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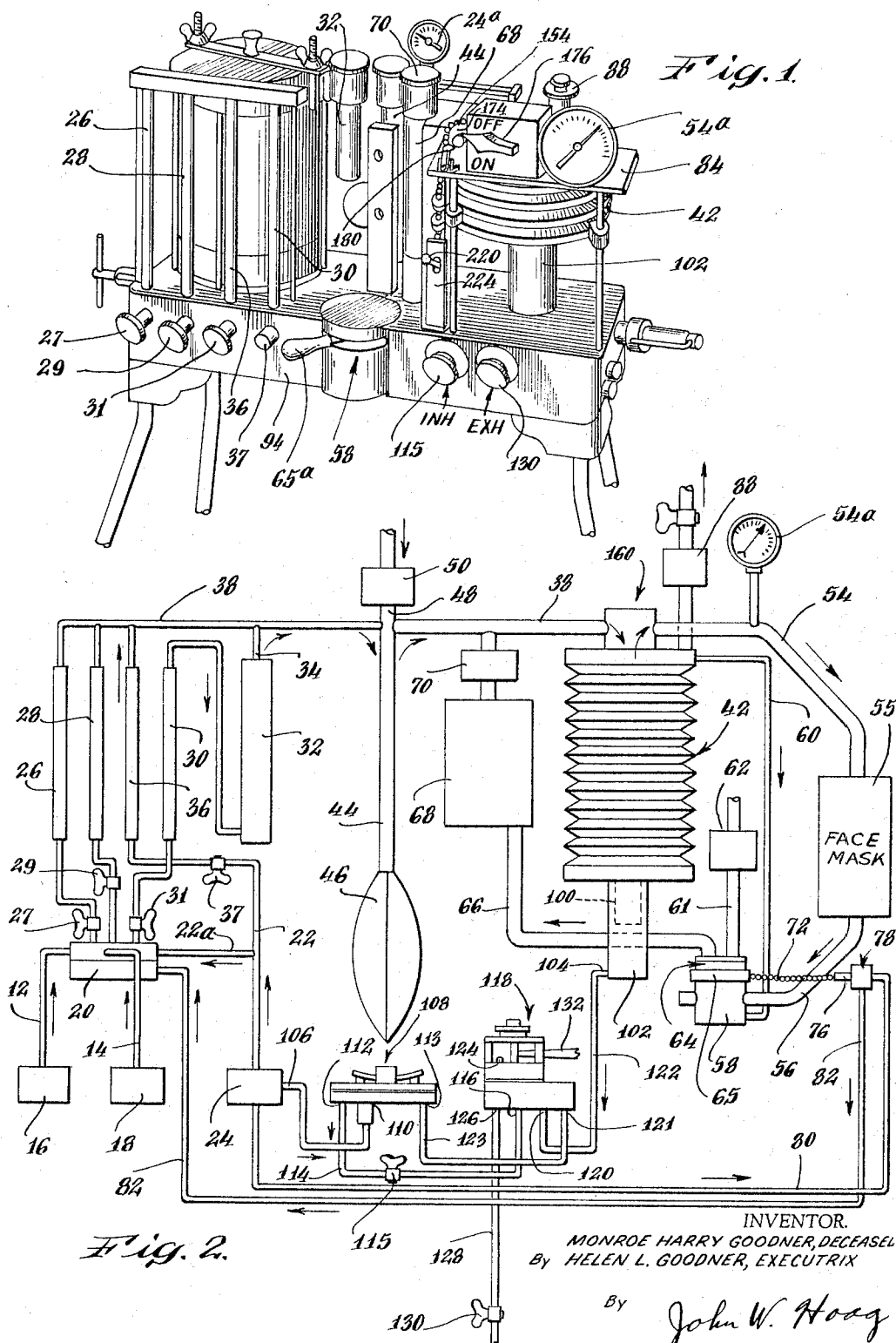
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3,283,754

