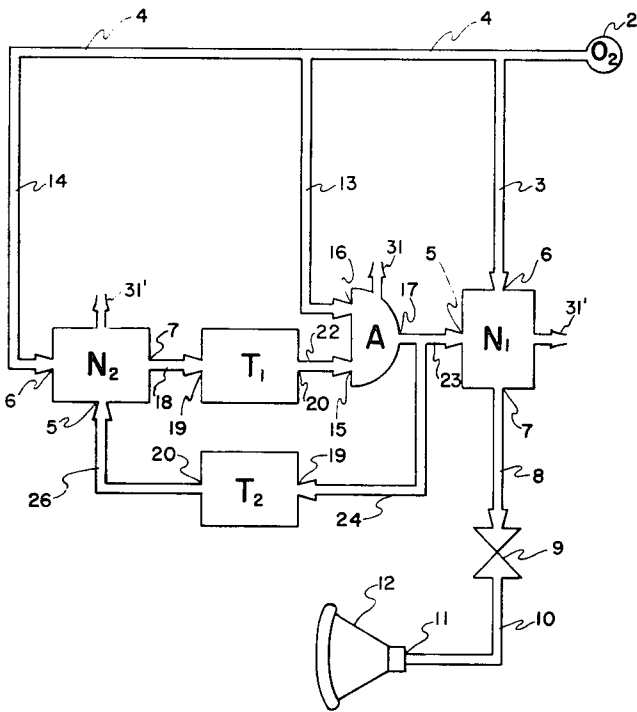


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[54] PATIENT VENTILATOR
5 Claims, 4 Drawing Figs.
[52] U.S. Cl. 128/145.8,
137/624.14
[51] Int. Cl. A61m 16/00
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.42, 145.6, 145.5, 146, 142.7, 140; 137/624.14,
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ABSTRACT: A ventilator for artificial respiration is automatically controlled by a fluid logic circuit comprising three pneumatic logic cells, all fed directly with ventilating gas under pressure, and two delay cells for separately adjusting gas flow to the periods of inhalation and exhalation of a patient.



