

- [54] **PNEUMATICALLY OPERATED VENTILATOR**
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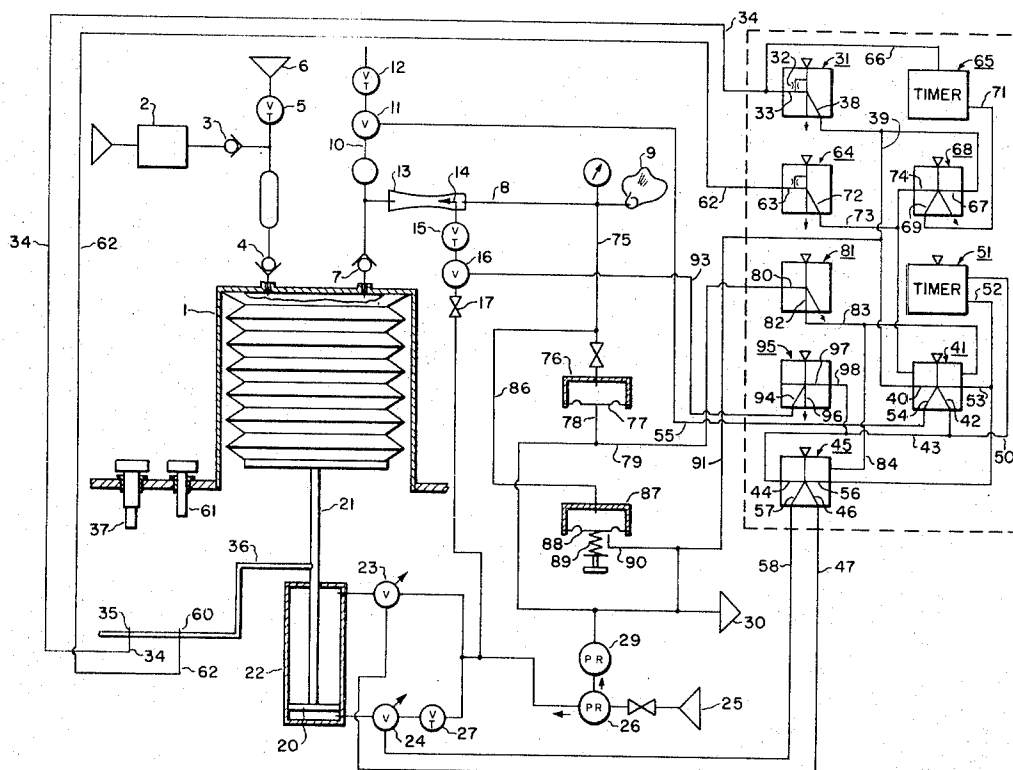
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[57] **ABSTRACT**