APPARATUS FOR ADMINISTERING CONTROLLED VOLUMES OF GAS

Filed July 12, 1963

4 Sheets-Sheet 1



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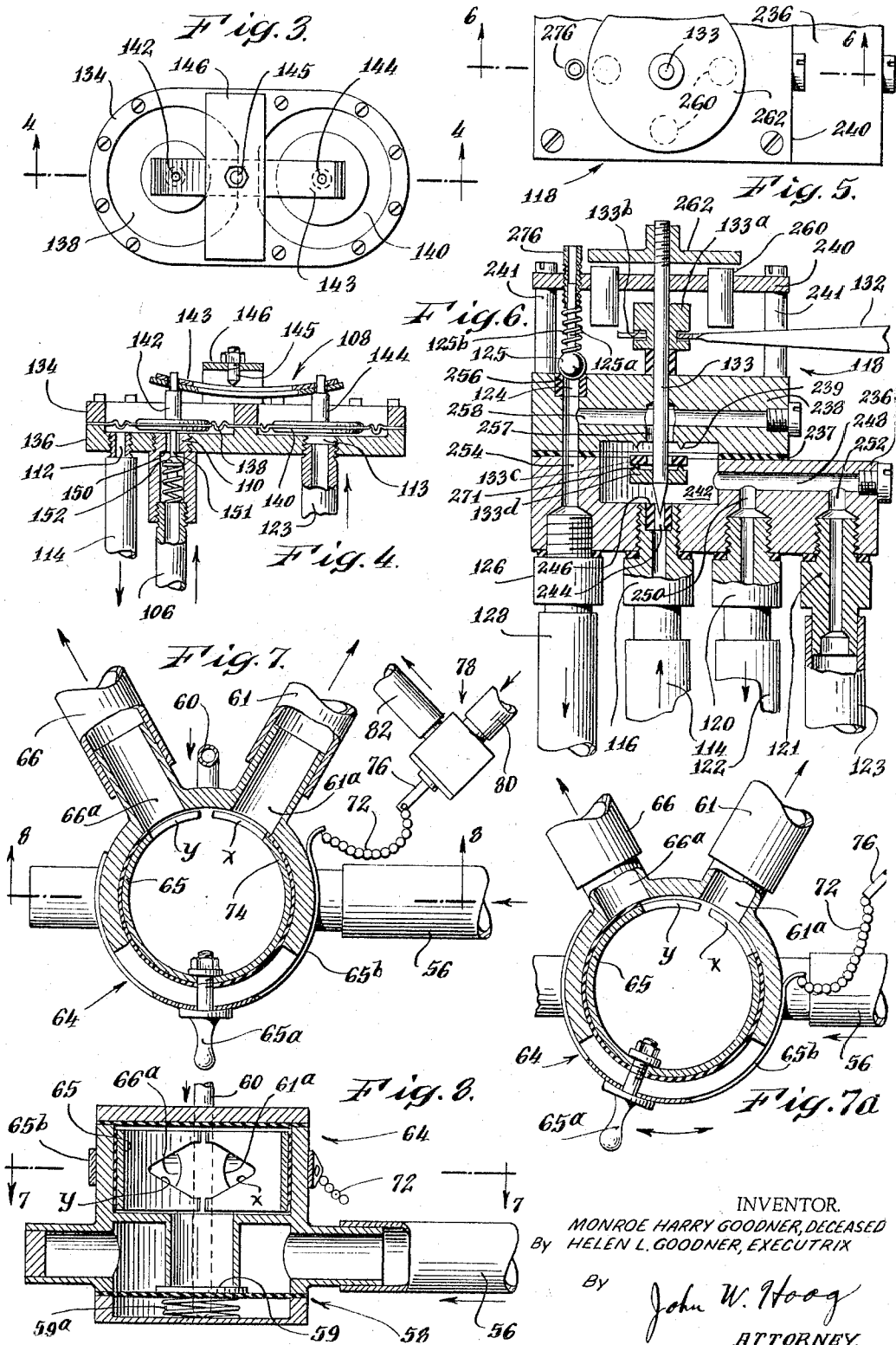
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4 Sheets-Sheet 2



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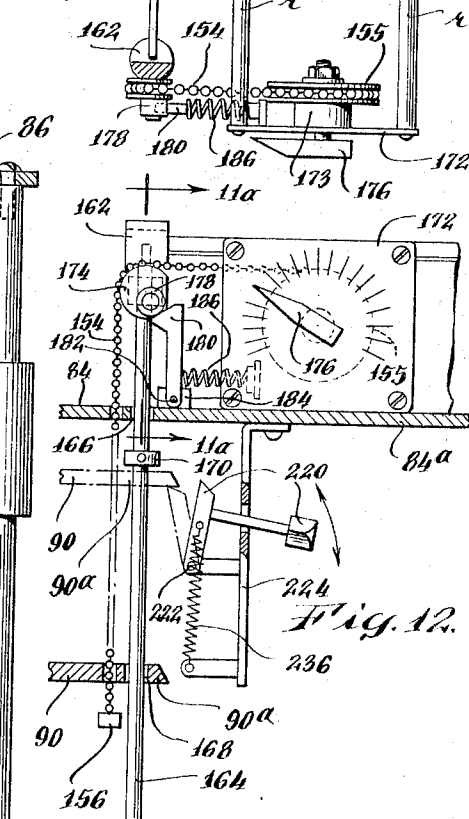
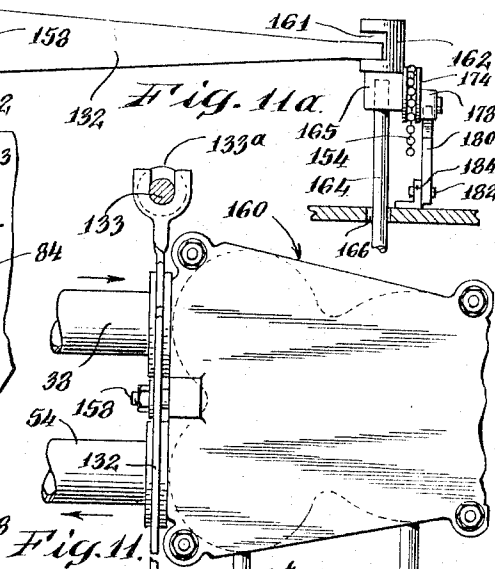
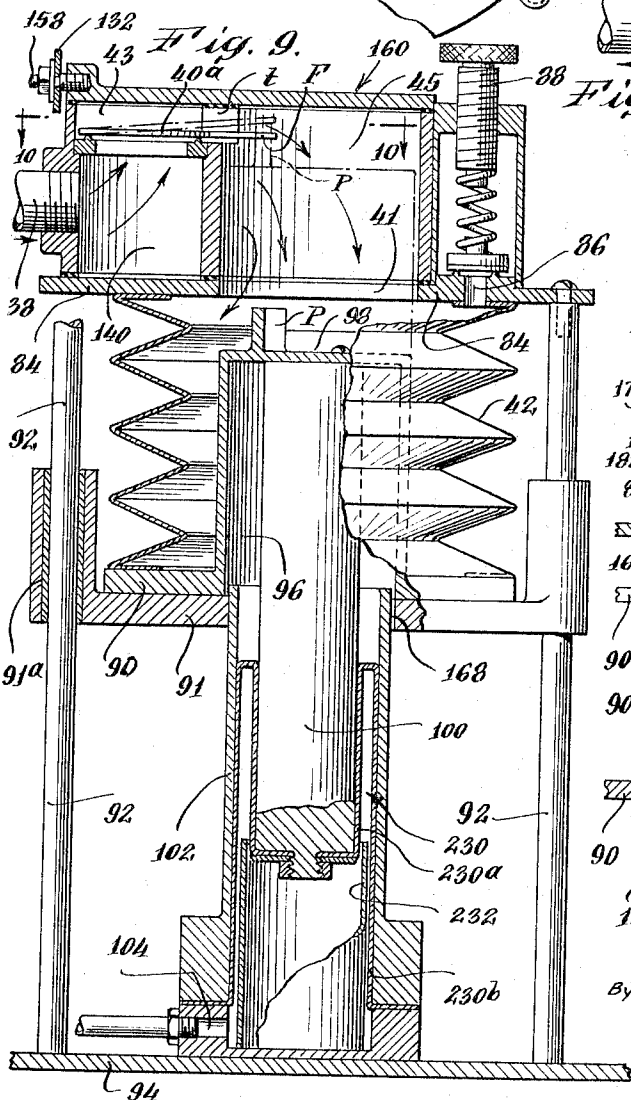
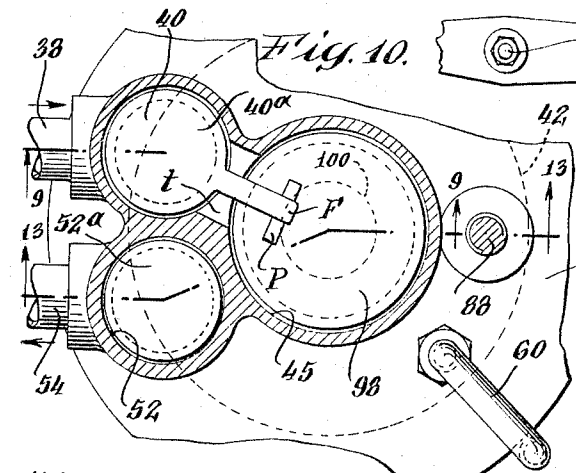