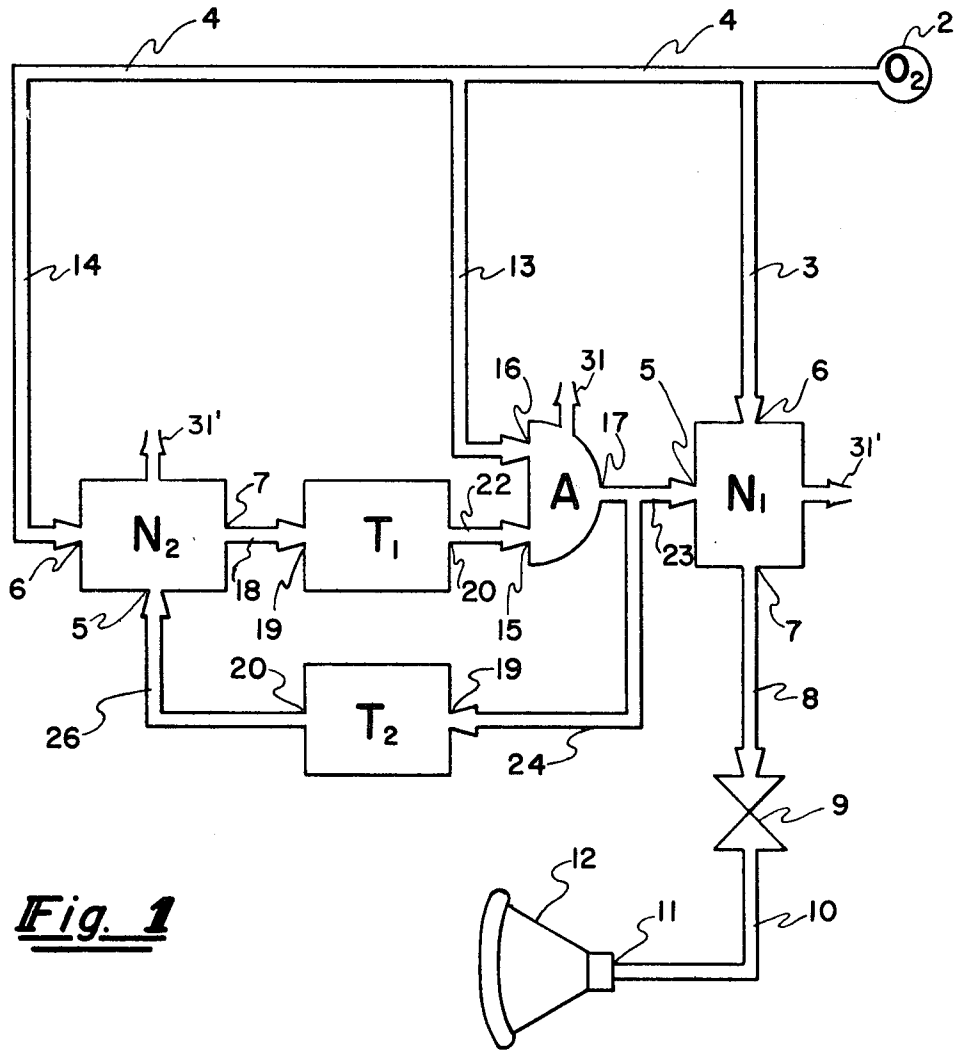


Fig. 1

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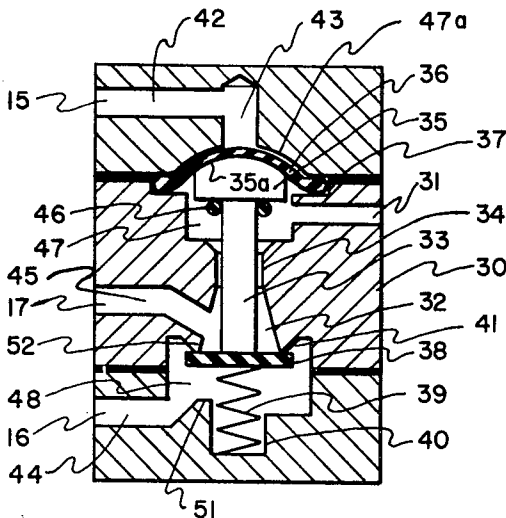


Fig. 2

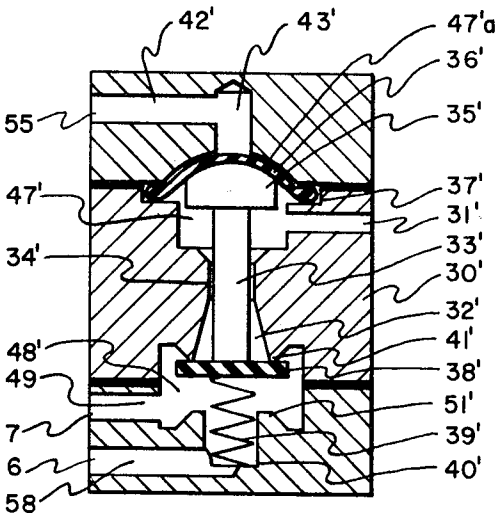


Fig. 3

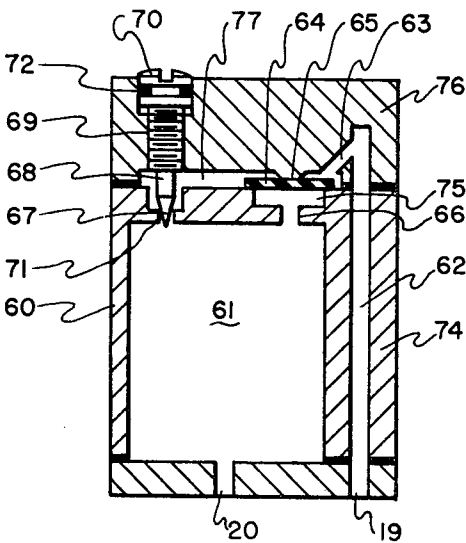


Fig. 4

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PATIENT VENTILATOR

FIELD OF THE INVENTION

The present invention relates to a system for artificial ventilation of a patient's breathing circuit, and more particularly to a ventilating apparatus comprising a simple arrangement of pneumatic logic components interconnected between a source of air or oxygen under pressure and a means for delivery to a patient.

BACKGROUND OF THE INVENTION

Respirator devices in the prior art have usually involved complicated combinations of mechanical and pneumatic parts, and the complexity of these mechanisms has made them expensive and difficult to operate. The apparatus of the present invention avoids these difficulties by its simplicity and minimum number of moving parts.

OBJECT OF THE INVENTION

It is accordingly an object of this invention to provide a controlled periodic flow of air or oxygen to a patient by means of a simple arrangement of fluid logic elements which are actuated by the fluid flow they control.

