April 7, 1970 O. A. HOEL 3,504,670

RESPIRATOR

Filed Nov. 13, 1967 3 Sheets-Sheet 1

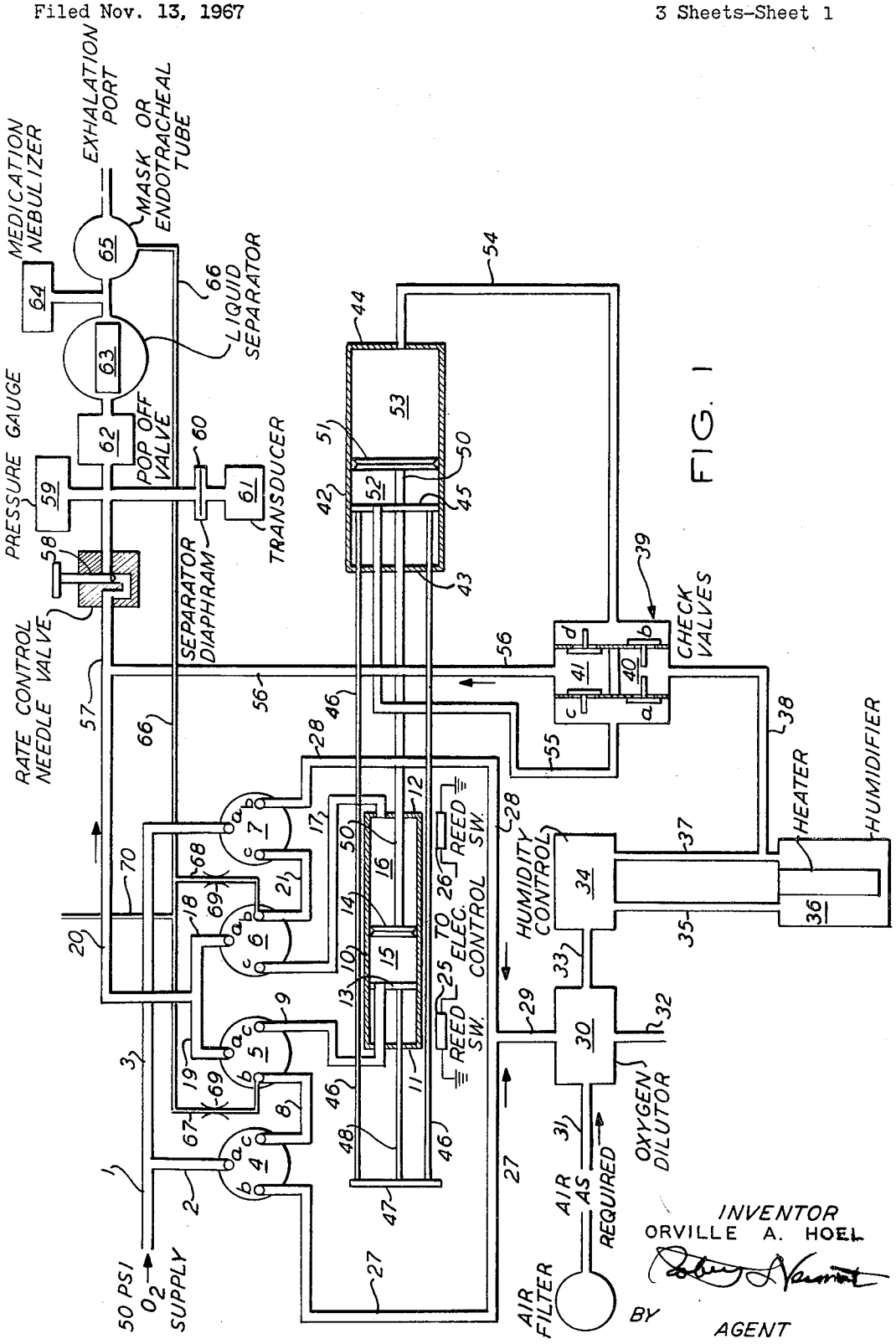


FIG. 1

INVENTOR
ORVILLE A. HOEL

BY

AGENT

April 7, 1970 O. A. HOEL 3,504,670

RESPIRATOR

Filed Nov. 13, 1967 3 Sheets-Sheet 2

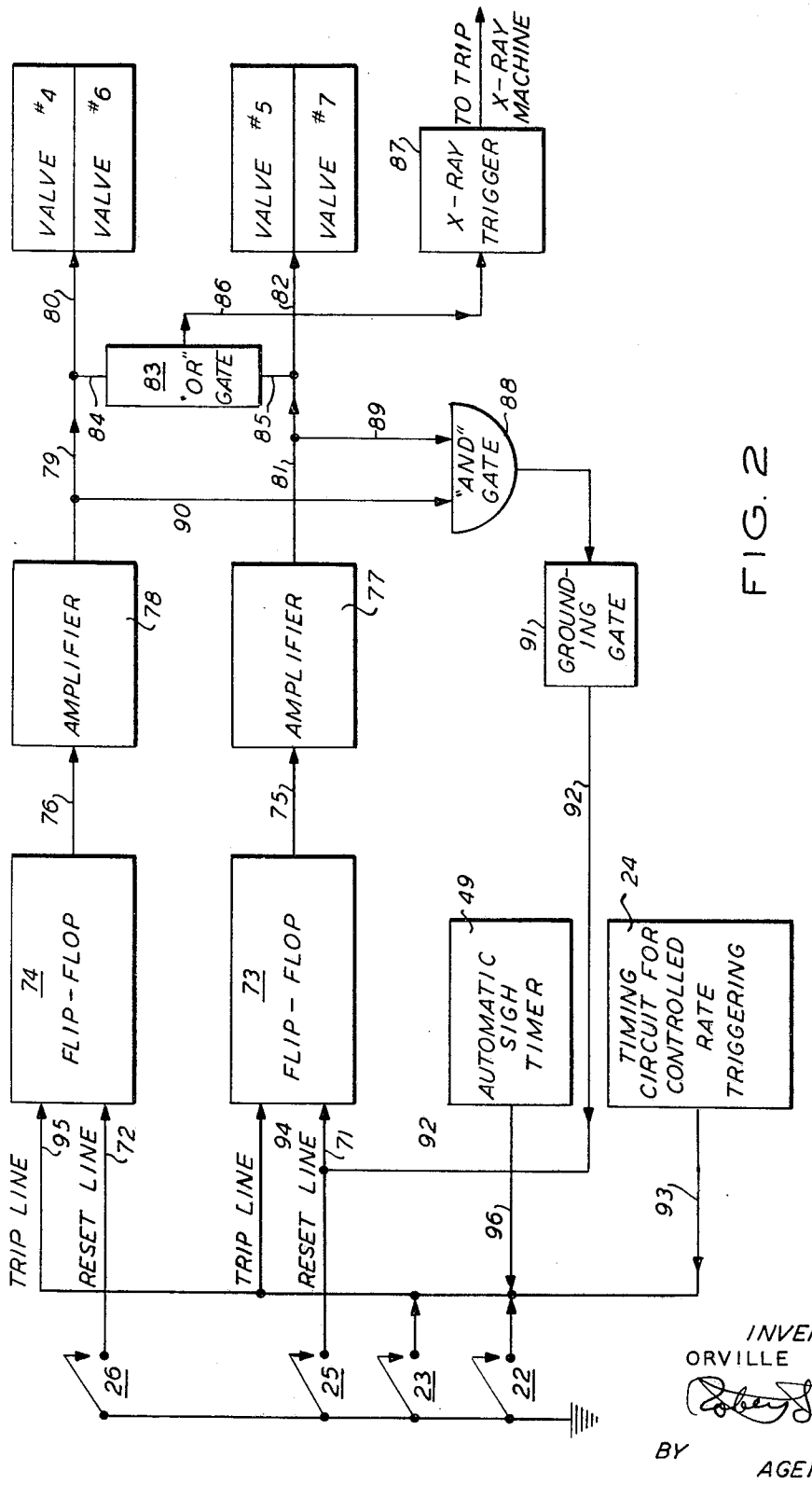


FIG. 2

INVENTOR
ORVILLE A. HOEL

BY

AGENT

April 7, 1970 O. A. HOEL 3,504,670

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FIG. 3

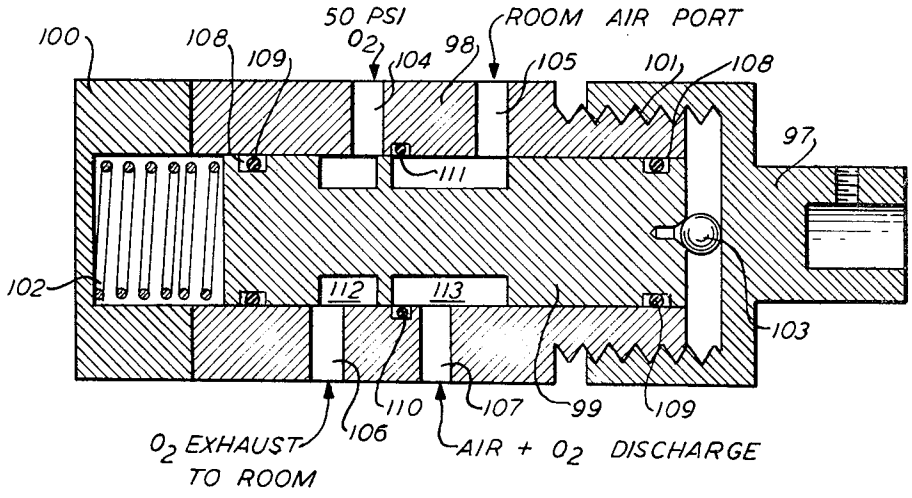
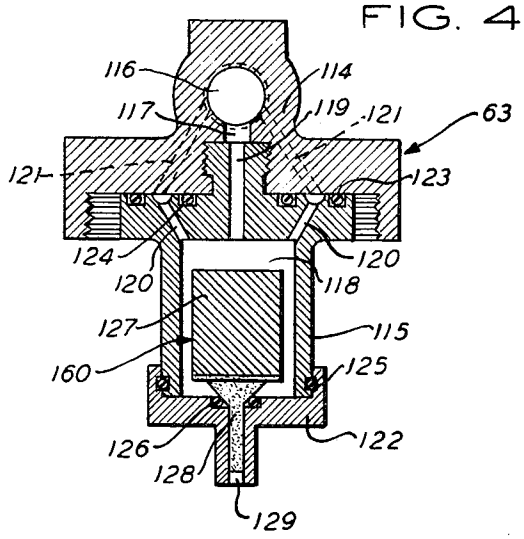


FIG. 4



INVENTOR
ORVILLE A. HOEL

BY AGENT

United States Patent Office

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RESPIRATOR

Orville Alf Hoel, Madison, Wis., assignor to Air Reduction Company, Incorporated, New York, N.Y., a corporation of New York

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Int. Cl. A62b 7/02
U.S. Cl. 128—145.8 4 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus comprising a pair of aligned cylinders each having a piston therein with the pistons being fixed on a common rod, one cylinder being fed alternately on opposite piston sides through a first pair of solenoid operated valve assemblies from an oxygen supply and the other being fed alternately on opposite piston sides through a first pair of check valves from an air supply combined with exhaust oxygen from said one cylinder. A second pair of solenoid operated valve assemblies alternately govern the feeding of a direct supply line to a patient with oxygen from said one cylinder, and a second pair of check valves alternately govern the feeding of said supply line to said patient with a combination of air and exhaust oxygen from said other cylinder. Initiation of flow is controlled either by the patient's inhalation response, an electronic timer circuit or by manual control while termination of flow by de-energization of the solenoids is controlled by Reed switches. Percentage air-oxygen delivered is governed by a new oxygen dilutor valve, volume of inhalation is controlled by adjustable cylinder ends, and liquid is removed from the system by a new liquid separator.