Fig. 12.

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APPARATUS FOR ADMINISTERING CONTROLLED VOLUMES OF GAS

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8 Claims. (Cl. 128—29)

This invention relates to apparatus for supplying a controlled volume of gas to a patient's lungs. It can be used for supplying gases comprising anesthesia gas, as for example during an operation, or for supplying oxygen alone or mixed with air, as for example for resuscitation. It can be quickly shifted from one of these uses to the other or for manually controlled resuscitation.

The term "gas" is used herein broadly and includes ambient air, oxygen, anesthesia gases and any gas or gases used in connection with anesthesia or reviving a patient or promoting his breathing.

It is an object of the invention to provide improved apparatus of the above mentioned kind.

Another object of the invention is to supply a predetermined volume of gas for each inhalation phase of the breathing cycle.

Another object of the invention is to provide apparatus which will not only deliver a constant volume of gas to the patient's lungs during each inhalation phase for each volume setting of the device, but will also deliver the successive equal volumes of gas during substantially the same periods of time, thus maintaining an even breathing rhythm.

Another object of the invention is to provide power means for intermittently collapsing a gas container to supply gas to a patient's lungs, in combination with self regulating control means responsive to variations in the force required to deliver gas through a patient's breathing passages to his lungs.

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

FIGURE 1 is perspective view looking at the front and one end of an embodiment of the invention,

FIGURE 2 is a diagrammatic and schematic view of the device illustrated in FIGURE 1, showing particularly the conduit and control means of both the therapeutic and power systems comprising the embodiment,

FIGURE 3 is a top view, and FIGURE 4 is a side view partly in cross section of valve means for controlling the supply of power gas in proportion to the power required under changing conditions of the patient's breathing passages, for delivering a predetermined volume of gas to a patient's lungs within a predetermined period of time,

FIGURE 5 is a top view, and FIGURE 6 is a side elevation largely in cross section of cycling valve means for controlling the flow of power gas to and from the power cylinder,

FIGURES 7 and 7a are top views, partly cut away and in section, and FIGURE 8 is a front elevation, partly cut away and in cross section, of valve means in the patient's exhalation conduit and of means for setting the device selectively for open or closed circuit operation,

FIGURE 9 is an elevational view showing a bellows, power cylinder means by which it is intermittently collapsed, and a valve assembly through which gases for the patient's lungs are intermittently supplied to the bellows and exhausted from the bellows to the patient, showing the inlet valve open,

FIGURE 10 is a horizontal section taken on the line 10—10 of FIGURE 9,

FIGURE 11 is a top view of FIGURE 9, showing also

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means for controlling and adjusting the volume of gas supplied to a patient during each inhalation phase and for actuating the power cylinder cycling valve,

FIGURE 11a is a detail elevation view looking toward one side of beam 132 and showing how it is related at one end to rod 164,

FIGURE 12 is a side elevation partly in section of the structure shown in FIGURE 11,

FIGURE 13 is a detail view of the bellows valve assembly, similar to the view shown in FIGURE 9 but with the inlet valve closed and the outlet valve open for exhausting gas from the bellows,

FIGURE 14 is a vertical sectional view of means controlled by the circuit selector (open or closed) means for turning on or off the supply of anesthesia gases,

FIGURE 15 is a top view; FIGURE 16 is a vertical sectional view taken on line 16—16 of FIGURE 15; and FIGURE 17 is a view taken on the line 17—17 of FIGURE 16, of valve means responsive to the valve means shown in FIGURE 14, for simultaneous turning on or off the supply of a plurality of anesthesia gases.

