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Dudley

[11] **3,905,363**

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[54] **DUAL MODE FLUIDIC VENTILATOR**

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[52] **U.S. Cl.** **128/145.8;** 137/102

[51] **Int. Cl.**[2] **A61M 16/00**

[58] **Field of Search** 128/145.8, 145.6, 145.7, 128/145.5, 145, 142, 142.2, 188; 137/63, 102

[56] **References Cited**

UNITED STATES PATENTS

3,669,108	6/1972	Sundblam	128/145.6
3,730,180	5/1973	Davison	128/145.6
3,756,229	9/1973	Ollivier	128/145.6

OTHER PUBLICATIONS

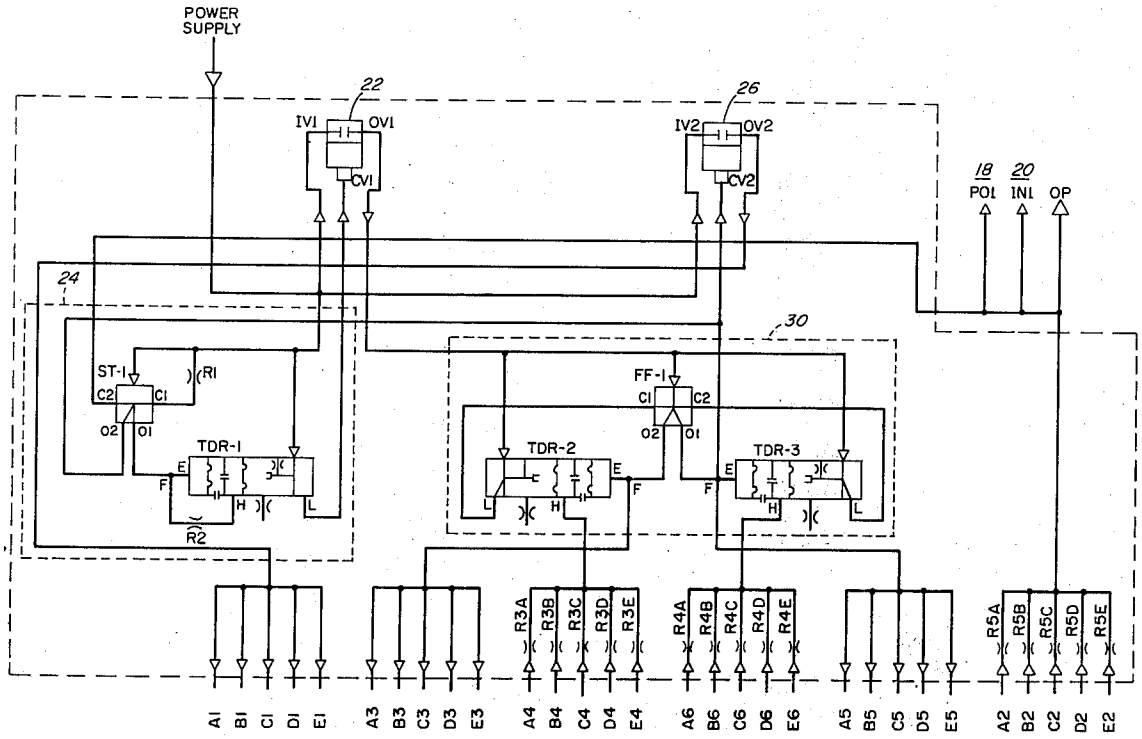
"Logic Circuit of Artificial Respiration" Fourth Cranfield Fluidics Conference, Coventry, Gt. Britian, Belforte.

Primary Examiner—Gaudet, Richard A.
Assistant Examiner—Henry J. Recla
Attorney, Agent, or Firm—Richard L. Stevens

[57] **ABSTRACT**

A ventilator employs a fluidic circuit which alternates between a control mode and a demand mode. The control mode provides oxygen to a non-breathing patient at a predetermined rate and volume. The demand mode provides oxygen to a breathing patient to assist the patient in his breathing. The fluidic circuit automatically switches between these modes in response to the patient's needs. A multiposition switch assembly provides different flow rates and volumes during the control mode depending upon the patient's size.

12 Claims, 5 Drawing Figures



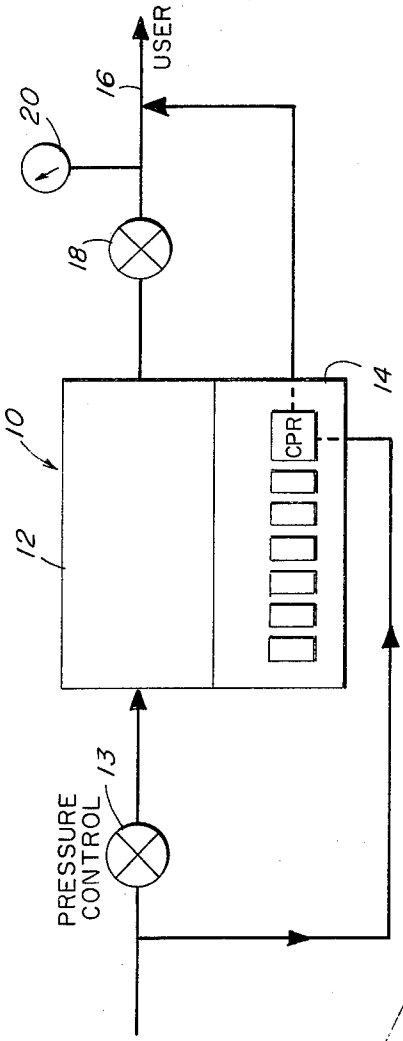
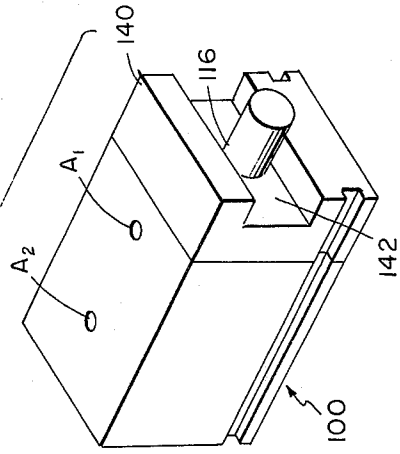


