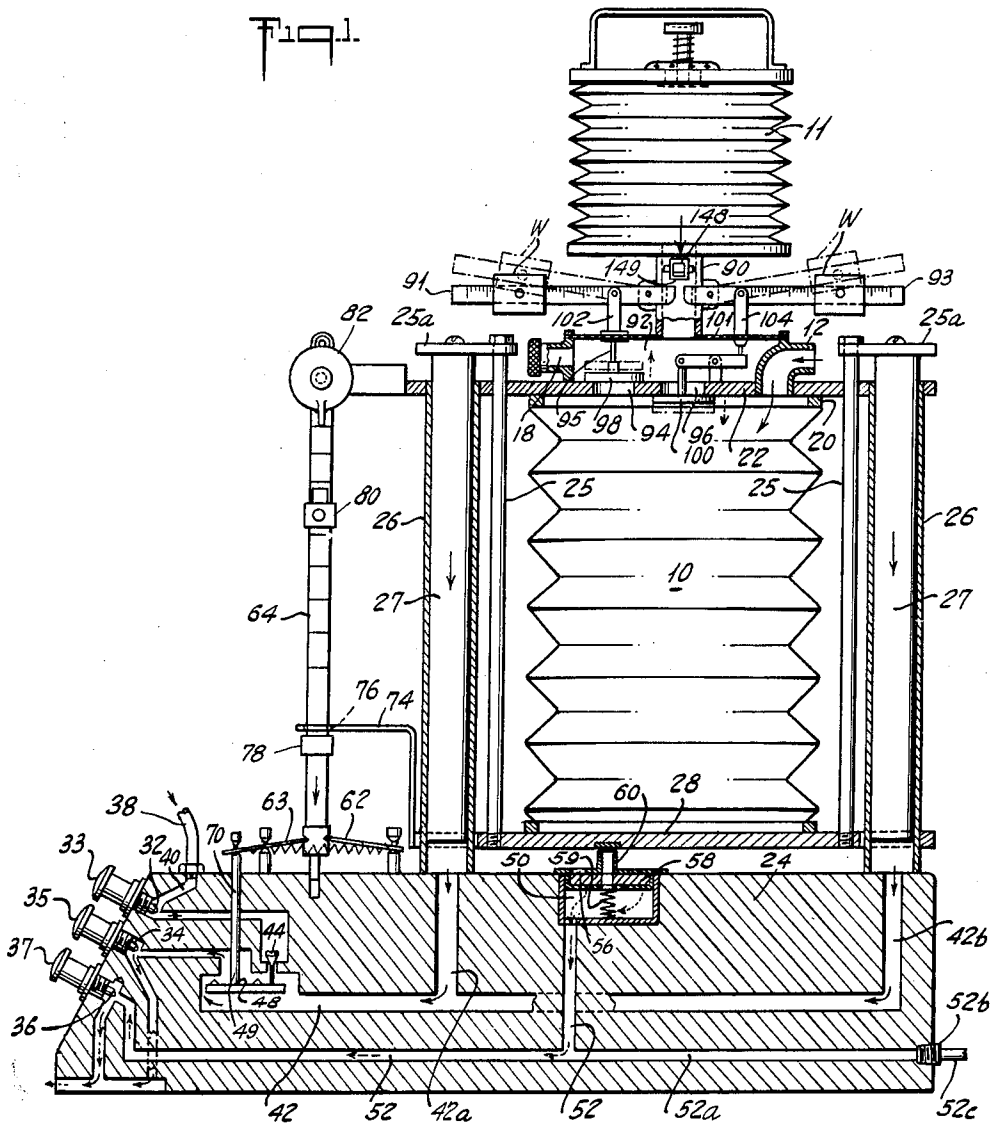
M. H. GOODNER
APPARATUS FOR SELECTIVELY PROVIDING CONTROLLED
BREATHING OR ASSISTED BREATHING

3,057,346

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Fig. 1.