The apparatus disclosed herein comprises a first conduit system interconnecting between one or more sources of gas and a bellows, and between the bellows and a patient's face mask, and a second conduit system interconnecting between a power cylinder and piston, by which the bellows is intermittently collapsed, and a source of gas under pressure for actuating the piston, and also between a source of gas under pressure and a triple valve actuating valve. For convenience the gas or gases to be supplied to the patient may be referred to as patient's gas and the gas for actuating the piston and the triple valve may be referred to as power gas. One of the patient's gases is oxygen under pressure supplied from a pressure container, and gas from the same container, indicated as 24 in FIGURE 1, may conveniently be also employed as power gas, to operate the power cylinder and the triple valve, as will be described.

The apparatus includes yokes for supporting tanks of gases, such as oxygen, cyclopropane and nitrous oxide, and having ports for connecting them to the conduit system leading to the patient. The yoke means for the oxygen supply also has a plurality of ports for oxygen to be used as power gas, for operating the power cylinder and the triple valve.

As shown herein conduits 12 and 14 lead from a plurality of sources 16 and 18 of anesthetic gas under pressure (FIGURE 4) to a triple valve 20, and conduit 22, leading from a source 24 of oxygen under pressure, has a branch 22a which leads to said triple valve 20. From this triple valve 20 tubes 26 and 28 lead to a conduit 38 which leads to the bellows inlet chamber 40, and tube 30 leads from triple valve 20 to a vaporizer 32 for ether which in turn is connected to conduit 38 by conduit 34. Conduit 22 leads from the oxygen source 24 to a tube 36 which, like tubes 26 and 28 leads to the conduit 38. Tubes 26, 28, 30, and 36 are tapered from bottom to top and have therein floats (not shown) of known kind which indicate by their positions in the tubes the amount of gas flow within said tubes respectively. In addition to the triple valve means 20 the tubes 26, 28, 30 and 36 have the individual valve means 27, 29, 31 and 37 for controlling the amount of gas supplied through the tubes respectively.

Communicating with conduit 38 in advance of bellows 42, through branch conduit 44, is a flexible storage bag 46 which serves both as a gas mixing chamber and a reserve supply of mixed gases. Bag 46 may be manipulated by hand if for any reason manual control of the supply of gases to the patient is desired. In that event the bellows is locked in collapsed position by latch means, such for example as is shown in FIGURE 12, and is by-

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passed the patient's gases flowing from bag 46 directly to the patient's face mask, and the flow of power gas to the power cylinder is cut off automatically, as will be described.

Also communicating with conduit 38, through branch conduit 48, is an adjustable air intake valve 50 through which air may be supplied to the patient, usually mixed with oxygen, or with oxygen and the anesthesia gases as desired. In FIGURE 1 a dial 24a is shown which indicates the pressure of oxygen in a tank which has been placed in operative position in the machine.

Gas which is supplied into the bellows through conduit 38 when the bellows expands, which it does by force of gravity, is expelled from the bellows 42 when it is collapsed, into the patient's lungs through the bellows outlet chamber 52 and conduit 54, which leads to the patient's face mask 55. Although a volume of gas, which is constant for each inhalation phase of the breathing cycle while the volume setting remains unchanged, is forced into the patient's lungs, it is expelled from the lungs by the natural reflex action of the patient. When this occurs gas flows from the patient's lungs through the face mask, and through conduit 56 into the valve housing 58 which is also connected by conduit 60 with the interior of bellows 42. The pressure in the bellows 42 while it is being collapsed by power means, as will be described, closes the valve means 59 within valve housing 58 and prevents the patient from starting to exhale until the predetermined volume of gas for which the volume control means, to be described, is set, has been supplied into the patient's lungs. When the bellows 42 is collapsed i.e.: at the end of the inhalation phase, the exhaled gases depress spring 59a and open valve 59 in housing 58 and the exhaled gas passes through valve 59 into the circuit selector valve 64 from which it is either partly or entirely exhausted to atmosphere through conduit 61 and exhaust valve 62, or, depending upon the setting of the circuit selector valve 64, it is entirely or partly recycled, passing through conduit 66 to the filter 68, which may desirably be a soda lime canister of known kind, and from it through the one way valve 70 back into conduit 38, between the branch conduit 44 and the bellows 42.

Circuit selector valve 64 comprises the ports 61a and 66a, the ring shaped valve member 65 which is rotatable by the handle 65a and has the openings x and y adapted in one position to fully register with the ports 61a and 66a, and the member 65b which is engaged by handle 65a and rotates on the outer surface of the valve body in unison with the member 65. The position of member 65 determines whether all or part of the exhaled gas will be recycled. When it is positioned for a fully open circuit, which is the position when operating the device for resuscitation, the chain 72, which connects the rotatable member 65b of the selector valve 64 to the valve stem 76 of the triple valve actuating valve means 78 (see FIGURES 7, 9 and 14) raises the valve stem 76 from port 77 of conduit 80 permitting gas under pressure to flow through 82 to the triple valve, and causes the triple valve 20 to close and cut off simultaneously the flow of anesthesia gases and oxygen from a number of gas sources, as will be explained; similarly when ring 65 is positioned for a closed circuit, valve stem 76 is returned to its seat spring 74 and cuts off the flow of gas through 82 to the triple valve allowing the triple valve 20 to open and provide passage for the gases.