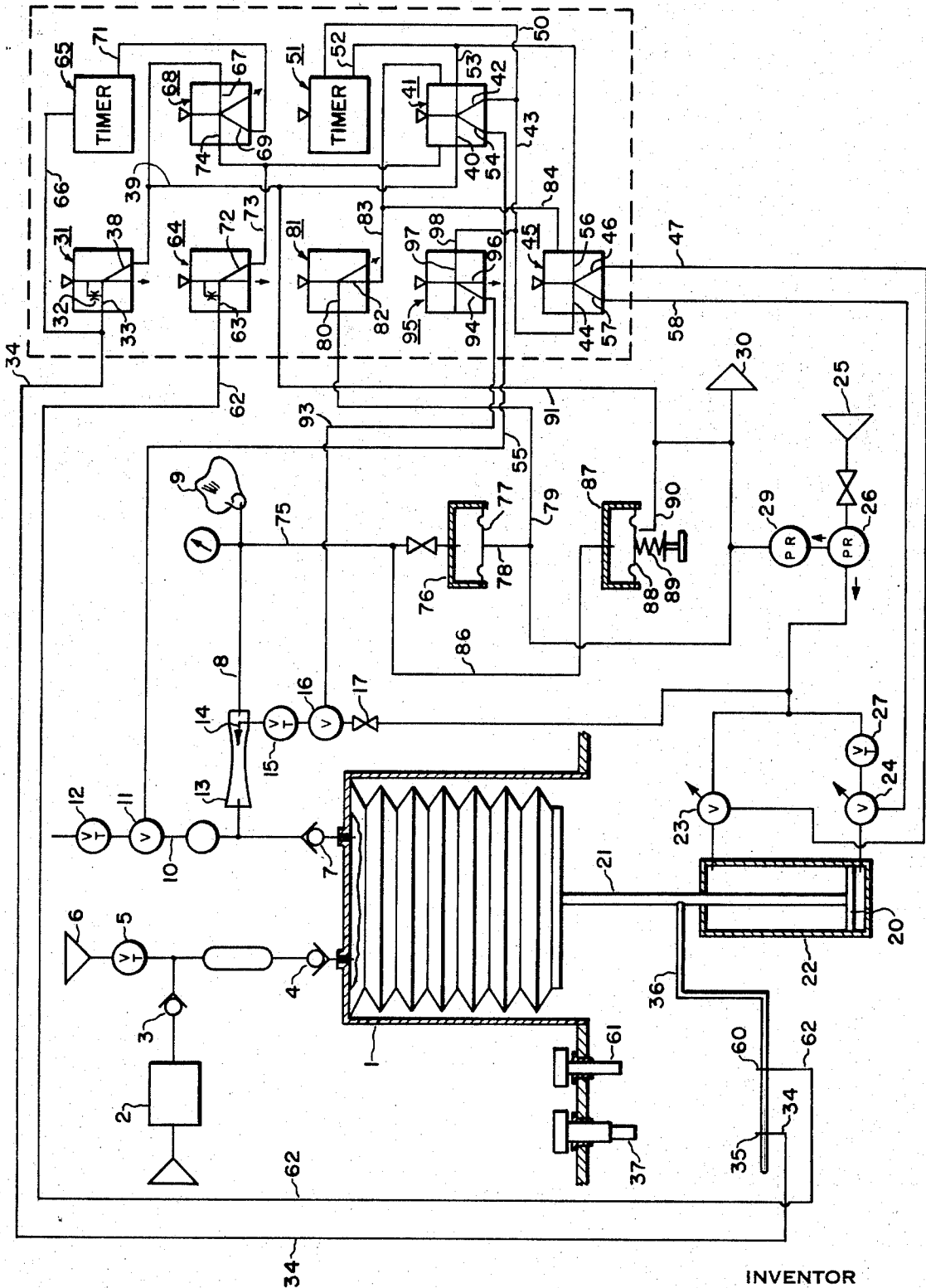
A pneumatically operated pump is connected with a conduit for supplying a gas to a patient's lungs. A first fluidic control element and a pneumatic timer control means for delivering air under pressure to the pump for operating it. The fluidic control element is controlled by a second fluidic control element, which in turn is controlled by a third fluidic control element. The latter is controlled by the movement of the pump during lung inflation to reverse the pump in order to allow exhalation. The second control element also controls an exhalation valve. Other elements provide for periodic longer inhalation periods, excess pressure release and sudden inhalation.

8 Claims, 1 Drawing Figure



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PNEUMATICALLY OPERATED VENTILATOR

For any one of several reasons, such as being heavily drugged or having a damaged respiratory system, a person may require assistance in breathing. Or, it may be desirable to administer an anesthetic gas to a patient. For these purposes ventilators are provided that pump a gas, such as air, oxygen, an anesthetic and the like, into and out of the patient's lungs. The ventilators generally are electrically operated, but there are situations where electricity may not be available or where it may fail. Also, an electrically operated ventilator may be sensitive to radiated electrical signals, or an electric spark from it may set off an explosion.

It is among the objects of this invention to provide a ventilator which is completely automatic, which does not depend upon electrical or mechanical power to operate it, which is not affected by electrical radiations, which cannot cause an explosion if there is an explosive atmosphere around it, which is dependable in operation and which is constructed from a minimum of moving parts.

The preferred embodiment of the invention is illustrated in the accompanying drawing, which is a diagram of the entire system.