FIG. 1

FIG. 4



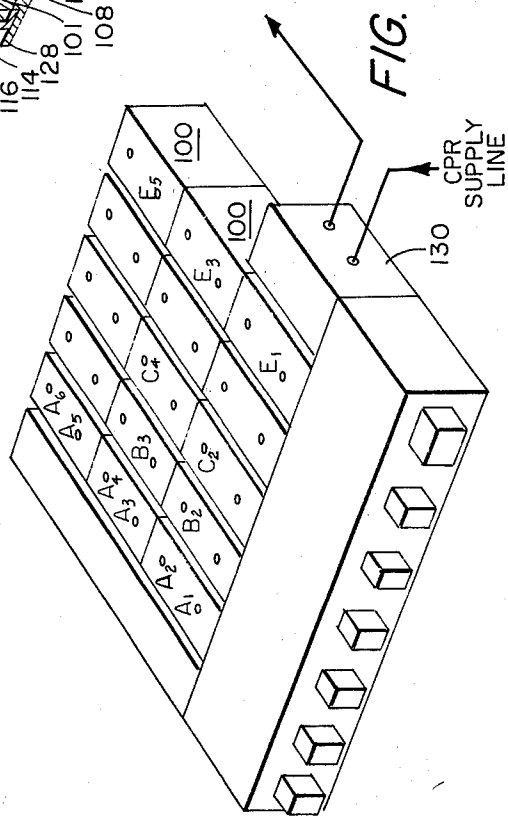


FIG. 5

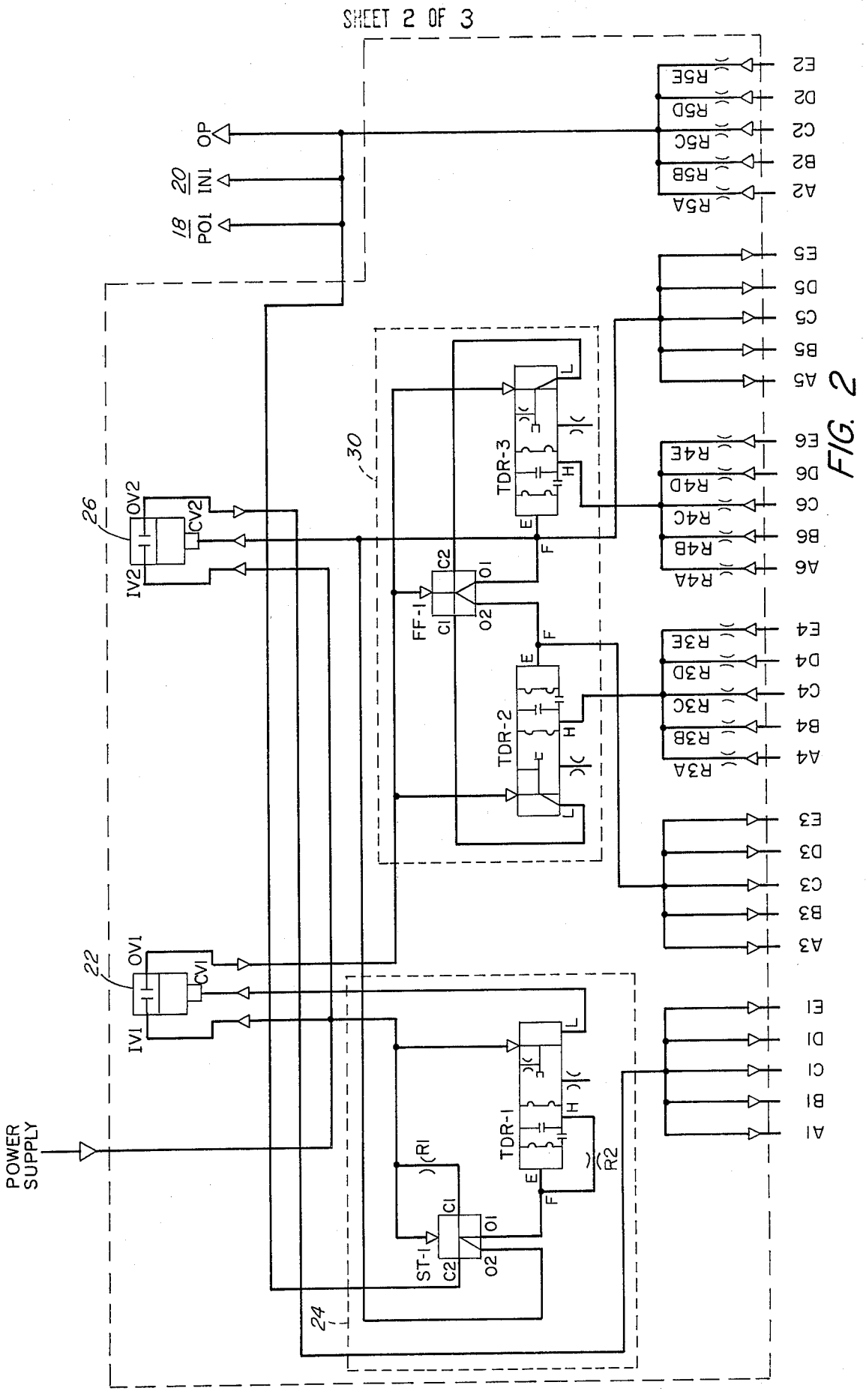

OP
IN1
PO1
20
18
R5E
R5D
R5C
R5B
R5A
E2
D2
C2
B2
A2
E5
D5
C5
B5
A5
E6
D6
C6
B6
A6
R4E
R4D
R4C
R4B
R4A
E4
D4
C4
B4
A4
R3E
R3D
R3C
R3B
R3A
E3
D3
C3
B3
A3
E1
D1
C1
B1
A1
TDR-3
TDR-2
TDR-1