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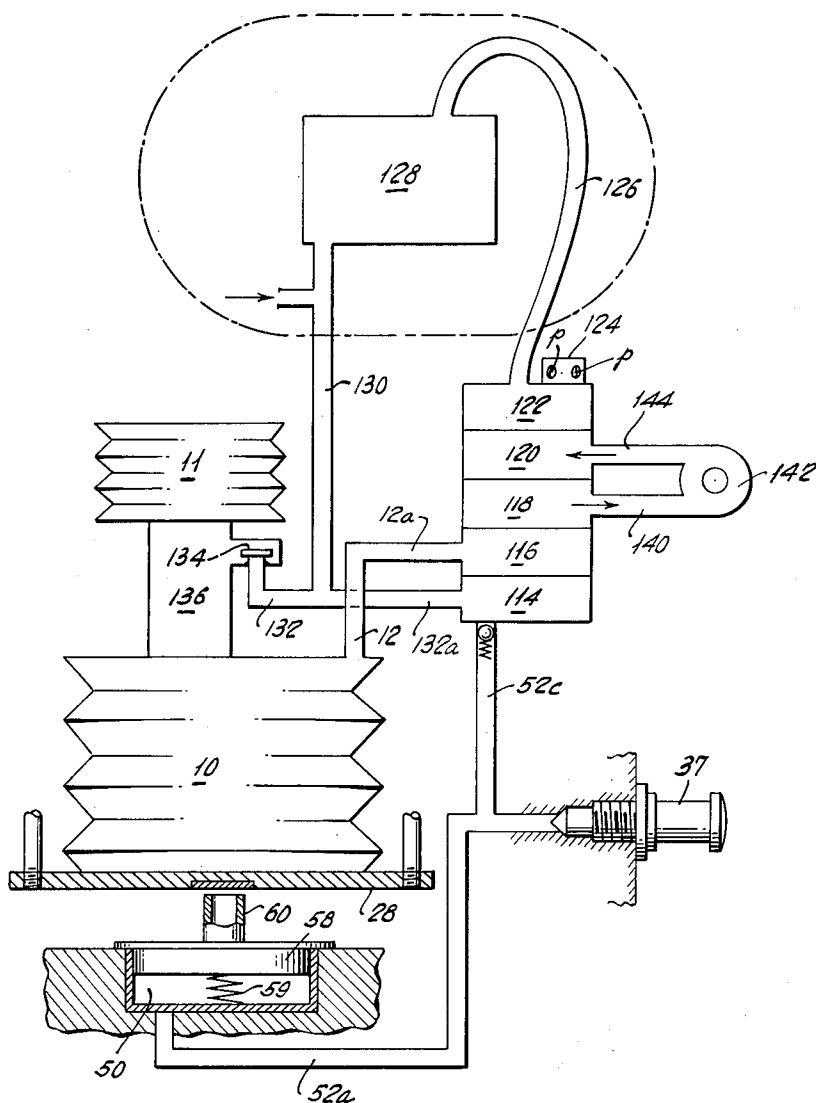
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Fig. 2.



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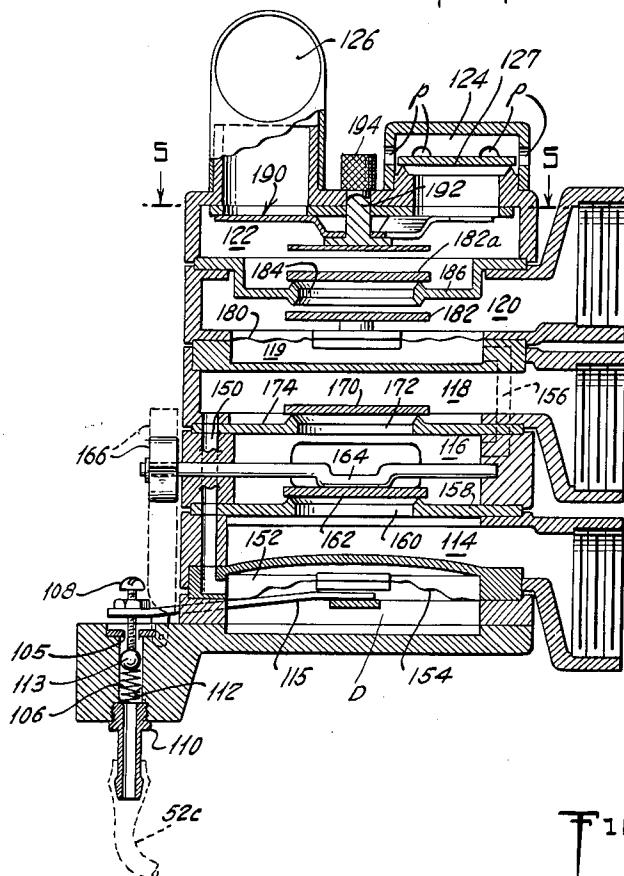
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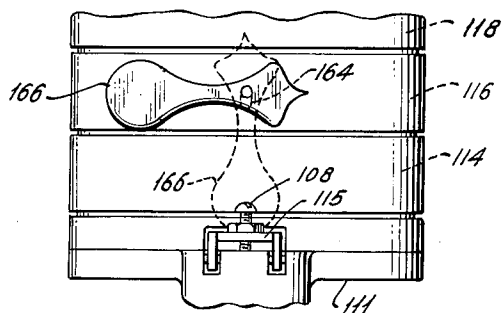
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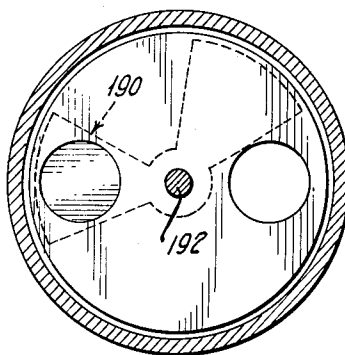
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APPARATUS FOR SELECTIVELY PROVIDING CONTROLLED BREATHING OR ASSISTED BREATHING