Referring to the drawing, a bellows 1, that forms part of a gas pump, has an inlet through which air can be drawn through a filter 2 and two check valves 3 and 4. Between the check valves there is a connection from a needle valve 5 connected with an optional oxygen supply 6 or a tank of anesthetic gas or the like. The bellows has an outlet connected through a check valve 7 to a conduit 8 that extends to a mask 9 to be worn by a patient requiring ventilation. Connected with this conduit is an exhalation conduit 10 containing a pneumatic solenoid valve 11 and a modulating valve 12 leading to the atmosphere. Valve 11 is an exhalation valve, preferably normally open, and the modulating valve controls exhalation rate. Conduit 8, between the exhalation conduit and the mask, may include a venturi 13 that has a power jet 14 directed away from the mask and connected through a needle valve 15, a way pneumatic solenoid valve 16 and an on and off valve 17 to a source of air under pressure. When the last-mentioned valve is opened, the venturi helps the patient exhale by withdrawing air or other gas from his lungs and forcing it out through the exhalation valve.

To actuate the pump, which will be described as if in a vertical position, the movable bottom wall of the bellows is reciprocated. This can be done by a fluidic control element, or by a piston 20 connected to it by a rod 21. The piston is disposed in a cylinder 22 having a combined inlet and outlet near each end. The cylinder ports are connected through three-way pneumatic solenoid valves 23 and 24 with a source 25 of air under pressure. The initial pressure may be over 50 p.s.i., but it is reduced by a regulator 26 to a pressure of about 20 p.s.i. The regulator may also supply the air pressure to on and off valve 17. When the lower valve 24 is operated to connect the air supply with the lower end of the cylinder, the piston is raised at a rate determined by a needle valve 27. At the same time, air above the piston escapes to the atmosphere through the upper valve 23. When the valves are reversed, the piston is moved down rapidly, the air below it being exhausted to the atmosphere through the lower valve 24. Consequently air, for example, is forced into the lungs of

the patient at a desired slow rate, but during exhalation the bellows is expanded rapidly so that the bellows will be full of air in case the patient requires air before the normal exhalation cycle of this ventilator terminates, as will be explained presently.

It is a feature of this invention that all of the pneumatic valves are actuated by pneumatic pressure controlled by fluidic control elements, often referred to as fluid amplifiers. The air for operating these control elements, and by which they operate the valves, preferably comes from the main pressure source 25, but it first passes through a second regulator 29 that reduces the pressure to only a few pounds p.s.i. Air flows continuously down through all of the control elements, the connection from regulator 29 to them being indicated by triangle 30 and the small triangles at the control element inlets.

The main passage through a monostable fluidic control element 31 has a restricted by-pass 32 that connects it with the lateral control passage 33, which in turn is connected by a line 34 with a vertical nozzle 35 carried by an arm 36 projecting from the side of the piston rod above the cylinder. Some of the air entering control element 31 flows continuously from this nozzle until the piston rises high enough for the nozzle to engage and be closed by a vertically adjustable spring loaded plunger 37 above it. When this occurs, the air flowing through restriction 32 exerts enough pressure against the side of the main stream through the control element to deflect it into the power outlet passage 38 that is connected by a line 39 with a control passage 40 of a fluidic control element 41. The power stream through this control therefore is deflected into the right-hand outlet passage 42 that is connected by a line 43 with a control passage 44 of a bistable control element 45. This deflects the power stream through element 45 into its right-hand outlet passage 46 that is connected by a line 47 with upper valve 23 for the pump cylinder to operate that valve so that it will admit air pressure into the top of the cylinder to drive the piston downwardly rapidly. At the same time, lower valve 24 shifts to connect the lower end of the cylinder with the atmosphere.

Air from outlet 42 of element 41 also is delivered through a line 50 to a pneumatic timer 51, through which a power stream of air normally flows to atmosphere. The pressure of air from line 50 sets the timer operating and after a predetermined length of time, which is the period desired for exhalation, the timer times out and a pulse of power stream air is delivered through a line 52 to the right-hand control passage 53 of element 41 to shift the power stream therein into its left-hand outlet passage 54. This stream, flowing through a line 55, closes the normally open exhalation valve 11. At the same time, a pulse of air from timer line 52 enters the right-hand control passage 56 of element 45 to shift the main stream therein to its left-hand outlet passage 57 by that is connected by line 58 with the lower valve 24 of the pump cylinder. This will shift the valve to connect the main air supply with the lower end of the cylinder so that the piston will be driven upwardly to force air out through conduit 8 and into the lungs of the patient. At the same time, valve 23 returns to its normal position, in which it connects the upper end of the cylinder with the atmosphere. As soon

as nozzle 35 again engages plunger 37, valves 23 and 24 and the movement of the piston will be reversed to repeat the cycle just explained.