FF-1
ST-1
OV2
CV2
IV2
OV1
CV1
IV1
C1
C2
O1
O2
E
F
H
L
R1
R2
26
30
22
24
POWER SUPPLY

FIG. 2

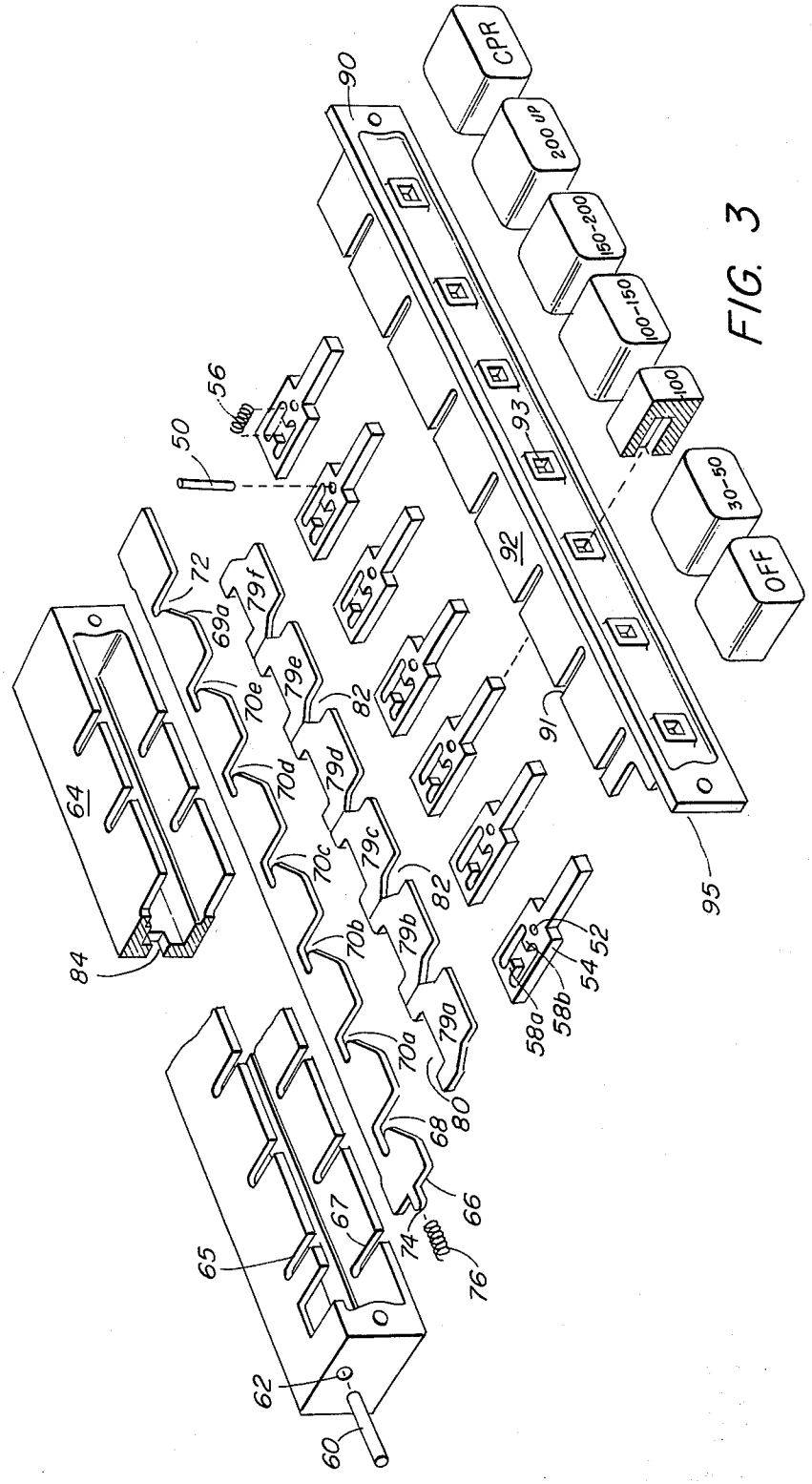

CPR
200 UP
150-200
100-150
100
30-50
OFF
90
93
92
91
95
50
56
72
69a
79f
70e
79e
82
70d
79d
70c
79c
70b
79b
70a
79a
68
80
66
74
76
67
65
62
60
64
84
58a
58b
54
52