Background of the invention

This invention relates to a respirator apparatus for mixing two gaseous fluids in a predetermined proportion and for delivering a predetermined volume thereof to a patient.

Difficulty in using respirator apparatus of the prior art have been encountered in providing a patient who could partially breathe on his own with a predetermined volume of a predetermined mixture of air and oxygen.

One of the reasons for this difficulty has been the lack of efficient variable volume supplying means which is required because a patient may be capable of breathing to varied degrees. The apparatus should be employed to aid the patient's breathing and not replace the patient's own efforts. In some instances, however, a patient may require external means for initiating inhalation when there is extreme difficulty in the patient's self-initiation of inhalation, and, in such cases, the apparatus must be capable of supplying an entire breath volume.

Also, need exists for proper means to remove condensed liquid in the system as well as efficient means to regulate delivery of air-oxygen to the patient.

Summary of the invention

It is a primary object of the present invention to provide efficient means for mixing a pair of fluids in a given proportion.

It is another object of the present invention to provide apparatus for delivering a predetermined volume of fluid to a subject which volume can be varied.

It is a further object of the present invention to provide a fluid delivery system which is responsive to inhalation, manual control, or an electronic timer circuit.

It is also an object of the present invention to provide means for removing liquid from the delivery system and means for providing humidity control.

These and other objects, accomplished by use of a piston-cylinder construction, and other features and advantages will become apparent when viewed in the light of the following description, claims, and drawings.

Brief description of the drawings

FIGURE 1 is a fluid circuit diagram embodying the invention;

FIGURE 2 is a block diagram of the electrical circuit embodying the present invention;

FIGURE 3 is a cross-sectional view of the oxygen dilutor; and

FIGURE 4 is a cross-sectional view of the liquid separator.

Description of the preferred embodiment

Referring now more specifically and with reference characters to the drawings, in FIGURE 1, main line **1** receives oxygen at approximately 50 p.s.i. from an oxygen supply, not shown. Line **1** splits into parallel lines **2** and **3**, which lines, respectively, feed the oxygen flow to three-way valves **4** and **7**. Three-way valves **5** and **6** are associated with valves **4** and **7** in a manner to be explained hereinafter.

Each of the valves **4–7** has an intake port *a*, exhaust port *b*, and cylinder port *c*. It should be noted that paired valves **4** and **6** and valves **5** and **7** each operate as a unit with the intake ports **4***a* and **6***a* governed identically and simultaneously by a pair of solenoids as are intake ports **5***a* and **7***a*. Furthermore, the exhaust and cylinder ports of each valve are connected for flow when the solenoids governing the intake ports of their respective valve are de-energized while the intake and cylinder ports of each valve are connected for flow when the solenoids governing the intake ports of the respective valves are energized. Thus, with the solenoids governing intake ports **4***a* and **6***a* energized, oxygen flows through lines **1** and **2** into port **4***a* and out of port **4***c* of valve **4** into line **8**. Since the solenoids governing intake ports **5***a* and **7***a* are de-energized, the oxygen flows into port **5***b* and out of port **5***c* of valve **5** into line **9**. Line **9** leads the oxygen flow into cylinder **10** which comprises end walls **11**, **12** and movable closure panel **13**. Magnetic piston head **14** is reciprocably movable within cylinder **10** from end wall **12** to panel **13** thereof. At any given time, piston **14** divides cylinder **10** into chambers **15** and **16**. With the oxygen flow through line **9** entering chamber **15**, the piston, as shown in FIGURE 1, moves to the right. As piston **14** moves to the right, the volume of chamber **16** decreases thereby forcing the gaseous content therein into line **17**. The gaseous content of chamber **16** is oxygen delivered therein in a manner to be explained hereinafter.