It has been found that a patient being ventilated, periodically requires an extra volume of air, which is manifested by a sigh. To provide for this extra volume the piston arm carries a second nozzle 60 below a vertically adjustable stop 61, the lower end of which is located at a higher level than the lower end of the plunger beside it. This second nozzle is connected by a line 62 with the control passage 63 of a monostable fluidic control element 64 having the same construction as control 31. Since the second nozzle ordinarily does not rise high enough to be closed by the stop above it, control 64 normally remains inactive and the power stream simply flows straight through it. However, the second nozzle does move higher periodically, which is allowed by the upwardly movable spring-loaded plunger 37. It is accomplished by a timer 65 that has a normally closed inlet connected by a line 66 with the line 34 between control 31 and its nozzle 35.

When control 31 is actuated to direct air out of its power outlet passage 38, some of this air enters the right-hand control passage 67 of a bistable control element 68 to deflect the power stream therein into the left-hand power outlet passage 69, which is connected by a line 71 to timer 65. This sets the timer to operating so that after a selected period of time, which may be ten to twenty minutes, its normally closed inlet will be opened to by-pass the air from the lateral control passage 33 of control element 31. Consequently, the next time nozzle 35 engages the plunger, control element 31 will not be affected because there will be no back pressure to cause air in passage 33 to shift the power stream, and the piston will continue to rise until the second nozzle 60 engages stop 61. When this occurs, the power stream through control 64 will be shifted to its outlet passage 72, which is connected by a line 73 with the left-hand control passage 74 of control element 68 and the flow of air through line 71 to timer 65 will be cut off so that the timer will reset to close line 66, and control element 31 will be made operative again. Of course, while nozzle 60 is rising the extra distance to its stop, a larger volume of air is being forced out of the bellows and into the lungs of the patient. Line 73 also is connected to a second inlet to control element 41 to reverse that element.

In case the patient inhales while the piston is at the lower end of the cylinder and waiting for timer 51 to let it move upwardly again, provision is made for short circuiting the timer so that the patient will be supplied with the air he desires. For this purpose the conduit 8 to the mask is connected by a line 75 to a chamber 76, one wall of which is a flexible diaphragm 77. This diaphragm normally closes the end of a tube 78 leading from a line 79, through which a stream of air flows continuously into the lateral control passage 80 of a monostable fluidic control element 81 to normally cause the power stream of air flowing through that control to pass into the atmosphere. However, if the patient inhales while the bellows is expanded and stationary, waiting for the timer to allow it to be compressed, the air pressure in chamber 76 will be reduced so that its diaphragm will rise and open tube 78. This will allow air to escape from the tube so that the power

stream flowing through control element 81 will be permitted to shift back and flow out through an outlet passage 82 connected by a line 83 with a second right-hand control port for control element 41, whereby to cause the power stream flowing through that element to leave through passage 54 to close the exhalation valve. At the same time, the stream from control 81 will also flow through a line 84 to a right-hand side control port for control element 45 and shift the stream therein to the left-hand outlet passage 57 so that the lower cylinder valve 24 will be opened to admit air pressure to the bottom of the cylinder. This piston therefore will rise immediately and deliver air to the patient without waiting for timer 51 to time out.

Another feature is that if the gas pressure in the patient's lungs starts to become excessive, it can be relieved. To do this, a line 86 connects conduit 75 with a second chamber 87 having flexible diaphragm wall 88 that normally is held in a raised position by an adjustable spring 89. Spaced a short distance from this diaphragm is the open end of a tube 90, through which a stream of air flows continuously. This tube is connected by a line 91 with line 39 and therefore with control passage 40 of control element 48. Normally, the stream of air entering tube 90 has no effect on anything because the tube, being open, pressure cannot be built up. However, if the pressure in the patient's lungs starts to exceed a predetermined value the pressure in chamber 87 will increase and move its diaphragm down until it closes the tube. The air stream then will be diverted through lines 91 and 39 to control element 41. This will shift the power stream in control 41 to outlet passage 42 so that control 45 also will be shifted and the upper cylinder valve will be opened to drive the piston down immediately. At the same time, the exhalation valve 11 will open and relieve the pressure in the patient's lungs.