FIG. 3

DUAL MODE FLUIDIC VENTILATOR

BACKGROUND OF THE INVENTION

In the field of respirators or ventiltors, it is known to provide apparatus which can function without moving parts through the employment of fluidic circuits (see, for example, U.S. Pat. No. 3,736,949). Ventilators, whether or not employing fluidic circuits, generally control the duration of the inspiration and expiration phases (I/E ratio) and the flow rate, such as tidal volume.

In the use of ventilator there are two types of patient conditions which require separate modes of operation: controlled ventilation, that is, totally controlling the breathing of the patient; and demand ventilation, that is, aiding the patient in his breathing as a function of his demand. Ventilators currently available provide both modes of operation, and can switch from assisted ventilation to controlled ventilation automatically. However, if the patient recovers while on controlled ventilation, then, in most ventilators, an alarm is actuated and to place the respirator in the assisted ventilation mode, manual actuation is required.

In ventilators, there are ranges over which the apparatus must be capable of functioning to handle all situations. That is, there is a requirement to control the breaths per minute (BPM), the I/E ratio, and the tidal volume entering the patient's lungs. The BPM and I/E ratio and tidal volume vary depending upon patient condition and size. These conditions can be categorized whereby a plurality of defined operational parameters can be established to handle most situations. In some ventilators, multiposition switches are employed. Each position of the switch corresponds to a given set of conditions, i.e., BPM, I/E ratio, and tidal volume. However, these switches incorporated into the ventilator are electrically operable and increase the danger of an explosion based on the fluid used, and additionally do not allow the unit to be easily sterilized.

SUMMARY OF THE INVENTION

The present invention is directed to a method and apparatus for controlling the flow rate of a fluid into an enclosure. More particularly, the method and apparatus of the invention are directed to a ventilator which may alternate between a controlled ventilation mode and a demand ventilation mode. The control mode insures that an enclosure is filled intermittently with a fluid in uniform cycles of duration including a first phase for delivering the fluid to the enclosure and a second phase for interrupting the flow to the enclosure.

In another aspect of the invention, a manually operative pneumatic switch is provided, which is devoid of electrical dependence, and which provides the capability of switching from one of a plurality of positions corresponding to pre-established sets of conditions.

In the preferred embodiment of the invention, a ventilator is provided which automatically alternates between a damand ventilation mode and a controlled ventilation mode. This alternation between modes is controlled solely by the patient's needs. A fluid supply is provided and communicates with the ventilator. The ventilator includes a fluidic integrated circuit necessary to control the demand ventilation mode, the controlled ventilation mode, and the alternation between these modes and is solely responsive to the level of pressure in the conduit which communicates with the patient.

When the patient only requires assistance, the demand ventilation mode functions. If the patient requires full control, then the ventilator automatically switches to the controlled ventilation mode. If the patient subsequently requires only assistance, then the ventilator automatically switches to the demand ventilation mode.

More particularly, the invention is directed to a ventilator to control the flow of fluid to a patient in at least two modes, and means responsive to the pressure variations in the ventilating conduit to alternate between a first demand ventilation mode to a second controlled ventilation mode. Further, the invention includes a switch which controls the BPM, I/E ratio, and tidal volume during the controlled ventilation mode.

The method of the invention comprises measuring the pressure in an enclosure, providing a first fluid flow to the enclosure in response to the measured pressure at a first level, and providing a second fluid flow to the enclosure at a second pressure level in response to a change in the pressure level in the enclosure, and alternating between the first and second modes solely in response to the pressure in the enclosure.

Another aspect of the invention is directed to a multiposition switch to function in combination with the fluidic integrated circuit. A switch assembly is provided which comprises a plurality of mechanical switches or buttons, each switch in communication with at least one valve, the valve in communication with a fluidic circuit. Actuation of the button opens its corresponding valve and deactivates all other valves.

More particularly, the switch assembly comprises a push button selector and a valve assembly. The selector includes a plurality of valves associated therewith. The valves communicate with the fluidic integrated modular circuit and correspond to a set of conditions of operation: BPM, I/E ratio, and tidal volume. Actuation of a push button will insure the desired conditions are met for the ventilator.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a ventilator, which embodies the invention;

FIG. **2** is a schematic illustration of a circuit employed in the ventilator;

FIG. **3** is a perspective telescopic view of the push button selector;

FIG. **4** is a side sectional view of a valve block assembly, engaged to the push button selector; and

FIG. **5** is a perspective view of the switch assembly.

DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

In FIG. **1**, a ventilator **10** which embodies the invention is shown in block diagram form and includes a fluidic integrated circuit module **12** mated to a switch assembly **14**. A delivery line or conduit **16** places a patient in communication with the ventilator **10** and includes any of the well-known devices adapted for such purpose, such as masks or mouthpieces (not shown). A pressure-relief valve **18** to insure that the pressure developed does not reach a level which would be injurious to the patient and an indicator **20** to demonstrate visibly the operating pressure of the ventilator are secured to the line **16**.