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7 Claims. (Cl. 128—29)

This invention relates to a device which, when attached to, or otherwise combined with, apparatus for controlling the volume of gas introduced into a patient's lungs during inhalation, the volume of gas exhausted from the patient's lungs during exhalation, and the pressure built up in the patient's lungs during each of these two phases of the breathing cycle, is capable of modifying the apparatus, by permitting the patient, within a predetermined time limit to initiate the inhalation phase of each breathing cycle and to exhale naturally. Such apparatus is disclosed in co-pending application, Serial Number 633,163, filed January 8, 1957, and in application Serial Number 559,889, filed January 18, 1956, now abandoned, of which said co-pending application is a continuation in part. By the device disclosed herein apparatus such as that disclosed in said co-pending applications may be limited to controlling the volume of gas introduced into the patient's lungs and an exhalation phase may be shortened in response to an inhalation effort by the patient, and the patient may thereafter exhale naturally provided his successive inhalation efforts occur within a predetermined interval.

The apparatus disclosed in said co-pending applications has been proven very valuable, especially for times when the patient is under anesthesia, as for example during surgery, and in a variety of other situations where it is helpful to control the duration of each phase of a breathing cycle, and also a period during each cycle when the breathing level approaches zero, while at the same time introducing a predetermined volume of gas into the patient's lungs and withdrawing a predetermined volume of gas from the patient's lungs, and controlling the pressure within the patient's lungs. However, in many instances, such for example as just before and just after an operation, it is desirable to have the patient initiate the inhalation phase of each breathing cycle and then have the apparatus of said co-pending application control the volume he inhales, but leaving exhalation uncontrolled. Since breathing is a reflex action, except in extreme situations of shock, paralysis, etc., some expansion and contraction of a patient's lungs occurs naturally even when the patient is unconscious. If the patient's breathing is very shallow it may be advisable to force a greater volume of gas into his lungs than he would be able to breathe in naturally. However, to be able himself to initiate the breathing cycle, even if his breathing rate is very shallow with little inspiratory effort, I have found helps the patient to remain calmer than he might otherwise be, as for example, just prior to an operation.

It is accordingly an object of this invention to provide a device, to serve as an attachment for apparatus for controlling breathing of a kind disclosed in said co-pending application, which is triggered by the inspiratory reflex action of the patient in attempting to suck in air, and then becomes operative to speed the ending of an exhalation phase when the inspiration attempt occurs during the exhalation phase.

The invention will best be understood if the following description is read in connection with the drawings, in which

FIGURE 1 is a side elevation, partly schematic of the apparatus which is the subject of co-pending application

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S.N. 633,163, modified by the addition of the branch conduit 52a and coupling 52b.