SUMMARY OF THE INVENTION

The ventilating apparatus of the invention includes an arrangement of pneumatic logic elements interconnected to control the flow of oxygen or air under pressure from a source to a device which utilizes a periodic flow, such as the face mask of a patient. Three logic cells having working parts are directly connected to a source of gas under pressure. These three cells have three ports each, a supply port, a signal port, and an output port. Two of these three cells are operable to pass air or oxygen out at their output ports whenever they are not receiving a fluid signal at their signal ports. The other of the three working cells passes gas out at its output port only when it is receiving a fluid signal at its signal port. The two other logic elements of the circuit have no parts in motion during operation and are effective to delay the passage of a fluid signal from the output port of one of the working cells to the signal port of another element. Selective adjustment of the charging times of the two delay elements permits independent setting of the frequency as well as of the relative durations of the inhalation and exhalation portions of the ventilation cycle.

For a fuller understanding of the invention, its mode of operation, and its advantages, reference will now be made to the accompanying drawings, illustrating an embodiment of the ventilating apparatus, and to the detailed description following the identification of the figures of the drawings.

In such drawings:

FIG. 1 is a diagrammatic view of the apparatus.

FIG. 2 is a view in section of the pneumatic logic cell A of FIG. 1.

FIG. 3 is a view in section of one of the pneumatic logic cells N of FIG. 1.

FIG. 4 is a view in section of one of the pneumatic delay elements T of FIG. 1.

Referring now to the details of the drawings commencing with the diagrammatic illustration of FIG. 1, the fluid logic components N_1 , N_2 , A, T_1 and T_2 are shown to be interposed between a source of oxygen (or air) 2 and a face mask 12 for delivery of a periodic flow of oxygen (or air) to a patient under controlled ventilation. In the following discussion it will be assumed that the gas used is oxygen, since it will be obvious that if a mixture of oxygen and some other gas, or air under pressure, is to be used, the operation of the ventilating apparatus will be the same.

The arrowheaded flow lines in FIG. 1 indicate the direction of oxygen flow through the system. Thus oxygen under pressure from a regulated source shown schematically at 2 flows through supply conduit 4 and to the supply ports 6 and 16 of

the cells N_1 , N_2 , and A, respectively, by way of the conduits 14 to N_2 , 13 to A and 3 to N_1 . The delay element T_1 , with an inlet 19 and an outlet 20, is connected between the output port 7 of cell N_2 and the signal port 15 of cell A by conduits 18 and 22. A conduit 23 connects the output port 17 of cell A to the signal port 5 of cell N_1 .

The delay cell T_2 , with its inlet 19 and outlet 20, is connected between the output port 17 of cell A and the signal port 5 of cell N_2 by means of conduits 24 and 26. From the output port 7 of the cell N_1 , the conduit 8 extends to a shut off valve 9 and from valve 9 the conduit 10 extends to conduct oxygen to face mask 12 at its input 11. The input 11 may commonly include a nonbreathing valve.

Having described the arrangement of the logic elements and the flow connections therebetween the structures and functions of the three types of logic cells A, N, and T employed will now be discussed with reference to FIGS. 2-4. These FIGS. illustrate typical embodiments of fluid logic cells adapted for use assembled in the relations indicated to make up the ventilating apparatus of the invention.

Referring first to FIG. 2, a typical embodiment of the cell A of FIG. 1 is shown, with supply port 16, output port 17, signal port 15 and exhaust passage 31. The cell A as used in this circuit is adapted to pass oxygen from supply port 16 out at output port 17 whenever it is receiving a controlling fluid signal at signal port 15. To actuate the cell the fluid signal pressure at port 15 may be approximately two-thirds of the pressure at port 16.

The cell A has a fluid tight housing generally indicated by the reference numeral 30, which may be of metal, synthetic plastic, or other suitable material. The housing 30 is shown as made in three parts for ease of manufacture. An irregularly shaped central cavity 32 within housing 30 communicates with the ports 15-17 and 31, and a snap action actuating mechanism mounted within the cavity 32 is effective to selectively open flow paths for gas to pass through passages within the housing 30 from one port to another.

The actuating mechanism includes a central cylindrical rod 33 extending longitudinally through the cavity 32. The cavity 32 has an enlarged upper chamber 47 and an enlarged lower chamber 48 and a narrowed intermediate portion which tapers inwardly from top and bottom to its narrowest part at a cylindrical portion 34 where the chamber walls are closest to the periphery of the rod 33. Though not ordinarily in contact with the rod, the cavity walls at cylindrical portion 34 serve to limit movement of the rod 33 to the up and down directions. The rod 33 has a radially enlarged head 35 on its upper end with a convex end face 35a thereon. This end face 35a engages a dish shaped diaphragm 36 of rubber or suitable resilient synthetic material lying across its path.