If the assistance of venturi 13 is desired during exhalation, valve 17 is opened manually and after that the action of the venturi will be automatic. This is because normally closed pneumatic solenoid valve 16 is connected by a line 93 with the power outlet passage 94 of monostable fluidic control element 95 that also has an outlet 96 to atmosphere. A lateral control passage 97 is connected by a line 98 to line 43. When the system switches to the exhalation cycle and air from control element 41 is directed into line 43, the power stream through control element 95 is diverted into passage 94 and line 93 to open valve 16 so that air under pressure will issue from jet 14 of the venturi. As soon as the pressure in control passage 97 is relieved by the change to the inhalation cycle, valve 16 closes.

The ventilator disclosed herein has many advantages. Its construction and simple an: it has only a few moving parts. It can be used anywhere that a supply of compressed air is available. No electrical connections are required. It is completely automatic and dependable in operation. The ventilator also automatically relieves the pressure in the patient's lungs if it becomes excessive and periodically gives the patient an extra supply of air. If the patient inhales of his own accord, the controls are overridden and he is immediately supplied with the necessary amount of air.

According to the provisions of the patent statutes, I have explained the principle of my invention and have

illustrated and described what I now consider to represent its best embodiment. However, I desire to have it understood that, within the the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

I claim:

1. A ventilator comprising a conduit for supplying a gas to a patient's lungs, a pneumatically operated pump having a rapid suction stroke and a pressure stroke for alternately drawing in a charge of a gas and then forcing it out through said conduit, means for delivering air under pressure to the pump for operating it, pneumatically operated control means shiftable back and forth between two positions for controlling said delivery of air, means restricting flow of said air from said control means in only one of said positions to admit operating air to the pump slowly to produce a slow pressure stroke, means for supplying control air to said control means for the shifting thereof, a first fluidic control element controlling the supply of control air to said control means, a pneumatically operated timer, a second fluidic control element having an outlet for delivering control air to the first fluidic control element to cause it to shift said control means to connect said air delivering means with the pump to produce the rapid suction stroke of the pump, a first air line for also delivering air from said outlet to the timer to start it operating, a second air line adapted to be opened by the timer when the timer times out, said second air line being connected to the first fluidic control element to cause said first element to shift said control means to connect said air delivering means with the pump to produce the slow pressure stroke of the pump, a normally inoperative third fluidic control element having a power outlet, means controlled by the movement of the pump at the end of its pressure stroke for rendering the third fluidic control element operative, a third air line for delivering control air from said power outlet to said second fluidic control element to cause air to issue from said outlet of said second element, an exhalation valve connected with said conduit and having a closed position and an open position and normally being in one of said positions, means operatively connecting said second fluidic control element with said valve for shifting the valve to its other position, a venturi in series with the exhalation valve and having an inlet for communication with the patient's lungs, the venturi being provided with a power jet, a normally closed valve connected with said jet, means for supplying air under pressure to the jet when said normally closed valve is opened to thereby withdraw gas from a patient's lungs, and a fluidic control element controlled by said second control element for opening said normally closed valve while the exhalation valve is open.

2. A ventilator comprising a conduit for supplying a gas to a patient's lungs, a pneumatically operated pump having a rapid suction stroke and a pressure stroke for alternately drawing in a charge of a gas and then forcing it out through said conduit, means for delivering air under pressure to the pump for operating it, pneumatically operated control means shiftable back and forth between two positions for controlling said delivery of air, means restricting flow of said air from said control means in only one of said positions to admit operating air to the pump slowly to produce a slow pressure

stroke, means for supplying control air to said control means for the shifting thereof, a first fluidic control element controlling the supply of control air to said control means, a pneumatically operated timer, a second fluidic control element having an outlet for delivering control air to the first fluidic control element to cause it to shift said control means to connect said air delivering means with the pump to produce the rapid suction stroke of the pump, a first air line for also delivering air from said outlet to the timer to start it operating, a second air line adapted to be opened by the timer when the timer times out, said second air line being connected to the first fluidic control element to cause said first element to shift said control means to connect said air delivering means with the pump to produce the slow pressure stroke of the pump, a normally inoperative third fluidic control element having a power outlet, means controlled by the movement of the pump at the end of its pressure stroke for rendering the third fluidic control element operative, a third air line for delivering control air from said power outlet to said second fluidic control element to cause air to issue from said outlet of said second element, a second pneumatic timer for periodically lengthening said pressure stroke to expel a larger charge of gas than normally, means controlled by the movement of the pump at the end of its pressure stroke during lung inflation for resetting the second timer, a conduit connecting said third fluidic control element to the second timer and normally closed by the second timer, the second timer periodically opening said last-mentioned conduit to render said third control element inoperative.