FIGURE 2 is a side elevation, partly schematic of an "assistor" attachment,

FIGURE 3 is a side view partly in cross section of a vertical section through the "assistor" attachment,

FIGURE 4 is a detail side elevation showing the two positions of a lever which controls a cam by means of which the assistor is operatively connected to or disconnected from the apparatus of the kind illustrated in FIGURE 1, and

FIGURE 5 is a horizontal section taken on the line 5—5 of FIGURE 3.

The assistor disclosed herein is an attachment for the apparatus for controlling breathing which is fully shown and described in my co-pending application. However, since an understanding of that apparatus is necessary to a full understanding of the device disclosed herein that apparatus is illustrated in FIGURE 1 of this application and is briefly described herein.

FIGURE 1 in the present application corresponds with FIGURE 1 of said co-pending continuation-in-part application in all respects except that the passage 52 leading from the air chamber 50 to the control valve 37 is provided with a branch passage 52a, extending through the base of the device to a coupling nipple 52b. The assistor device which is the subject of this invention is connected to the apparatus shown in FIGURE 1 by connecting a conduit 52c between said coupling nipple 52b and the coupling nipple 110 of said device (see FIGURE 3).

The apparatus of said co-pending application comprises a pair of expansible and collapsible gas containers 10 and 11, the latter acting as an overflow and storage chamber for the former during automatic operation of the whole apparatus and being adapted to be employed alone for manual operation while container 10 is held stationary. Both 10 and 11 are exemplified as bellows. The main bellows 10 is interconnected with the reserve bellows 11 through valve means such that gas is exhausted from the main bellows into the reserve bellows only when the pressure in the main bellows exceeds a predetermined maximum, and gas is returned from the reserve bellows into the main bellows only when the pressure in the main bellows falls below a predetermined minimum. Through conduit means 12 gas is supplied to and exhausted from a patient, either directly through a face mask or other means for communicating with a patient's breathing passages, such for example as an endotracheal tube, tracheotomy tube or the like (not shown), or indirectly, as for example through anesthesia equipment. The term face mask is used broadly herein to include any means of communicating with a patient's breathing passages.

The device may be used as an automatically operated, or a manually operated, respirator by simply connecting conduit 12 directly to the patient and introducing compressed air or oxygen or other gas into inlet conduit 18, in which case the exhalation gas may be discharged at the face mask.

Container 10 is fixed at the top as by means 20 to the cross member 22 of support means comprising the base 24 from which rise the hollow columns 26 on which cross member 22 is mounted. Columns 26 have therein pistons attached by the brackets 25a to the rods 25, the lower ends of which are attached to the movable platform 28 to which the lower end of the container 10 is fixed. Platform 28 rises and falls with rods 25 thus collapsing and expanding container 10. Collapsing of container 10 is accomplished by air pressure acting on the bottom of pistons 27, and expansion of container 10 is accomplished by gravity alone, in which case platform 28 has substantial

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weight, or by gravity aided by counterbalancing air pressure on top of the heads of pistons 27a as shown in FIGURE 24 of said copending application.

Mounted on the base 24 are the three needle valves 32, 34, and 36 which are controlled respectively by knobs 33, 35 and 37 each of which is surrounded by a calibrated ring. Valves 32 and 34 control the flow of compressed air within passages 40, 42, 42a and 42b in base 24 communicating with the hollow columns 26 in which pistons 27 are contained. The compressed air used in the said passages is employed for collapsing container 10 and is entirely separate from the gas or gases contained within the container means and exchanged between said means and the patient.

Valve 36 controls the exhausting of air from air chamber 50 in base 24, through passage 52. Air chamber 50 is not supplied with compressed air but is open to atmosphere through passage 52. Piston 58 is urged in a direction away from the outlet to passage 52 by coil spring 59, and has the plunger 60 extending through the top of the chamber in which the small port 56 is provided. When the descending platform 28 strikes plunger 60 its downward movement is resisted and slowed in proportion to the rate at which the adjustment of valve 36 allows air to escape from chamber 50 through passage 52. Valve 36 may be adjusted to slow the downward movement of piston 58 so that during the final portion of the expansion of bellows 10 the negative pressure exerted on the patient's lungs from container 10 through the anesthesia equipment and face mask, is substantially level thus providing in effect a pause between the exhalation and inhalation phases of a breathing cycle. The leveling off of the pressure curve approaching zero provides a pause in the breathing cycle enabling the operator to make the cycle of the device correspond with the breathing cycle of the patient. The duration of the interval during which the pressure curve is thus substantially flattened is determined by the position of platform 28 when it strikes plunger 60 and in the illustrated embodiment of the invention this depends upon the distance to which plunger 60 extends above base 24.