The diaphragm 36 is of considerably larger diameter than rod head 35 and its edge is thickened in the form of a bead which seats in a circular groove 37 extending around the upper enlarged cavity portion 47. Above the diaphragm 36 a concaved top wall section 47a of the cavity forms a seat for diaphragm 36 when it is stretched upwardly as shown in FIG. 2.

The lower end of rod 33 is fitted with a poppet disk 38 of rubber or of suitable synthetic material having a smaller surface area than that of the diaphragm 36. A cylindrical well 40 formed in the bottom of the lower enlarged cavity chamber 48 houses a coiled spring 39 which is secured at its upper end to the poppet disk 38 to bias the disk 38 and the rod 33 upwardly, thereby pressing the diaphragm 36 against concaved wall portion 47a. A part circular rim 51 of the well 40 forms a lower seat for the poppet disk 38 and a circular rim 41 at the upper part of the lower cavity chamber 48 forms an upper poppet seat, against which disk 38 seats when the rod is in its upper position, as shown in FIG. 2.

The ports 15-17 and 31 communicate with the interior of the cavity in such a way that fluid pressure at the signal port 15 of the cell A forces the diaphragm 36 downward against the action of spring 39, opening the poppet valve by moving disk

38 from its upper seat 41 to its lower seat 51. This opens communication between supply port 16 and output port 17.

As shown in FIG. 2, a passage 42 extends inwardly through the cell housing 30 from signal port 15 and then makes a right angle turn downwardly to form a passage leg 43 aligned with the rod 33 and opening out through the concave wall 47a above diaphragm 36. Supply port 16 leads into the central cavity 32 through a passage 44 which opens at a level below the upper poppet seat 41 and above the lower poppet seat 51, and output passage 45 leads from the central cavity 32 at a point above the upper poppet seat 41. Thus when signal pressure at port 15 equal to about two-thirds of the pressure at supply port 16 is communicated to the diaphragm 36 by way of the passages 42 and 43 the diaphragm 36 and actuating rod 33 are pushed downwardly since the surface area of diaphragm 36 is greater than that of disk 38 moving the poppet disk 38 from its seat 41 to its lower seat 51. Then supply port 16 feeds gas through passage 44 into the central cavity 32, and gas flows unimpeded up the cavity, through passage 45 and out a output port 17.

Exhaust port 31 is closed when the actuating mechanism is in its lower position by the gasket ring 46 which seals off the lower part of the central cavity from its upper part. However, when the cell is uncontrolled by pressure on signal port 15 the exhaust port 31 is in communication with the output port 17. This relieves any residual pressure in the conduit fed by port 17 and prevents locking of the cell.

Referring now to FIG. 3 showing the structure of the cells N_1 and N_2 both of which are the same, it can be seen that these cells are very similar to the A cell of FIG. 2. The basic difference is that, because of the placement of the passages from the supply and output ports to the central cavity, the N cells only pass oxygen out at output ports 7,7 when they are not receiving a fluid pressure signal at signal ports 5,5. The primed reference numerals indicate parts shown in FIG. 3 which are similar to corresponding parts of FIG. 2.

Thus in the N cells, as shown in FIG. 3, the signal and actuating mechanisms have the same structure as in the A cell of FIG. 2. However, supply port 6 feeds its oxygen through a passage 58 which opens to the central cavity at the bottom of spring well 40', below the lower poppet seat 51'. Supply of oxygen to the cell is therefore shut off when the diaphragm is depressed by a fluid pressure signal at signal port 5,5. A passage 49 from output port 7 opens to the central cavity at a location between the upper and lower poppet seats 41' and 51' respectively and is therefore in communication with the supply port 6 when the cell is in the condition shown in FIG. 3. When a controlling fluid signal equal to about two-thirds the pressure at port 6 is received and depresses the diaphragm the output port 7 is cut off from supply port 6, but is open to the exhaust port 31', there being no sealing gasket around the actuator rod 33' of the N cells. The exhaust 31' functions as does exhaust 31 to relieve residual pressure and prevent locking.