Referring to FIG. **2**, the fluidic integrated modular circuit **12** is shown in detail and includes a fluid amplifier **22** disposed upstream of the indicator **20** and

downstream of the fluid power or air source and a switching circuit **24**. A control mode circuit **30** is shown in communication with the amplifier **22** and a control mode amplifier **26**. The circuit **30** also includes restrictors R3A-R3E; R4A-R4E; and R5A-R5E.

The switching circuit **24** comprises a Schmitt trigger ST1 in combination with a time-delay relay TDR-1. The Schmitt trigger ST1 includes a resistor R1, a reference control port C1, a control port C2 which is downstream of all circuits and in direct communication with the patient, and output ports **0-2** and **0-1**. The output **0-2** communicates directly with a control port CV-2 of the fluid amplifier **26**. The power supply PS flows to the Schmitt trigger ST-1 as shown and through restrictor R-1 which sets the level of ST-1 and to the reference control port **0-2**. The output port **0-1** provides a signal to the time-delay relay TDR-1. The time-delay relay includes a restrictor R2 to control the duration of the delay of the output signal of the relay, as will be described in the operation of the invention.

The fluid amplifier **22** includes a control port CV-1, in communication with the output, port L, of time-delay relay TDR-1. The fluid amplifier **22** also includes the inlet port IV-1, downstream of the power supply PS and an outlet port OV-1, which provides a signal to the control circuit **30**.

The control circuit **30** includes a flip-flop FF1 in communication with the outlet port OV-1 of the fluid amplifier **22**. The flip-flop FF1 includes control ports C1 and C2, and outlet ports **0-2** and **0-1**, which communicate with the time-delay relays TDR-2 and TDR-3, respectively. The time cycle of each leg of the flip-flop FF1 is determined by a combination of the time-delay relay and the restrictive device, e.g. R3A, R4A in which it is in combination with. The time-restrictive device is calibrated to establish both the I/E ratio and the BPM. This is determined by selection of the appropriate button on the switch assembly **14** as will be described in detail in the description of FIGS. **3** and **4**, and the operation of the invention. The inlets E of the time-delay relays TDR-2 and TDR-3 are in communication with both the control ports C1 and C2 of the flip-flop FF1 and the control port CV-2 of the fluid amplifier **22**.

SWITCH ASSEMBLY

The switch assembly comprises two sections: the push-button selector and the valve block assembly.

The switch assembly may, in addition to being used with the fluidic integrated circuit **12** of the present invention, be used with other pneumatic or fluidic circuits. The switch assembly shown in detail in FIGS. **3** and **4** is a 7-position switch and includes an off button which prevents operation of the entire unit and a CPR switch, which must remain manually depressed to function and provides fluid to the patient at a rate of **60** slpm for cardioarrest victims. The remaining five buttons control, in combination with the restrictors shown in FIG. **2**, predetermined conditions for tidal volume, BPM and I/E ratio. Push-buttons are identified as OFF, **30-50, 50-100, 100-150, 150-200, 200** up, and CPR.

Referring to FIG. **3**, the push-button selector of the switching assembly is shown in perspective telescopic view. The assembly comprises a dowel pin **50** received in an aperture **50** of a button-slide **54**. The dowel pin **50** is disposed in the button slide **54** by pressure fit such that an approximately equal length, say for example 11/32 of an inch protrudes from both the top and the bottom of the button slide **54**. For purposes of clarity, only one button slide-dowel assembly is shown in FIG. **3**. However, it should be understood that matching assemblies are provided for each of the buttons.

A spring **56** is received in the button slide **54** between the two protruding tails **58**(*a*) and (*b*) and extends beyond the upper and lower surfaces of the slide **54**.

A dowel pin **60** is received securely by pressure fit in an aperture **62** in the end of a valve button housing **64**. A valve interlock bar **66**, having L-shaped slots therein **68, 70**(*a–e*) and **72**, and a tab **74** at one end thereof is disposed in the valve button housing **64**. A spring **76** is disposed about the dowel pin **60** extends therebeyond to engage the tab **74** of the valve interlock bar **66** such that it biases the valve interlock bar **66** rightwardly as shown in FIG. **3**.

A plurality of separate button interlocks **79**(*a–f*), shown side by side, have U-shaped slots **80** at one side thereof. The reduced section of each button interlock when aligned side by side defines with the reduced section of the button lock it is contiguous to V-shaped slots **82**. The button interlocks **79**(*a–e*) are placed in the valve button housing **64** below the interlock bar **66** such that the V-shaped slots **82** register with aligned upper and lower control slots **65** and **67**, of the housing **64**, and the L-shaped slots of the interlock bar **66**. The back wall of the housing **64** is characterized by a plurality of uniformly spaced rectangular openings **84** each opening adapted to receive in a slidable manner a button slide **54**. The button slide **54** is received in the rectangular opening at the rear of the housing **84**, the spring **56** contacting the inner surface of the back wall, and the dowel pin **50** is received in a slidable manner in the slots **65** and **67** of the housing **64** in the slot **70**(*a*) of the interlock bar **66** and in the V-shaped slot of the interlock bar **78**. A valve button guide **90** having a plurality of parallel equally spaced slots **91** on its upper surface **92** and a plurality of equally spaced apertures **93** on the front thereof is secured, such as by screws, to the valve button housing **64** and the extended ends of the button slide **54** pass through the openings **93**. The buttons, identified as OFF, **30-50**, etc., are then secured by pressure fit to the elongated end of the button slide **54**. When assembled, the upper and lower surfaces **92** and **95** of the button guide are within the housing **64** such that the valve interlock bar is slidably secured between the top surface of the button guide **90** and the bottom surface of the top ledge of the housing **64**. The interlocks **79** are slidably secured between the bottom surface of the button guide **90** and the upper surface of the lower ledge of the housing **64**. The slide **54** is between the shelves of the button guide **90**. Slots **65, 70, 91, 82,** and **67** are all in register such that the dowel pin **50** of the buttons **30-50**, etc., passes through all. There are no corresponding slots **82** for the OFF and CPR buttons, and the dowel pins **50** engage the L-shaped slots **68** through **72** of the valve interlock bar **66** respectively.