For attachment or incorporation of the means to be described a branch or extension of passage 52 is provided in base 24 leading to a coupling 52b.

Control of the alternation of the phases of the breathing cycle is accomplished through valve mechanism in passages 40 and 42, FIG. 1, fully described in said copending application, actuated by the control rod 64 which is supported on the toggle arms 62 and 63 and is movable up and down to actuate the toggle mechanism, which in turn actuates said valve mechanism.

Projecting from the moving platform 28 is a lip 74, shown schematically in FIGURE 1 as an angle extension member, having a slot 76 through which the control rod 64 extends. On rod 64 below the outer end of extension 74 is a lower fixed stop 78, and above the outer end of extension 74 is an upper adjustable stop 80, rod 64 being preferably calibrated to facilitate setting of the position of adjustable stop 80 as may be desired to determine the volume of container 10, i.e., the extent to which it can be expanded of course determines the volume of gas it can receive from the patient's lungs, and the volume of gas it can transfer to the patient's lungs when it is collapsed.

When expansion of container 10 moves its lower end to the end of its downward stroke lip 74 contacts fixed stop 78 and moves control rod 64 downwardly enough to actuate said toggle arms downwardly, thus raising valve stem 70 and ending the negative or exhalation phase of the breathing cycle and starting the succeeding positive phase. When the collapsing of container 10 causes the lip 74 to strike the upper adjustable stop member 80 control arm 64 is elevated just enough to trip the toggle mechanism and lower valve stem 70 causing valve 44 to close and unseating ring 48, thus ending the positive phase of the breathing cycle and starting the negative phase.

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Control rod 64 may be raised or lowered and locked in either of said positions to stop automatic operation of the device, by means of the control dial 82 on the upper end of control rod 64, as is fully shown and described in said co-pending application.

Container 11 is connected to container 10 by the tube 90 and the valve chamber 92. Cross member 22 constitutes the lower wall of valve chamber 92 and has in it the two ports 94 and 96 controlled by the valves 98 and 100 respectively. The upper wall of chamber 92 is flexible diaphragm 101 on which the brackets 102 and 104 are supported. Pivotaly mounted on said brackets, by means fully described in said co-pending application are the calibrated balance arms 91 and 93 respectively on each of which the weights w are slidably mounted by means of which the pressure required to open said valves respectively is controlled. Valve 98 opens upwardly to pass gas from container 10 to container 11 through tube 90. When the pressure in container 10 overcomes the force with which pin 95 pushes down on the valve 98 said valve opens upwardly. Valve 100 opens downwardly into container 10 when its weight and the pressure in container 11 exceeds the pressure in container 10 and the force exerted from balance arm 93 tending to hold the valve in closed position.

Numerical 148 indicates a pivoted valve locking arm having at its lower end the cam end 149 which may be moved into contact with the inner ends of said balance arms 91 and 93 to depress them and thus open said valves 98 and 100, and lock them in open position. This may be done if for any reason it is desired to operate the device manually, in which case the rod 64 which controls automatic operation is also locked by means fully described in said co-pending application, and container 11 is then expanded and collapsed by the operator, the gas passing between container 11 and conduit 12 through the open valves 98 and 100 and the upper end of container 10 which remains stationary. Safety relief and bleed valve means (not shown) are provided in bellows 11 and in conduit 90.

In the operation of the apparatus of FIGURE 1 for automatic volume control the operator, having connected compressed air inlet conduit 38 to a source of compressed air, adjusts the volume of the device by positioning stop 80 as desired on rod 64 which controls automatic operation. The operator may adjust the position of weights w on balance arms 91 and 93 respectively to regulate the pressures necessary to open valves 98 and 100 respectively, which determine the positive and negative pressures that may be built up in container 10, during the inhalation phase of the breathing cycle. By adjusting valves 32, 34 and 36 the operator can regulate the duration of the expanding and contracting movements of bellows 10 and the overall duration of the cycle including a pause or interval between the said phases to accord with the breathing of the patient. If the patient's breathing cycle changes the operation of bellows 10 can be readily adjusted to conform.