Since the solenoid governing port **6***a* is energized, oxygen flow through valve **6** enters at port **6***c* and exits at port **6***a* in line **18**. Because port **5***a* is closed, when ports **4***a* and **6***a* are open, oxygen flow bypasses line **19** and enters line **20**.

Oxygen enters chamber **16** when the solenoids governing ports **5***a* and **7***a* of valves **5** and **7**, respectively, are energized. Oxygen flow enters lines **1** and **3** from the oxy-

gen supply since port 4*a* at the end of line 2 is closed. From line 3 oxygen flow enters valve 7 at 7*a* and exits at 7*c* into line 21 and enters valve 6 at 6*b* and exits therefrom at 6*c* into line 17 whereby oxygen is supplied to chamber 16.

Now, the oxygen which had been previously supplied to chamber 15 is forced into line 9 as piston 14 moves to the left and decreases the volume of chamber 15. Oxygen then flows into valve 5 at 5*c* and exits at port 5*a*, which is open under the influence of an energized solenoid, into lines 19 and 20 but avoiding line 18 because of closed port 6*a*.

It can be thus seen that when either valve unit, 4 and 6 or 5 and 7, has its solenoids energized, oxygen will flow from the oxygen supply to line 20.

As can be seen in FIGURE 2, the valve unit solenoids are energized either by patient trigger switch 22, manual trigger switch 23, or by the electronic timing circuit 24. The patient trigger switch 22 is responsive to the initiation of inhalation by the patient and closes at such inhalation, the closing of which permits energization alternately of the solenoids of valve unit 4 and 6 or 5 and 7.

Manual trigger switch 23 is connected in parallel to timing circiut 24 and is utilized manually if the operator so desires while the timing circuit provides automatic energizing intervals to the solenoids. An automatic Sigh Timer 49 is provided to enable a deep breath cycle to be superimposed on the regular cycle.

Returning now to FIGURE 1 and the construction of the cylinder 10, de-energization of the solenoids of each valve unit is accomplished by use of Reed switches 25 and 26 positioned adjacent the ends of the piston stroke. Since the piston is a magnet, each stroke of the piston actuates the adjacent Reed switch which opens the solenoid circuits of the most recently energized solenoids and thereby de-energizes them.

During the time after the piston stroke has been completed and oxygen delivered to line 20 and before the patient initiates another inhalation response, all the solenoids are de-energized and, therefore, all the valve ports *a* are closed. During this time interval, exhalation by the patient occurs and each valve port *b* is in flow communication with its respective valve port *c*.

By movement of the piston toward either cylinder wall, oxygen pressure in the expanding chamber approximates 50 p.s.i. and oxygen pressure in the decreasing chamber increases due to the decreasing volume of the chamber. Reduction of these chamber pressures to a predetermined pressure is desirable so that the volume of oxygen delivered to the patient can be readily determined.

When all solenoids are de-energized, the oxygen in chamber 15 and 16 under greater than atmospheric pressure flows into lines 9 and 17, respectively. The flow in line 9 continues through ports 5*c* and 5*b* of valve 5 into line 8 and from line 8 through ports 4*c* and 4*b* of valve 4 into lines 27. The flow in line 17 continues through ports 6*c* and 6*b* of valve 6 into line 21 and through ports 7*c* and 7*b* of valve 7 into line 28. The exhaust oxygen flow in line 27 joins with the exhaust flow of line 28 in line 29 which then enters oxygen dilutor generally designated at 30.