Referring now to FIG. 4, illustrating the structure of the delay elements T_1 and T_2 , both of which are the same, it can be seen that the delay element has a fluid tight housing 60, which may be of synthetic resinous material or of metal or other suitable material. The housing 60 may be formed of several sections, as shown, for ease of manufacture. Within the housing 60 is an enclosed chamber 61 having rectangular sides, the bottom one of which is provided with an outlet 20. The volume of the chamber is preferably about 1 cubic inch. One sidewall 74 of the housing 60 has an elongated passage 62 formed in it and extending from the inlet 19 to the head 76 of the delay element.

Within the head 76 of the delay element is formed a chamber 77 to which gas from inlet 19 is fed by passage 62 and a branch passage 63. A flexible check disk 64 of rubber or other suitable material is mounted in the chamber 77 at the point where branch passage 63 opens thereinto. When no input flow is fed into the inlet 19 the check disk 64 assumes a flat posture against a flattened projection 65 formed on the upper wall of the chamber 77 and its outer edges may be

pushed upward by pressure in chamber 61 to allow backflow to bypass the metering needle. A cut out cylindrical depression 75 below the disk having a pressure relief opening 66 to the timing chamber 61 allows the disk to be deformed downwardly by pressure from inlet 19 carried through the passage 63. This downward deflection allows gas to flow from passage 63 into the chamber 77, past the depressed check disk 64.

A metering orifice 67 opens from chamber 77 into timing chamber 61. The volume of the open orifice passage is determined by the position of a metering needle 68 having a pointed end 71 extending into the orifice 67. The needle 68 is threaded in an opening 69 in the head 76 of the housing 60 and has a slotted head 70 for receiving the blade of a screwdriver to screw the needle up or down, thus varying the space for gas flow through the orifice 67. Of course a control knob or other suitable adjusting means could be provided if desired. As shown in FIG. 4, the metering needle has a surrounding sealing gasket 72 to prevent gas leakage, and head 70 protrudes slightly from the housing 60. Selective adjustment of the metering needle thus permits the rate of gas flow to the timing chamber 61 to be accurately set to produce the desired pressure in chamber 61 in a chosen time interval. If it is desired therefore that this pressure reach a value of two-thirds of the supply pressure to the logic cells after an interval of, say, 10 seconds, thus actuating the logic cell controlled, the timing interval may be accurately set by adjusting the metering needle. It can be seen that the delay elements T_1 and T_2 act as pneumatic analogues of series connected electrical capacitors and resistors when connected in circuit with the A and N cells.

MODE OF OPERATION OF THE INVENTION

Having described in detail the arrangement of the elements of the ventilating apparatus of the invention and the structure of the various pneumatic logic components, the mode of operation of the apparatus in ventilation of a patient will now be set forth.

Referring again to FIG. 1 it can be seen that because the delay elements T_1 and T_2 do not feed oxygen out of their outlets 20 at sufficient pressure to control the cells N and A until they have been receiving an input at their inlets 19 for a definite period of time, the three working cells N and A of the circuit will be opened or closed for predetermined intervals depending upon the delay times of the delay elements T_1 and T_2 as independently set by adjusting their respective metering needles 68. As will be explained, the charging time of element T_1 controls the duration of the inhalation portion of the ventilating cycle; and the charging time of delay element T_2 controls the duration of the exhalation port of the ventilating cycle.

Throughout the respiratory cycle all of the cells A_1 , N_1 and N_2 are being fed with oxygen at their respective supply ports 16, 6, 6. The cells N_1 and N_2 are open at the outset of the inhalation part of the cycle, there being no closing control signal to their signal ports 5. Therefore cell N_2 feeds oxygen through line 18 to delay element T_1 , which starts charging up; and cell N_1 feeds oxygen through lines 8 and 10 and valve 9 to the face mask 12 of the patient.

Cell A is closed, there being no control signal to its signal port 15 to open it, since flow from N_2 to A is being delayed by delay element T_1 . Delay element T_2 is not receiving any oxygen input, for its supply must come through line 24 from cell A, now closed.

Thus all the while delay element T_1 is charging up gas is flowing to the patient.

After the passage of the preset charging, internal T_1 pressure has built up from the flow through line 18 and cell N_2 sufficient to open cell A. This may be effectively about two-thirds of the pressure at the supply port 16 of cell A. This pressure above diaphragm 36 triggers the snap action of the valve mechanism of cell A to open the flow to the output port 17.

The flow from cell A to cell N₁ through line 23 closes N₁, so no oxygen passes to the patient. Gas flow through branch line 24 from cell A to the inlet 19 of delay element T₂ starts T₂ charging up. Thus all the while T₂ is charging no gas flows to the patient, who is meanwhile exhaling to the atmosphere.