Thus it will be seen that the device can be employed to supply anesthesia gases to a patient, or the anesthesia gases may be shut off and the device operated as a resuscitator, in which case oxygen alone or mixed with air is supplied to the patient in an open system. In either use power gas is employed for collapsing the bellows to force into the patient's lungs a volume of gas which will be constant for each inhalation phase while the tidal volume control remains unchanged.

The bellows 42 is secured at the top to the valve plate

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84 from which it depends. Valve plate 84 has the ports 41 and 53 through which gases are supplied into and exhausted from, the interior of the bellows through the chambers and valve means provided in the housing 160 which is on top of plate 84. A third port 86 through plate 84 leads to the safety valve 88, which only opens to relieve pressure when the patient's breathing passages are completely closed. The lower end of the bellows is secured to the annular base plate member 90 which is mounted on and connected to the annular cross or a web member 91 having the upwardly extending sleeve portions 91a which are mounted for reciprocation on the guide rods 92, which extend upwardly from the top of the hood or housing 94, within which the conduit systems are housed, to the top plate 84 which is stationary.

A cylindrical recess 96 is provided extending through the bottom plate 90 and into the lower portion of bellows 42. It is closed at the top by the wall 98 against which the upper end of piston 100 presses when it is forced upward in its cylinder 102 by power gas which enters into and is also exhausted from, cylinder 102 through the port 104, at the lower end of cylinder 102. The pressure of piston 100 pressing upwardly on the wall 98 of the bellows collapses the bellows, the lower end of which moves upwardly and expels any gas within the bellows out through port 53 (FIG. 13) into chamber 52, and from chamber 52 into conduit 54 leading to the patient's face mask 55.

The power gas which is supplied into the power cylinder 102 flows from a source of gas under pressure, which is source 24 (oxygen) as shown herein, through the conduit 106 into the compensating valve 108, see FIGURE 4, through the port 110 and out of member 108 through the port 112, and through conduit 114 (FIGURE 2) and through valve 115 to the port 116 of the power cylinder cycling valve 118 (FIGURE 6) and from port 120 of the power cylinder cycling valve through conduit 122 to port 104 of the power cylinder 102, and raises piston 100 causing the bellows 42 to collapse.

When the bellows is substantially collapsed a projection 90a from its bottom plate 90 strikes the collar 170 on rod 164 and lifts the rod and triggers mechanism including pivoted beam 132 which moves valve stem assembly 133 to close port 116 of the cycling valve 118 and thereby initiates the beginning of the exhalation phase by allowing the power gas to escape from power cylinder 102 and piston 100 to return to its lowered position, causing bellows 42 to expand by gravity. The gas escaping from power cylinder 102 flows back through conduit 122 into the cycling valve 118 through port 120, and is in part quickly exhausted to atmosphere through the port 124 after lifting ball 125 and its stem 125a against the force of spring 125b, the remainder of the returning gas being exhausted more slowly through port 126 and conduit 128. The latter has in it the valve 130 by which the duration of the patient's exhalation phase may be controlled. Access to ports 124 and 126 is provided by the lowering of stem 133 and the valve members 133c and 133d which move down with it, as will be more fully explained.

When the bellows is substantially fully expanded the projection 90a strikes the stop or contact member 156 on the lower end of chain 154 (FIGURE 12) and thereby again triggers means to be described which swings the pivoted control beam 132 causing it to elevate valve stem 133, thus opening port 116 of the cycling valve 118 and causing gas from source 24 to again flow to the power cylinder through valve means 108 and 118. The elevation of valve stem 133 and associated parts closes access within the valve housing to port 124 and port 126, and gas again flows into 118 through port 116 and out of 118 through port 120 to the power cylinder 102 to again collapse the bellows and thereby supply gas into the patient's lungs.

If, while the bellows is collapsing, the patient's breathing passages become partly closed for any reason it will require more force to expel the gas from the bellows into

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the patient's lungs. This increased resistance will be communicated to the gas in power cylinder through the piston 100 and this back pressure is employed to increase the flow of power gas from its source 24 in proportion to the back pressure and thus maintain substantially constant the speed with which the bellows collapses, which is an important result since it maintains the breathing rhythm of the patient. The back pressure is communicated to cycling valve 118 (FIGURE 6) through conduit 122 and port 120, and from the cycling valve through its port 121 and conduit 123 to the port 113 of the compensating valve 108.

Valve 108 (FIGURE 4) comprises the metal plates 134 and 136 which clamp between them a flexible sheet material forming the two separate diaphragms 138 and 140 on the central portion of each of which a washer assembly *w* is provided to stiffen the center portions of the diaphragms respectively and increase the power they transmit when pressure is exerted against them. Pedestals 142 and 144 are integral with, and project upwardly from, the washer assemblies *w* of diaphragms 138 and 140 to the opposite ends of a leaf spring 143, the mid-portion of which is pressed downwardly by a pivot screw 145 which is supported by the saddle 146.