By means of the valve means in conduit 90 the amount of the gas in the apparatus may be maintained substantially constant thus avoiding building up the level of unexchanged gas in the patient's lungs due to an excess of the continuously added gas over the amount which is being continuously metabolized and taken up by the patient.

The device described in FIGURES 2-5 may be joined to the apparatus disclosed in my co-pending application by connecting conduit 12 of that apparatus to chamber 116 of said device as by conduit 12a, and connecting nipple 110 of the said device as by conduit 52c, to a coupling nipple 52b at the end of branch passage 52a provided in the base of that apparatus. The means shown in FIGURES 2-5 may be combined with or attached at any convenient distance from the apparatus of said copending application by making conduits 12a and 52c of suitable length.

Nipple 110 is screwed into one end of the bore 112 in the base 111 of the device shown in FIGURES 2-5. The other end of the bore 112 vents to atmosphere and in the bore a ball valve 113 is provided which is normally urged into closed position against its seat 105 by the spring 106. The ball valve member 113 is carried by the pin 108 which extends through the free end of the spring arm 115, which at its other end is connected to the diaphragm 154, movements of which act on spring arm 115 causing it to snap with a toggle-like action to unseat or seat the ball 113 and thereby open or close the passage leading from said air chamber 50 of the said apparatus for controlling breathing through conduit 52a, coupling 52b and conduit 52c (FIGURES 1, 2 and 3). When the action of the apparatus for controlling breathing, disclosed in said co-pending application, is modified by the device which is described herein, venting of said chamber 50 through valve 37, controlling passage 52 in the base of the apparatus described in said co-pending application, may be modified and greatly speeded.

The device shown in FIGURES 2-5 comprises a series of superimposed chambers indicated from bottom to top by the numerals 114, 116, 118, 120, 122 and 124. The gases of exhalation are either exhausted to atmosphere from chamber 124 through ports *p*, or are led through conduit 126 to a soda-lime cannister 128 in which they are filtered and purified and recirculated through conduit 130 and its branch 132 and one way valve 134 into a space 136 leading to the reserve bellows 11 above the valve means, described above, which controls the flow of gases between the main bellows 10 and the reserve bellows 11. Conduit 130 has another branch 132a which communicates with chamber 114 and is operative when fully controlled breathing is desired and it is not desired to use the "Assistor" capacity of the structure shown in FIGS. 2-5.

From the main bellows 10 conduit 12 leads to conduit 12a which is connected to chamber 116. Chamber 118 is connected through the conduit 140 to a patient's face mask 142, and conduit 144 leads from the patient's face mask to the chamber 120. Above chamber 120 is the chamber 122 which communicates selectively, as for example through a shutter valve 190 of the kind illustrated in FIGURE 5, either with a chamber 124 having the ports *p* leading to atmosphere, or through the conduit 126 to the soda-lime connector 128 as mentioned above.

Referring now to FIGURE 3, it will be seen that chamber 118 communicates through conduit 150 with the space 152 above the diaphragm 154 in a diaphragm chamber D, and chamber 116 is interconnected with space 119 below diaphragm 180 by means of conduit 156. Chamber 114 is separated from chamber 116 by the wall 158 having therein the port 160 controlled by the valve 162, which may be locked or unlocked by the cam 164 which is rotatable by the control lever 166. When the control lever 166 is in the position shown in broken lines in FIGURE 4 cam 164 is in raised position, and valve member 162 is unlocked and the lower end of the control lever 166 presses against the spring arm 115 thereby moving ball 113 away from its seat 105 and leaving the port in the seat open. Under these conditions the device shown in FIGURES 2-5 is not operative to assist natural breathing. When the control lever 166 is in the position shown in full lines in FIGURE 4 cam 164 is in lowered position, locking valve member 162 in closed position, but spring arm 115 and ball 113 are released, and the device shown in FIGURES 2-5 is operative to assist natural breathing.

Between chambers 116 and 118 the check valve 170 is shown seated over valve port 172 in the wall 174.

Chamber 120 is divided by a flexible diaphragm 180 extending over space 119, and mounted on this diaphragm for movement with it is a valve member 182 which controls the port 184 in the partition wall 186.