Once delay element T₂ has charged up it passes oxygen via line 26 to the signal port 5 of cell N₂ and establishes a pressure above diaphragm 36' sufficient to close the cell N₂, say about two-thirds of the pressure at supply port 6, thereby cutting off the flow of gas to delay cell T₁ and hence to the signal port 15 of cell A. Closure of cell N₂ permits backflow from delay element T₁ through line 18 to cell N₂ from which it is vented through vent 31'. This vents the pressure in delay element T₁ and also vents the pressure above the diaphragm 36 of cell A which backflows through line 22, element T₁ and vent 31' of cell N₂. Thus, cell A returns to its normally closed condition which stops further flow of oxygen to the signal port 5 of cell N₁. Closure of cell A also opens vent 31 to atmosphere, whereby the pressure above diaphragm 36' of cell N₁ is vented, and cell N₁ returns to its normally open condition thereby restoring flow of oxygen to applicator device 12. Opening of vent 31 of cell A also vents the pressure from delay element T₂ by backflow through line 24, and further vents pressure from above diaphragm 36' of cell N₂, by backflow through line 26, whereby cell N₂ returns to its normally open condition. Thus, the cycle is complete, and a new inhalation cycle begins as flow through cell N₂ begins to build up pressure in delay element T₁.

It will be obvious to those skilled in the art that the structures of the fluid logic elements of the circuit are merely illustrative and that other logic components adapted to function in the same manner as the cells N, A and delay elements T could be readily substituted in the ventilating arrangement of the invention.

As an example the above described timing determined by adjusting the orifices, leaving the capacities of the delay elements fixed can just as well be accomplished by the converse, i.e., leaving the orifices fixed and adjusting the capacities of chambers 61 by means such as a variable piston.

As another example the delay elements described as being independently adjustable can be just as well linked together mechanically, such as by a gear train, so that they can be varied in unison thereby producing a fixed ratio of inhalation to exhalation while maintaining the ability to change the overall period or frequency.

It will also be apparent that although the embodiment discussed relates to the supply of oxygen or air to a face mask of a patient for controlled ventilation, a similar arrangement could be used whenever a periodic fluid flow under controlled conditions of pressure and frequency is desired.

With logic elements of the type described above the switchover from open to closed is almost instantaneous. The two delay elements may be selectively adjusted independently of each other to regulate the duration of the periods of flow

and flow stoppage to the utilizing device.

It will be obvious to those skilled in the art that many other useful modifications may be made in the practice of the invention.

I claim:

1. A respirator system comprising:
 - a. a source of breathing gas under pressure,
 - b. an applicator device for supplying said breathing gas to a patient,
 - c. a first fluid logic cell having an inlet connected to said source of breathing gas and an outlet connected to said applicator device, said first fluid logic cell having actuator means for opening and closing said cell to the passage of breathing gas therethrough to said applicator device,
 - d. a pair of second and third fluid logic cells, one of said pair of fluid logic cells being normally open and including actuator means to close said cell, the other of said pair being normally closed and including actuator means to open said cell,
 - e. a pair of fluid pressure signal delay means,
 - f. passage means operatively connecting said pair of second and third fluid logic cells to each other and to said pair of pressure signal delay means for applying delayed fluid pressure signals to said actuator means for alternately opening and closing said second and third fluid logic cells, and
 - g. passage means connecting one of said pair of fluid logic cells to the actuator means of said first fluid logic cell for alternately opening and closing said first fluid logic cell and thereby intermittently passing breathing gas therethrough to said applicator device.
2. The respirator system as claimed in claim 1 further including variable fluid flow means for varying the rate of fluid flow to each of said delay means for varying the time periods of each of said delayed fluid pressure signals.
3. The respirator system as claimed in claim 1 wherein said first fluid logic cell is normally open, and said normally closed fluid logic cell is connected to the actuator means of said first fluid logic cell by said passage means (g).
4. The respirator system as claimed in claim 3 wherein each of said second and third fluid logic cells include fluid outlets, the outlet of said normally open fluid logic cell being connected through one of said delay means to the actuator means of said normally closed fluid logic cell, and the outlet of said normally closed fluid logic cell being connected through the other of said delay means to the actuator means of said normally open fluid logic cell.
5. The respirator system as claimed in claim 1 wherein said second and third fluid logic cells include vent means, said vent means being operatively connected to said delay means by said passage means (f) for alternately venting fluid pressure from one of said delay means when said normally open fluid logic cell is closed, and from the other of said delay means when said normally closed fluid logic cell is closed.

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