In the preferred embodiment of the invention, fifteen valve assemblies are required for the buttons **30-50**, etc. Three assemblies each are stacked in series and function as one unit as will be described to provide the input and output apertures for the openings required, as shown in FIG. **2** and identified as A(**1-5**) through E(**1-5**). One valve assembly is required for the CRT

button and no valve assemblies are required for the OFF button.

Referring to FIG. **4**, the valve block assembly is shown, a first valve schematically, the second valve in cross-section, and the third valve in partial section partial perspective.

The valve **100** includes a valve block **122** and a valve stem **101** shown in closed position having a rear shoulder portion **102** and a forward conical-shaped portion **104.** The rear-shaped and forward-shaped portions terminate in rear and front stems **108** and **106.** A spring **110** is received about the stem **108** and engages the shoulder **102** at one end and engages a spring retainer **112** at the other end. The spring retainer **112** is secured into the inner shoulder **113** of valve block **122** by press fit. A diaphragm **114** is secured in non-movable sealing engagement by press fit in the outer shoulder **115** of the valve block **122.** The seal retainer **116** is received in a slidable manner in the apertures of the retainer **112** and diaphragm **114.**

The central section of the valve block **122** has a chamber in which the valve stem **101** reciprocates between its open and closed positions, input and output conduits A_1-A_2, A_3-A_4, and A_5-A_6 respectively; a shoulder **124,** a conduit **132** and an outer ring portion **133.** A ring-like shoulder **126** on the forward portion of each valve mates with a corresponding recess **128** at the rear of each valve block **122.** The first valve **100** includes a section **140** through which the seal retainer **116** passes. The section **140** includes a rectangular recess **142** which receives the rear portion of the button slide **54** shown in FIG. **3.**

Referring to the second valve **100,** the conical section **104** of the stem **101** sealingly engages the shoulder **124,** preventing fluid flow between the ports A_3 and A_4. The stem is biased to to this closed position by the spring **110.** The stem **101** is partially received in conduit **132** where it contacts retainer **116.** Movement of the button slide **54** initially engages retainer **116** which moves rearwardly effecting movement of the subsequent valve stems **101** and retainers **116.**

Keyways **150** maintain the entire assembly in line and provide mounting holes for screws to clamp the valve assembly to the switching assembly.

FIG. **5** illustrates the entire assembly with the **30** ports corresponding to the ports of FIG. **2.** It being understood that for each button, except OFF and CRT these are the corresponding valves in series which provide six ports. Specifically, the following relationship is provided: button **30-50,** ports A(**1-6**); button **50-100,** ports B(**1-6**); button **100-150,** ports C(**1-6**); button **150-200,** ports D(**1-6**); and button **200** up, ports E(**1-6**). As shown in FIG. **1,** the power supply at **40-90** psig flows directly to the single valve **130** associated with the CPR button and the output flows directly to the patient by passing the entire fluidic integrated circuit.

The physical interface between the circuit **12** and the switch assembly **14** is accomplished by clamping the fluidic integrated circuit module **12** to the top of the valve assembly **14,** such as by screws being threaded into the holes in the valve assembly **14.** The sealing is accomplished by O-rings which fit into the standard counterboard holes in the fluidic integrated circuit module and actually seal against the valve assembly when the two parts are clamped together.

OPERATION

The operation of the invention will be described in reference to the use of the ventilator as an emergency unit, wherein a patient of from 30 to 50 lbs. requires artificial ventilation. Referring to FIG. **1,** a power supply of fluid supply such as oxygen tank is turned on and its output controlled at 3–10 lb. per square inch gauge pressure by pressure regulator **13** which is all that is required to operate the fluidic devices of the circuit **12.** Upstream of the pressure regulator **13,** the line branches and is connected to the input side of the valve **130** in combination with the CPR button. This flow of oxygen to the patient will hereinafter be referred to as the signal. Under operating conditions, the fluid supply will be at **50** standard liters per minute at the reference gauge pressure. A mask or tracheal tube, as is well known in the art, is placed about or in the patient's mouth and/or nose as appropriate. The pressure relief valve **18** insures that an injurious amount of pressure in the event of malfunction is not transmitted to the patient, and for example, would insure that no pressure above 50 CMH_2O reaches the patient.

The ventilator is activated by power turn on, and based on the size of the patient, the **30-50** button is actuated. This insures that a defined BPM and I/E ratio will be provided for the patient as required during the controlled ventilation mode. The restrictor R5A (ports A_1, A_2) is placed on line downstream of amplifier **22** and upstream of the delivery line **16.** As long as the button **30-50** is actuated, R5A will control the flow rate whether the ventilator is in the demand or controlled ventilation mode.