Mounted for rotation in chamber 122 is the shutter

valve 190 which has the stem 192 extending to the outside of the casing and the thumb piece 194 on its outer end by which the valve may be rotated to selectively cover the entrance end of the conduit 126 or the lower end of chamber 124. When the check valve 127 is unseated gases entering chamber 124 are exhausted to atmosphere through the ports *p*.

In operation, during the collapsing action of the bellows 10 when the control lever is set to permit the device of FIGURES 2-5 to respond to an inspiration effort occurring toward the end of exhalation phase, gas is supplied through conduits 12 and 12a to chamber 116 and the resulting increase of pressure in chamber 116 unseats check valve 170 causing the gas to flow to the patient through conduit 140, the volume of gas so supplied and its pressure being determined by the apparatus shown in FIGURE 1. At the same time, due to the conduit 156 interconnecting chamber 116 and space 119, the pressure under diaphragm 180 elevates valve 182 into closed position for the duration of the inhalation phase.

As soon as the exhalation phase starts gas is discharged from the patient's lungs through conduit 144 into chamber 120. The resulting increase in pressure in chamber 120 causes diaphragm 180 to move downwardly thus unseating valve 182 and raising valve member 182a so that the exhalation gases flow into chamber 122 from which they are exhausted selectively, through conduit 126 for re-circulation through the soda-lime cannister 128, or through chamber 124 and ports *p* to atmosphere, the increased pressure in chamber 124 serving to open the check valve 127 for this purpose.

When the patient makes a natural effort to inhale while the exhalation phase is being prolonged by control of the escape of air from chamber 50 through conduit 52, the pressure in chamber 118 is reduced, and through conduit 150 also reduces the pressure in the space 152 above the diaphragm 154 in diaphragm chamber D, thus causing spring arm 115 to snap upwardly which action lowers the ball 113 and opens the valve port in seat 105, thus speeding the exhausting of air from air chamber 50 (FIGURE 1), and causing the apparatus shown in FIGURE 1 to reopen valve 49 and thereby begin again to collapse the main bellows 10 thus expelling air from bellows 10 through conduit 12 into chamber 116 from which it flows into chamber 118 and to the patient.

When it is desired to have controlled breathing without utilizing the "assistor" capability of the device shown in FIGURES 2-5, but without disconnecting it from the device shown in FIGURE 1, the control lever 166 is positioned to raise cam 164 and free valve 162 while holding down the diaphragm-operated arm 115. The operation during the inspiration phase will be as described above. During the exhalation phase gases will either be exhausted to air through ports *p* or if recirculated they will flow from return conduit 130 through branch conduit 132a into chamber 114, and since valve member 162 is unlocked it will rise and the exhalation gases will flow through chamber 116 and conduits 12a and 12 into the bellows 10.

By the means disclosed herein the operation of apparatus for controlling breathing by controlling volume as well as pressure during successive inhalation and exhalation phases, may be modified to permit a patient to maintain his own breathing pattern, while at the same time providing the patient with a greater volume of anesthetic or gas, therapeutic gas, or air, per breath, than he would normally inhale.

There has thus been provided a device in which the above stated objects are accomplished in a thoroughly practical way.

What I claim is:

1. Apparatus for use with a device of the kind adapted to alternately supply and withdraw from a patient's lungs controlled volumes of gas, and including a face mask, a gas conduit, and means including a control fluid con-

duit and valve means to provide a period of time between the withdrawal phase and the supply phase, comprising an extension of said gas conduit leading to the face mask, an extension of said control fluid conduit, a chamber having a diaphragm therein, and a valve in said control fluid conduit responsive to movements of said diaphragm, and a gas conduit leading from the face mask to an exhaust port, the extension of the gas conduit leading to the face mask including a plurality of chambers, a port connecting the chambers, and a one-way valve controlling said port and adapted to open when gas is supplied from said gas conduit and said gas conduit extension into said first chamber and the pressure therein is increased, the said discharge conduit leading from the face mask to an exhaust port includes a third chamber communicating with the face mask, a fourth chamber comprising said exhaust port, a port interconnecting said third and fourth chambers, and a plurality of valve means controlling said port, the first of said valve means being adapted to close the port when gas is being supplied under pressure into said first chamber, and the other of said valve members being adapted to open when gas is flowing from the face mask into said third chamber and thus increasing the pressure in the third chamber, a conduit for communicating to the first valve means changes in pressure occurring in said first chamber, and a conduit interconnecting said second chamber and said diaphragm chamber.