It should be noted that the piston moves reciprocably under the oxygen pressure and is arrested by frictional forces within the cylinder and the pressure of the oxygen residue in the decreasing chamber which is not delivered to the patient. However, the piston could be moved reciprocably by an electric motor and the oxygen introduced to the chambers at much lower pressures.

Oxygen dilutor 30 receives filtered air through line 31 and combines the air with the oxygen from line 29 in a predetermined proportion in accordance with the novel dilutor structure to be described hereinafter with the exhaust of a known percentage of oxygen to the atmosphere at 32. The combined air-oxygen flow enters a conventional humidity controller 34 from line 33. Humidity controller 34 permits flow through heated vaporizer assembly 36 from line 35 or through by-pass line 37 or a combination of flows through both lines 35 and 37, the flow therethrough joining in line 38. The humidified air-oxygen then passes into check valve assembly generally designated at 39.

Check valve assembly 39 comprises four check valves *a*, *b*, *c*, and *d* regulating flow through two cells 40 and 41. Humidified air-oxygen flows from line 38 into cell 40.

Aligned with cylinder 10 is cylinder 42. Cylinder 42 comprises end walls 43 and 44 and movable closure panel 45. Panel 45 of cylinder 42 is fixed with relation to panel 13 of cylinder 10 by tie rods 46, tie plate 47, and tie rod 48. Thus, the effective stroke length and volume for each cylinder can be changed by a predetermined amount by moving the tie plate 47. Tie plate 47 is moved by the Rotary Manual Control, not shown, which governs the volume of air-oxygen delivered to the patient.

Piston rod 50 extends through but in sealed relation to cylinder end walls 12 and 43 and acts as a common rod for magnetic piston 14 and piston 51. It should also be noted that panels 13 and 45 and tie rods 46 and 48 are in sealed, reciprocal relation to the respective cylinders.

In operation, as piston 14 moves to the right under the oxygen flow pressure from line 9 when the solenoids governing ports 4*a* and 6*a* are energized, the fixed connection by piston rod 50 causes piston 51 to move to the right in cylinder 42. This movement creates a partial vacuum in expanding chamber 52, while relief of pressure build-up in decreasing chamber 53 is permitted into line 54. In order to supply air-oxygen to chamber 52, check valve 39*a* opens permitting air-oxygen from cell 40 to enter line 55 and enter chamber 52. At the same time, the air-oxygen from line 54 enters cell 41 through check valve 39*d* and then exits cell 41 into line 56. The humidified air-oxygen flow of known proportion in line 56 joins the 100% pure oxygen flow in line 20 to provide a final air-oxygen flow of known proportion in line 57. The flow in line 57 is controlled by needle valve 58. Line 57 also includes a pressure gauge 59; a separator diaphragm 60 leading into transducer 61 which actuates switch 22 upon inhalation; a pop-off valve 62 for pressure relief to a predetermined level; a liquid separator 63 to be described hereinafter to remove liquids which might have condensed during flow, especially moisture from the heated vaporizer 36; a medication nebulizer 64; and finally leads into mask or endotracheal tube 65.

When pistons 14 and 51 reach the end of their stroke to the right, the initiation of another inhalation response permits oxygen under pressure to enter chamber 16 and force pistons 14 and 51 to the left. This creates a partial vacuum in chamber 53 which is filled by air-oxygen flow from cell 40 through valve 39*b* into line 54. Air-oxygen which entered chamber 52 on the prior piston stroke to the right is forced by piston 52 into line 55, through valve 39*c* and into line 56 from cell 41 to join with the oxygen flow in line 20. Thus, line 57 is provided with a known proportion of humidified air-oxygen based on knowledge of the cylinder chamber volumes.

Control pressure line 66 leads from mask 65 to exhaust ports 5*b* and 6*b* through lines 67 and 68, respectively. Reduced orifices 69 in lines 67 and 68 restrict the amount of O_2 available to inflate the mask valve during inhalation cycle of the patient.

Vent 70 allows O_2 in mask valve to go to atmosphere during exhalation patient phase.