Referring to FIGS. **3** and **4,** as the **30-50** button is pushed, the button slide **54** is forced rearwardly against the bias of the spring **56,** which spring engages the inside wall of the back of the housing **64** and the slide **54.** Assuming no other button is engaged at the time, the dowel pin **50** travels in the slots **64** and **67** in the housing **64,** cams against the angular surface **69***a* of the L-shaped slot **70***a* in the valve interlock bar **66.** The dowel **50** will also travel in the slots **91** upper and lower of the valve button guide **90.** The action will cam the interlock bar **66** to the left against the bias of the spring **76.** At the same time, the dowel pin also cams against the inclined surfaces of the button interlocks **79***b* and **79***c*. It should be understood that the button interlocks in this embodiment comprises six separate pieces and, as shown, they are simply lying side by side. The left outer edge of interlock **79***a* is spaced apart from the left inner side wall of the housing **64** and the right outer edge of the interlock **79***f* is spaced apart from the right inner side wall of the housing. The movement of the button interlocks **79***b* and **79***c* by the action of the dowel pin **90** cause interlock **79***a* to move to the left and interlocks **79***b*, *c*, *d*, *e*, and *f* to move to the right such that the other buttons cannot be activated at the same time.

The button slide **54** travel is terminated when the dowel pin has traveled or cammed to the L-shaped portion of the slot **70***a*. After the dowel has cammed over the surface of the L-shaped slot **70***a*, it is received in the leg portion of the slot and the action of the spring **76** biasing the valve interlock bar **66** rightwardly locks the dowel pin into position and thereby locks the button **30-50** into position.

The rectangular section on the back of the slide now protrudes approximately one-fourth inch from the back side of the housing **64**, and is received in the recess **142** and activates the corresponding valves in the valve assembly with this displacement. Specifically, the end of slide **54** contacts and moves the retainer **116**. The length of the stem **101** is designed such that there is a small gap, say for example 0.15 inches, between the back of one valve stem and the front of the succeeding valve stem, insuring that when in the closed position each valve can properly close by the action of its own spring and not be interfered with by the positions of the other valves in the line. As the **30-50** button is pushed, in the selector section, the back of the button slide **54** pushes the corresponding valve stem back against the action of the spring **110**, thereby providing communication between the input and output ports A_1-A_2, A_3-A_4, and A_5-A_6 of the first, second and third valves, only the action of the first and second valves being shown in section, it being understood that all valves are identical. The design of the valve assembly and fluidic integrated modular circuit permits only one pair of paths for air flow for each valve to be opened at one time, or three sets of air paths for each button selection. Therefore, with the button **30-50** now actuated, the passageways for the restrictors R3A, R4A, and R5A are now available for operation during the controlled mode of the respirator.

When any of the buttons with the exception of the OFF and CPR buttons, are actuated, the following ports open and restrictors are made operable: button **30-50**, ports **A1-2**, restrictor R5A; ports **A3-4**, restrictor R3A; ports **A5-6**, restrictor R4A. Correspondingly, for button **50-100**, ports **B1-2**, restrictor R5B; ports **B3-4**, restrictor R3B . . . **200** up, ports **E3-4**, restrictor R3E; and ports **E5-6**, resistor R4E. The tidal volume restrictors shown in FIG. **2** are such that they provide the following flow rates:

Restrictor	Flow(SCC/M)	Flows(L/M)
R5A	2600	2.6
R5B	3000	2.0
R5C	7500	2.5
R5D	10,000	10.0
R5E	10,500	10.5

For the controlled ventilation mode to establish the BPM and I/E ratio at 1:2 one pair of restrictors (4 ports) is operated at one time. This is achieved by setting the time lapse before resetting flip-flop **FF1**.

Restricted Coordinated Pair	Frequency of Breath	I/E Ratio
R3A-R4A	40 BPM	1:2
R3B-R4B	30 BPM	1:2
R3C-R4C	25 BPM	1:2
R3D-R4D	20 BPM	1:2
R3E-R4E	15 BPM	1:2

Referring to FIG. **2**, the restrictors control the duration of the time-delay relays TDR **2** and **3**, which in turn allow actuation of the flip-flop FF1 between its first and second states. For the valve position **30-50**, the volume through the tidal restrictor R5A, ports **A1-2** open, is 65 cc. with an I/E ratio of 0.5 to one seconds. Correspondingly, for the remaining four positions, the volume, BPM, and I/E ratios are 100 cc., 40 BPM, 0.8 seconds to 1.6 seconds; 200 cc., 30 BPM, 0.67 seconds to 1.33 seconds; 300 cc., 25 BPM, 0.80 seconds to 1.60 seconds; 500 cc., 20 BPM and 1.0 to 2.0 seconds; and 70 cc., 15 BPM, 1.33 to 2.67 seconds.

After the ventilator is activated, referring to FIG. **2**, there is a signal immediately present at one side of the restrictor **R1**, and at the input ports of the Schmitt trigger ST1 and the time-delay relay TDR-1 at the input port IV-1 of the amplifier **22**. Also, there is a signal present at the input port IV-2 of the amplifier **26**. The Schmitt trigger ST1 functions in its normal manner such that its input will switch between first and second states depending upon control signals.