In port 110 of member 108 a fitting 148 is provided which defines a valve seat 150, and a valve stem 151 projects from diaphragm 138 through the fitting 148 and has a conical head portion 152 which is normally lifted somewhat from its seat to allow gas under pressure from source 24 to flow past it into the space below diaphragm 138 and out through port 112 through conduit 114 to the cycling valve as has been explained. When back pressure from the power cylinder is communicated to port 113 of compensating valve 108, through port 121 from the cycling valve, it presses diaphragm 140 upwardly, elevating pedestal 144 against one end of leaf spring 143 which reacts by pressing downwardly from its other end on pedestal 142 and a diaphragm 138, thus further lowering the head 152 of valve stem 151 from valve seat 150 and allowing an increased amount of gas to flow from the power gas source 24 into the space below diaphragm 138 and out through port 112 and through conduit 114 to the power cylinder 102 through ports 116 and 120 of the cycling valve. The increased flow of power gas equalizes the increased resistance of the patient's breathing passages to the flow of gas from the bellows and enables the bellows to expel its gas and to be successively collapsed at substantially the same speed thus producing an inhalation period which is constant.

The means for controlling the volume of gas to be supplied to a patient is shown in FIGURES 11 and 12 which also show the cycling valve actuating means 132. The chain 154, which is wound around drum 155, passes through an opening in the extension 90a of the plate 90 at the lower end of the bellows and has at its lower end a collar or stop member 156. When the extension 90a strikes the member 156 it pulls down on chain 154 and the pressure exerted on the chain guide 174 lowers rod 164 causing it to swing beam 132 on its pivot and raise stem 133 in the cycling valve 118, thus changing the phase of the power cylinder valve and ending the unfolding movement of the bellows. Since it is during this movement that the bellows becomes filled with gas, the extent of such movement determines the volume of gas which will be forced into the patient's lungs when the bellows is collapsed. By adjusting the length of chain 131 as by turning 176 to rotate drum 155, the total volume of gas which the apparatus will supply into the patient's lungs is changed.

The beam 132 is pivoted at 158 on the valve housing 160 for the bellows inlet and outlet valves. One end of beam 132 extends into the peripheral slot 133b in the collar 133a on the valve stem 133 within the cycling valve 118, and its other end is loosely fitted in a recess defined by member 162 which is disposed at the upper

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end of the vertically movable rod 164 on the enlarged head portion 165 of the rod. The plate 84 at the top of bellows 42 has the extension 84a, and the plate 90 at the lower end of the bellows has the extension 90a, mentioned above. Apertures 166 and 163 are provided in vertical alignment in the extensions 84a and 90a respectively of the bellows end plates and rod 164 extends through these apertures. On the rod 164, between plate extensions 84a and 90a, a collar or stop 170 is provided. The guide 174 for chain 154 is supported on the side of the rod head 165 and the roller 178 is supported on the guide 174, on the far side of guide 174 from the rod head 165.

From the bellows valve housing 160 project four rods *r* which serve to support a plate 172 through which extends the hub 173 of drum 155 on which one end of chain 154 is secured. On the hub 173, in front of plate 172, a combination finger piece and pointer 176 is provided, and the face of the plate is calibrated in terms of volume of gas expelled from the bellows each time it is collapsed. By turning member 176 drum 155 is rotated to wind chain 154 on, or unwind it from, the drum, thus increasing or decreasing the length of chain 154 which results in increasing or decreasing the volume of gas which will be drawn into the bellows when it expands, and expelled from the bellows when it is collapsed.

Roller 178 coacts with a pawl 180 pivoted adjacent its lower end on pivot 182 which is supported by bracket means 184 projecting upwardly from plate extension 85. The head of the pawl is urged to swing inwardly toward roller 178 by spring 186. When the bellows reaches the top of its stroke the plate extension 90a strikes the stop 170 on rod 164 and pushes the rod 164 upward until roller 178 has contacted pawl 180 and passed over its point, after causing the head of the pawl to swing inwardly against the force of spring 186. When the roller 178 reaches the upper slope of the head of pawl 180 the tension of spring 186, acting to urge the head of the pawl against roller 178, will raise rod 164 further until it swings the beam 132 on its pivot 138 and pushes down the valve stem 133 of the power cylinder cycling valve 118 thereby closing off any flow of power gas from the source 24 to the power cylinder, and releasing the gas accumulated under pressure in the power cylinder, allowing the gas to exhaust from the power cylinder through the cycling valve to atmosphere through ports 124 and 126 as described above, and thus conditioning the bellows 42 to expand by gravity. When the extension 90a of the bellows bottom plate 90 strikes the stop or collar 156 at the lower end of chain 154, rod 164 will be moved downwardly causing beam 132 to be swung on its pivot in a direction to raise valve stem 133 of the power cylinder cycling valve, allowing power gas from source 24 to again flow to the power cylinder, through port 110 and 112 of the compensating valve, and ports 116 and 120 of the cycling valve, and initiate the next inhalation phase for the patient by again collapsing bellows 42.

The triple valve 20 has passages which communicate respectively between three separate sets of inlet and outlet ports, 196 and 198, 200 and 202, and 204 and 206, and comprises means for opening and closing all of the passages simultaneously. Valve 20 comprises the three portions 190, 192 and 194. A flexible sheet of rubber or similar material 208 is clamped between body members 190 and 192 and passes through the spaces 193 provided in member 20 between the inner ends of the inlet ports 196, 200 and 204 and the inner ends of outlet ports 198, 202 and 206 respectively, thus forming three flexible diaphragms *d* disposed under the inner ends of the outlet ports respectively. A second flexible sheet of material 210 is clamped between body members 192 and 194 and extends through, and divides into two portions, a circular chamber 212 defined by the body members. The port 214 communicates with the portion of chamber 212 which is on the far side of the flexible diaphragm 210a from the outlet ports 198, 202 and 206 and from the three flexible diaphragms *d* defined by member 208.