3. A ventilator comprising a conduit for supplying a gas to a patient's lungs, a pump having an outlet connected with the conduit and having a fluid pressure cylinder and a piston movable back and forth therein for alternately drawing gas into the pump and forcing it out through said conduit, pneumatically operated valves connected with the opposite ends of the cylinder, means for supplying operating air under pressure through said valves to the cylinder, means for supplying control air to said valves for operating them, means restricting flow of operating air from one of said valves in one position to one end of the cylinder to cause the pump to force gas out through said conduit, said valves in another position by-passing said restricting means to admit operating air to the other end of the cylinder rapidly to cause the pump to draw in gas, a first bistable fluid amplifier controlling the control air supply to said valves, a pneumatically operated timer, a second bistable fluid amplifier having an outlet for delivering control air to said first fluid amplifier to cause it to operate the valves to connect said air supplying means to said other end of the cylinder, a first air line for delivering air from said outlet to the timer to start it operating, a second air line adapted to be opened by the timer when the timer times out, said second air line being connected to the first fluid amplifier to cause said first fluid amplifier to operate said valves to connect said air supplying means to said one end of the cylinder, a normally inoperative third fluid amplifier having a power outlet, means controlled by the movement of said piston during lung inflation for rendering the third fluid amplifier operative, and a third air line for delivering control air from said power

outlet to said second fluid amplifier to cause air to issue from said outlet of said second fluid amplifier, said third fluid amplifier being a monostable element having an inlet passage, a normal outlet passage, a control passage for shifting a stream of air from the normal outlet to said power outlet, and a by-pass connecting said inlet passage to the control passage for normally directing a stream of air through the control passage away from said fluid amplifier, and said piston-controlled means including means for blocking said stream from the control passage to cause it to effect said stream shift.

4. A ventilator comprising a conduit for supplying a gas to a patient's lungs, a pump having an outlet connected with the conduit and having a fluid pressure cylinder and a piston movable back and forth therein for alternately drawing gas into the pump and forcing it out through said conduit, pneumatically operated valves connected with the opposite ends of the cylinder, means for supplying operating air under pressure through said valves to the cylinder, means for supplying control air to said valves for operating them, means restricting flow of operating air from one of said valves in one position to one end of the cylinder to cause the pump to force gas out through said conduit, said valves in another position by-passing said restricting means to admit operating air to the other end of the cylinder rapidly to cause the pump to draw in gas, a first bistable fluid amplifier controlling the control air supply to said valves, a pneumatically operated timer, a second bistable fluid amplifier having an outlet for delivering control air to said first fluid amplifier to cause it to operate the valves to connect said air supplying means to said other end of the cylinder, a first air line for delivering air from said outlet to the timer to

start when the timer times out, said second air line being connected to the first fluid amplifier to cause said first fluid amplifier to operate said valves to connect said air supplying means to said one end of the cylinder, a normally inoperative third fluid amplifier having a power outlet, means controlled by the movement of said piston during lung inflation for rendering the third fluid amplifier operative, and a third air line for delivering control air from said power outlet to said second fluid amplifier to cause air to issue from said outlet of said second fluid amplifier.

5. A ventilator according to claim 4, including a pneumatically operated normally open exhalation valve connected with said conduit, said second fluid amplifier having a second outlet, and said second air line also delivering control air from the timer to said second fluid amplifier to cause it to deliver air from its second outlet to the exhalation valve to close it.

6. A ventilator according to claim 4, including an exhalation valve connected with said conduit having a closed position and an open position, the valve normally being in one of said positions, and said second fluid amplifier being operatively connected with the valve for shifting it to its other position.

7. A ventilator according to claim 4, including normally inactive means responsive to excessive gas pressure in a patient's lungs while the pump is forcing gas through said conduit for reversing said first fluid amplifier, whereby to start the pump drawing in gas.

8. A ventilator according to claim 4, including a second pneumatic timer for periodically lengthening said pressure stroke to thereby expel a larger charge of gas than normally, and means controlled by the movement of the pump at the end of its pressure stroke during lung inflation for resetting the second timer.

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