2. Supplementary apparatus, for use in conjunction with a device for providing to, and withdrawing controlled volumes of gas from, a patient's lungs and including means for determining the duration of a period of time between the gas withdrawing phase and the next succeeding gas supply phase, which comprises, a number of chambers including a diaphragm chamber, a diaphragm in said diaphragm chamber, a spring arm responsive to movements of the diaphragm extending through the wall of the diaphragm chamber, a first chamber having a port to receive gases from said apparatus, a second chamber having a coupling to receive a connection leading to said face mask, one-way valve means between said first and second chambers adapted to open only when gas is being supplied under pressure into the first chamber, a third chamber having a coupling to receive a connection leading from the said face mask, an exhaust port, and valve means in said third chamber operative to permit communication between the third chamber and said exhaust port only during the exhalation phase, when gas is flowing from the face mask into said third chamber, means for communicating between said second chamber and the said diaphragm chamber to cause movement of the diaphragm when pressure in the second chamber is reduced due to an inspiratory effort of the patient, and means responsive to movement of said diaphragm occurring during said period of time and coactive with the said means for determining the duration of the period of time, to terminate the period of time and thus hasten the next gas supply phase.

3. The apparatus claimed in claim 2 including means for rendering the said diaphragm inoperative, an additional chamber having a port communicating with said first chamber, a valve controlling said port, a return conduit leading from said exhaust port to said additional chamber, means for locking the valve controlling said port in closed position, and for unlocking said valve when said diaphragm is inoperative, to permit gas from said return conduit to flow into said additional chamber and through said port and back to said device through said first chamber and the gas conduit communicating between said first chamber and said device.

4. A supplementary apparatus for use in conjunction

with a device for providing to, and withdrawing controlled volumes of gas from, a patient's lungs which includes means for creating and controlling the duration of a period of time between the gas withdrawing phase and the next succeeding gas supply phase which comprises, a first chamber having a port to receive gas supplied by said device, a second chamber having a coupling for a connection leading to a patient's face mask, a third chamber having a coupling for receiving a connection leading from a face mask, a fourth chamber having a discharge port venting to atmosphere, a diaphragm chamber having a diaphragm therein, a spring arm extending from said diaphragm, a control fluid conduit having at one end a coupling for connection to a control fluid conduit within said device and having valve means responsive to movements of said spring arm to open and close said control fluid conduit, a port communicating between said first chamber and said second chamber, a one-way valve for said port positioned in the second chamber and adapted to open only to permit gas supplied under pressure into the first chamber to flow into said second chamber, a tube interconnecting said second chamber and said diaphragm chamber, a port communicating between said third chamber and said fourth chamber, said third chamber being divided into two portions by a flexible diaphragm, a tube interconnecting said first chamber and the portion of said third chamber below said diaphragm, a first valve member carried by said flexible diaphragm and adapted to close said port in response to an increase in pressure in the portion of said third chamber which is below said flexible diaphragm, and one-way valve means positioned within said fourth chamber and adapted to open said port only to permit gas supplied into said third chamber under pressure to flow into said fourth chamber.

5. The supplementary apparatus claimed in claim 4 in which said fourth chamber has a second exhaust port and said apparatus includes a fifth chamber having a port communicating with said first chamber, floating one-way valve means controlling said port and adapted to open only to permit flow of gas from said fifth chamber into said first chamber, a return conduit leading from said second exhaust port and having a first branch communicating with said fifth chamber and a second branch leading back to said device and having one-way control valve means adapted to open only to permit return flow of gas into said device, and valve means in said fourth chamber for selectively determining whether the gas will be discharged from said fourth chamber to atmosphere or recirculated.

6. The apparatus claimed in claim 5 including a control lever, a cam movable with the control lever to lock in closed position the valve means controlling the port between said fifth and first chambers, and to unlock said valve means, said lever being operative to simultaneously unlock said valve means and lock the spring arm extending from said diaphragm chamber, and to simultaneously lock said valve means in closed position and unlock said spring arm.

7. The apparatus claimed in claim 5 including means for locking and unlocking the valve means controlling the port between said fifth and first chambers and for unlocking and locking said spring arm.

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