Referring now in more detail to FIGURE 2, the energizing of either pair of solenoids is accomplished by the closing of switch 22 or 23, switch 23 being manually controlled whereas switch 22 is controlled either by the transducer 61 or the timing circuit 24. Reed switches 25 and 26 de-energize the solenoids and are actuated through their magnetic relation with piston head 14.

Switches 25 and 26 are connected by leads 71 and 72, respectively, to conventional flip-flop circuits 73 and 74.

Circuits 73 and 74 are connected by leads 75 and 76, respectively, to amplifiers 77 and 78. Amplifier 78 is operably connected to valves 4 and 6 by lines 79 and 80 while amplifier 77 is operably connected to valves 5 and 7 by lines 81 and 82. The amplifiers 77 and 78 are also connected to a conventional "or" gate 83 by lines 81, 85, and 79, 84, respectively, said "or" gate being operably connected by lines 86 to a relay 87 which triggers an X-ray machine not shown.

Amplifiers 77 and 78 are also operably connected to a conventional "and" gate 88 by lines 89 and 90, respectively. The "and" gate is connected to a grounding gate 91 which leads to line 71 by line 92. Thus, if flip-flops 73 and 74 should both be tripped to energize the respective valve pairs, line 92 is brought to ground by the grounding gate 91 thereby resetting flip-flop 73.

Timing circuit 24 is operably connected to flip-flops 73 and 74 through lead 93 by trip lines 94 and 95, respectively. Sigh Timer 49 is also connected to the flip-flops 73 and 74 by lines 94 and 95, respectively, from lead 96.

Switches 22–26 are all connected to suitable electrical potential when activated. It should be noted that switches 22 and 23 are both operably connected to flip-flops 73 and 74 through lines 94 and 95, respectively.

Referring now in more detail to FIGURE 3, dilutor 30 comprises cap 97, body 98, spool 99, and end 100 secured to body 98 as by welding, each being cylindrical in cross-section. Cap 97 is threaded on body 98 at 101 while spool 99 is slidably received with body 98 and urged against the cap by spring means 102, the spool being spaced from the cap by ball 103. Thus, the spool is adjustably positioned within the body by the adjustable threaded engagement 101 between cap and body. Body 98 includes oxygen inlet port 104 connected to line 29, room air inlet port 105 connected to line 31, oxygen exhaust port 106 connected to line 32, and air and oxygen exhaust port 107 connected to line 33, each port communicating between the body periphery and its hollow interior and each port being axially offset from each other. Spool 99 includes peripheral grooves 108 adjacent its ends for reception of O ring gaskets 109 to provide a sealed relation between body and spool. Body 98 includes internal groove 110 with O ring 111 therein as shown.

The spool further includes peripheral grooves 112 and 113. As can be seen in FIGURE 3, spool grooves 112 and 113 are so spaced from each other and of such an axial length as to adjustably communicate with body ports 104–107 to provide variable ratios of air and oxygen at port 107. For example, in the preferred embodiment spool 99 is approximately one-half inch in diameter, ports 104–107 are approximately ⅛ inch in diameter with grooves 112 and 113 approximately .218 inch and .437 inch, respectively. Thus, if spool 99 travels ⅛ inch or more toward the left as seen in FIGURE 3 upon rotation of cap 97, port 105 would be closed and groove 113 would place ports 104 and 107 in communication to provide 100% oxygen. If rotation of the cap moves the spool to the left a distance less than ⅛ inch, line 33 will receive a predetermined proportion of air and oxygen depending on the distance moved by the spool. The threaded relationship between cap and body provides a known movement of the spool.

Referring now more specifically to FIGURE 4, the liquid separator 63 connected in line 57 includes head 114, body 115, drain 122, and float 160. Head 114 comprises inlet-bore 116 which has a transverse bore 117 communicating therewith. Body 115 includes hollow interior 118 which receives therein the float 160. The body also includes bore 119 providing a passage between the interior 118 and bore 117 and bores 120 providing a passage between the interior 118 and bores 121 shown in dotted lines. Bore 121 opens into bore 116 at a point thereon remote from bore 117.