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Between diaphragm 210a and diaphragms d the members 216 are provided. As shown herein, the lower ends of the members 216 extend through recesses in the body portion 192 and rest upon the top of a rigid disc 218, which in turn rests on the diaphragm 210a and has a stem 218a which extends up loosely through a bore b in the body portions 190 and 192 and acts as a guide keeping the diaphragm 210a disposed in a straight line when it is moved upward by pressure entering from conduit 82. When this occurs, the diaphragms d under the inner ends of outlet ports 198, 202 and 206 move up against the inner ends of these outlet ports simultaneously and effectively seal them until the pressure under diaphragm 210a is relieved.

The triple valve actuating means 78 is a two way valve that in one position allows pressure to actuate means in the triple valve to close the gas passages within the triple valve 20, and in its other position provides passages for exhausting gas from the triple valve 20 thus relieving the pressure under diaphragm 210a of the triple valve. The port 77 is normally closed by the valve stem 76, preventing pressure from the gas container 24 from being communicated into valve 78 through conduit 80. However, when the circuit selector valve 64 is positioned for an entirely open circuit the chain 72 will raise the stem 76 in valve 78 and pull valve member 79 against floating valve member 79a which in turn will be raised against valve seat 79b thereby preventing the gas from escaping to atmosphere through the body of the valve housing and the vents 75. Gas from the pressure line 80 will flow into valve 78 through port 77 and out through the port 81 which connects to the conduit 82, and through conduit 82 into the triple valve 20, through port 214 raising the diaphragm 210a and closing the gas passages within the triple valve 20. When setting of the selector valve permits, the stem 76 will be returned by spring 74 to close port 77 and this action allows the power gas to be exhausted from the triple valve by flowing back through conduit 82 into the body of valve 78 and out of valve 78 through the vents 75. The reduction of pressure under diaphragm 210a will permit renewed flow of anesthesia gases through valve member 20 to their respective flow meter tubes and to the conduit 38.

The bellows valve assembly comprises a housing 160 having therein inlet and outlet chambers 40 and 52 and a space 43 which is above, and communicates between inlet chamber 40 and chamber 45 which communicates with the bellows through port 41. Inlet chamber 40 has the one-way flap valve 40a, and outlet chamber 52 has the one-way flap valve 52a. A space 43 is provided in inlet chamber 40 above valve 40a and it communicates with chamber 45 through a slot t in the wall dividing chamber 40 from chamber 45. The valve 40a is heavy enough to close and prevent gases from flowing into the inlet valve chamber on the upward stroke of the bellows. However, it is light enough so that it will lift in response to the reduced pressure within the bellows when the bellows is expanding. Valve 40a has a projecting finger F which extends into the chamber 45 over the top of the bellows port 41 and in alignment with the projection P extending up from the wall 98 inside the bellows.

A light weight disc 52a is also provided at the bottom of the outlet valve chamber 52 and rests on ring seat 51. It is similar to disc 40a, without the extension arm. It opens when pressure is exerted on its under face through port 53 during the compression stroke of the bellows, and allows gas expelled from the bellows to flow from chamber 52 to exhaust conduit 54 and the patient's face mask 55.

It will be understood that if it is desired to supply gas to the patient manually the bellows 42 is locked in collapsed position, as by latch 220 (FIGURES 1 and 12) and that in this position the projection P which extends upwardly from the wall 98 defining the upper end of the recess 96, prevents the disc valve member 40a from closing, thus conditioning the bellows valve assembly to by-

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pass the bellows and to permit the gases from conduit 38 to flow directly through it from inlet port 40 through port 41 to outlet port 52. Latch 220 is shown pivoted at 222 on bracket 224 depending from the extension 84a of the bellows top plate, and held in operative or inoperative position by the toggle spring 226.

A flexible sleeve 230 is provided within the power cylinder 102, above port 104, and its upper portion 230a is bent over inwardly and extends under, and is secured to the lower end of the piston 100. A sleeve 232 of rigid material, preferably "Teflon" because of its lubricating qualities, is provided within the lower portion of cylinder 102 on the inside of the lower portion 230b of the flexible sleeve. The sleeve 232 is positioned so that it separates the lower portion 230b of the flexible sleeve 230 from frictional contact with the turned over and telescoped upper portion 230a of the flexible sleeve as it descends with the lower end of the piston.

The power cylinder cycling valve 118 has been referred to and partly described above. It comprises the body portions 236 and 238 and the top plate 240 which is spaced from body portion 238 by the spacers 241. A gasket 237 is provided between 236 and 238. Defined by the body portion is a chamber 242. A passage 244 extends through body portion 236 from said chamber and has a valve seat 246, preferably of rubber or composition material, at its inner end, and a tubing union connection at its other end which defines the port 116. From chamber 242 a passage 248 extends laterally in body portion 236, at right angles to passage 244, and communicates with two branch passages 250 and 252 which are parallel to passage 244 and have at their outer ends tubing union connections respectively defining the ports 120 and 121. Another passage 254 parallel to 244 extends through the body and at one end has the tubing union connection which defines the port 126 and at its other end, defining port 124 a composition valve seat 256 is provided. Chamber 242 communicates with passage 254 through a port 257 and a passage 258 on the opposite side of chamber 242 from passage 244, extends through the body portion 238, in alignment with port 256 and passage 244. A valve stem 133 extends through an opening in the top plate 240, and through passage 258, and its tapered head extends into passage 244. When the apparatus is at rest, the head stem 133 seats against the seat 246, being urged into this position by the attraction exerted by permanent magnets 260, supported in top plate 240, upon the soft iron disc 262 which is screwed onto the upper end of valve stem 133.