O ring gaskets 123 and 124 provide a sealed relation between the head and body while gaskets 125 and 126 provide a sealed relation between the body and drain.

Float 160 comprises a buoyant member 127 and a plug 128 which is slidably received in through-bore 129 of drain 122.

In operation, the humidified air and oxygen flow of predetermined proportion in line 57 enters bore 116 and hollow interior 118 through bore 117 and 119. The flow on reaching buoyant member 127 leaves any condensate carried thereby at the member to fill the vacant space between the member and body. As condensate accumulates sufficiently to lift the buoyant member 127, plug 128 which is attached thereto is lifted out of its sealed relation with O ring 126 to permit condensate to drain through bore 129. The condensate-free flow re-enters bore 116 to line 57 through bores 120 and 121.

Since numerous changes may be made in the above description without departing from the spirit of the present invention, the above description should be viewed as illustrative and not in a limiting sense.

Having thus described my invention, what I claim as new and desire to secure Letters Patent of the United States is:

I claim:

1. Respirator apparatus comprising a pair of interconnected cylinders, each of said cylinders having a piston reciprocably mounted therein, each of said cylinders being operably connected to at least one fluid source and to an inhalation line, electrically responsive valve means regulating the flow of the fluid from said at least one source into at least one of said cylinders, magnetic field responsive switch means adjacent said at least one cylinder and operable to actuate said valve means and magnetic means associated with the piston of said at least one cylinder to actuate said switch means.

2. The apparatus set forth in claim 1 wherein each cylinder has a fluid source associated therewith, each source containing a different fluid, at least one of said cylinders receiving a fluid from both sources in a predetermined proportion through a dilutor, said dilutor including a body having a hollow interior, a cap threadedly mounted on one end of said body, an end piece connected to said body at the other end thereof, a spool slidabily mounted in said body, a spring between said end piece and said spool adjacent said other body end urging said spool toward said cap and a ball positioned between said spool and said cap so that threaded movement of said cap slidably moves said spool within said body, said body having a plurality of transverse, axially spaced openings extending from the periphery thereof to said hollow interior, each fluid source having an opening in communication therewith, and said spool having a plurality of spaced peripheral grooves thereon such that upon movement of said spool within said body to a predetermined position, said plurality of spool grooves permit communication between desired ones of said plurality of body openings to provide the desired proportion of said fluids to said cylinder and thereafter to said inhalation line.

3. The apparatus set forth in claim 2 wherein said inhalation line includes a liquid separator, said separator comprising a head having a through-bore, a body having a vacant interior, a drain having a through-bore and a float having a buoyant member within said vacant interior and a plug slidably received within said drain through-bore, said body being positioned between said head and said drain, a plurality of passages in said body and said head related to permit communication between said head through-bore and said vacant interior and to provide means of ingress and egress of fluid in said inhalation line to said vacant interior to thereby permit condensate in said fluid to collect in said vacant interior to lift said buoyant member and said plug and allow said condensate to drain through said through-bore.

4. The apparatus set forth in claim 1 wherein said inhalation line includes a liquid separator, said separator comprising a head having a through-bore, a body having a hollow interior, a drain having a through-bore and a float having a buoyant member within said hollow interior and a plug slidably received within said drain through-bore, said body being positioned between said head and said drain, a plurality of passages in said body and said head related to permit communication between said head through-bore and said hollow interior and to provide means of ingress and egress of fluid in said inhalation line to said interior to thereby permit condensate in said fluid to collect in said interior to lift said buoyant member and said plug and allow said condensate to drain through said drain through-bore.

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RICHARD C. PINKHAM, Primary Examiner

T. BROWN, Assistant Examiner