Also mounted on valve stem 133, in the space between top plate 240 and body portion 238 is the collar 133a which has the peripheral slot 133b in which is engaged one end of pivoted beam 132, as has been described. And adjacent its tapered end, within chamber 242, stem 133 has the integral radially extending flange 133d, which on its upper surface defines a valve seat 271 which is below and opposed to a valve seat 239 on the surface of body portion 238 which coacts with body portion 236 to define chamber 242. A floating, annular valve member 133c extends around stem 133 between the opposed valve seats. When stem 133 is seated, the floating member 133c rests on seat 271 but when stem 133 is raised member 133c is held between seats 271 and 239 thus closing port 257 which leads to passage 254. The ball valve 125, referred to above, is mounted on a stem 125a which is reciprocal in sleeve 276 which extends through top plate 240. The spring 125b extends around the stem 125a between the ball 125 and the sleeve 276 and urges the ball to seat against seat 256 at the top of port 124. When port 257 is closed, power gas cannot flow into passage 254 but when port 257 is open power gas being exhausted from the power cylinder and entering member 118 through port 120 can pass into passage 254 and is exhausted from both ends of said passage, first by lifting ball 125 against the force of spring 125b, and then more gradually, through

port 126, conduit 128 and valve 130 as described above.

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

What is claimed is:

1. Apparatus for intermittently administering controlled volumes of gas which comprises, a bellows, a cylinder, one or more sources of gas under pressure, first conduit means leading from one or more sources of gas to the bellows, second conduit means leading from the bellows to supply gas to the patient, third conduit means leading from a source of gas under pressure to said cylinder, means movable in said cylinder in response to pressure of gas in said cylinder, means for communicating movement of said means within the cylinder to the bellows to intermittently collapse the bellows and deliver to the second conduit means equal volumes of gas within equal periods of time, and means responsive to back pressure in the cylinder to pass additional gas from said source to the cylinder in proportion to the amount of said back pressure.

2. The apparatus claimed in claim 1 including plural valve means for controlling the supply of gas to the bellows simultaneously from a plurality of said sources.

3. The apparatus claimed in claim 1 in which the means responsive to back pressure in the cylinder comprises compensator valve and cycling valve means in the conduit means between said source and said cylinder, and said compensator valve includes a first port communicating with said source, a second port communicating with the cylinder intermittently through the cycling valve, and a third port through which back pressure from the cylinder is communicated, and means operative in response to said back pressure for opening said first and second ports in proportion to the back pressure communicated to said third port.

4. The apparatus claimed in claim 1 in which the said third conduit includes compensator valve means and a cycling valve including means responsive to said bellows to stop the flow of gas to the cylinder and permit the return flow, and exhaust to atmosphere, of gas from the cylinder.

5. The apparatus claimed in claim 2 comprising means for selectively exhausting exhaled gases to atmosphere or returning them to the bellows for recycling and including a selector valve, and actuating means responsive to the position of the selector valve for controlling the operation of the plural valve.

6. The apparatus claimed in claim 5 in which the actuating means for the plural valve comprises, a closure having first, second and exhaust ports, a first conduit connecting the first port to a source of gas under pressure, a second conduit communicating between the second port and the plural valve, and means movable in said closure in response to movements of the selector valve to open said first port and permit gas from said source to flow to the plural valve and to close the plural valve, and to close

the first port and connect the second port to the exhaust port to permit gas to flow from the plural valve and to open the plural valve.

7. The apparatus claimed in claim 5 in which the plural valve comprises, a housing defining first and second chambers, first and second flexible diaphragms extending through said chambers respectively, a plurality of ports in the housing wall for connecting said first chamber to a plurality of sources of therapeutic gas under pressure, a plurality of ports in the housing for connecting the first chamber to said bellows, the ports of said first chamber being disposed on the far side of the diaphragm therein from the second chamber, means carried by the first diaphragm on the opposite side thereof from the ports of said first chamber, but in alignment respectively with the said ports for connection to the bellows, extending into the second chamber and into contact with the near surface of the diaphragm in said second chamber, and a port communicating with said second chamber, on the far side of the diaphragm therein from the said means carried by the first diaphragm, through which operating gas may be supplied or discharged to move said second diaphragm and cause it, through the means carried by the first diaphragm, to move the first diaphragm to close or open the said ports in said first chamber which are for connection to said bellows.

8. The apparatus claimed in claim 4 in which the cycling valve means comprises, a housing defining a chamber having a first port for connection through the compensator valve to a source of operating gas, means movable within said chamber to open and close said port, said means being actuated by the collapsing and expanding movements of said bellows, a second port for connecting said chamber to said cylinder, a third port for communicating between said chamber and the compensator valve, to transmit to the compensator valve the back pressure in the cylinder, a fourth valve operative when the first port is closed to provide a speedy partial exhaust of gases returned to said chamber from the power cylinder when the bellows is expanding, and a fifth port connected to the atmosphere through a control valve to provide a supplementary means for exhausting operating gas returned from the cylinder and control the rate of expansion of the bellows thereby controlling the length of the exhalation phase of a breathing cycle.

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