The signal at control port C1 is set by the restricting device **R1**. A signal appearing at control port **C2** greater than the signal at **C1** will shift the output of the Schmitt trigger to output port **O1**. Conversely, when the input signal at **C2** is less than that at **C1**, the output will shift to the O2 port. It should be noted that the control port C2 is directly in communication with the patient at a point downstream of all devices.

If the patient is breathing, as he inhales he will cause the signal at C2 to decrease, shifting the output of the Schmitt trigger to **O2**. Port O2 is connected to control port CV2 of amplifier **26**, which amplifier is activated when the O2 port is activated, causing the normally closed amplifier **26** to open and permit the supply to pass through the valve through the tidal volume restrictor R5A and to the patient.

If the patient is not breathing, the rise in signal at C2 switches the output of the Schmitt trigger to **O1**, shutting off the supply to the patient by closing amplifier **26** (no signal from O2 of ST1) and causes the signal to be present at the input port E of the time-delay relay, TDR-1. TDR-1 delays the signal for a preset time, e.g., 15 seconds, before it allows the signal to exit at port L. If the patient inhales before the time delay elapses, the signal at C2 decreases and then the Schmitt trigger switches to its O2 state and the amplifier **26** is opened. The time-delay relay TDR-1 is disabled. As long as the patient is breathing, the fluidic circuit remains in its first or demand ventilation mode, namely through activation of the fluid amplifier **26** allowing the flow of supply to the patient based on the patient's control (pressure in the respiratory system).

If the patient does not breath during the delay, then the signal appears at the output port L of TDR-1 and the control port CV1 of the fluid amplifier **22**. When the signal is present at the control port CV1 of the fluid amplifier **22**, the valve opens and permits a signal to pass through and to be introduced to the PS control ports of the flip-flop FF1 and the two time-delay relays TDR-2 and TDR-3, as well as one side of each of the two restrictive devices R3A and R4A, ports **A3-4**, **A5-6** being open, button **30-50** being actuated.

FF1 immediately and indiscriminately assumes either its O2 or O1 output state. Assuming that it takes the O2 state, then the signal exits through O2 and enters port E on TDR-2. The delay network in the device in conjunction with the restrictive device R3A permits exit of the signal at port L after the time set has elapsed, which is 0.5 seconds the flip-flop then switches to its O1 state, providing a signal at E of TDR-3 and CV-2 of amplifier **26**. The fluid amplifier **26** remains open the period of time that it takes for the delay restrictive circuit of the TDR-3 and the restrictor R4A to emit the signal at port

L of the relay and at the control port C2 of the flip-flop. When this occurs, the flip-flop changes to its O2 state and the entire cycle is repeated until the patient starts spontaneous breathing or the machine is shut off. Thus, if the patient does not start spontaneous breathing, then the apparatus continues in its controlled mode cycle. The fluid amplifier **26** also allows the tidal volume to flow through the restrictor R5A, ports A5-A6 being open.

The time cycle of each leg is set by a combination of time-delay relay and restrictive device calibrated to establish both the I/E ratio and the BPM. Once in the controlled mode, as soon as the patient commences spontaneous breathing, then the inhalation will cause the Schmitt trigger at input port C1 to switch, allowing the fluid amplifier **26** to open to assist the patient in breathing. If the patient does not continue spontaneous breathing within the fixed period of time, then the Schmitt trigger, in combination with the time-delay relay TDR-1 will switch to the controlled mode, employing the fluid amplifier **22** and the combination of restrictors as described.

Referring to FIGS. **3** and **4**, if a different set of conditions are required for a patient, when another button is pushed, say for example the **150-200** button, the same action initially takes place as when the **30-50** button is pushed, and the corresponingly dowel pin of the **150-200** button moves forward in its slots, it cams the interlock bar **66** to the left prior to engaging and separating the button interlocks **97***d* and *e*, permitting the **30-50** button that was previously activated to return to its inactive position forced by the action of the spring **56** between the housing **64** and the button slide **54.** More specifically, as the interlock bar **66** moves to the left, the dowel **50** of the slide **54** is moved closer to the longer leg of the L-shaped slot **70***a*. When the movement of the dowel associated with the **150-200** button completes its camming action but prior to its entry into the short leg of the slot **70***d*, the action of the spring **56** forces the slide **54** back to its closed position. The button **150-200** does not slide back, of course, because of the manual pressure being applied. The portion of the dowel which extends below the slide does not engage the interlocks **79***d* and *e* until the dowel is pressed into the short leg portion of the slot **70***d*. At that time, the bar **66** moves rightwardly locking the **150-200** button into position, and opening its corresponding valves, and the button interlocks **79***d* and *e* are separated. The movement of the button interlock as before prevents the actuation of two buttons at the same time.

The OFF button will not act to open any valve and is only used to disconnect all other positions when desired. The CPR button is momentary, providing the same action on the button interlocks **79,** but can only be held in place manually, as is apparent from its corresponding slot in the interlock bar **66.** This button operates a single valve, two ports, identical to those previously described, which supplies oxygen to the patient at a rate of **60** slpm directly from the source by passing the fluidic circuit entirely as long as the button is held in place providing the ventilation requirements for cardiopulmonary resuscitation for cardiac arrest victims.

Although my invention has been described with reference to particular values as far as I/E ratios, BPMs and tidal volumes, it is obvious that these may be varied by those skilled in the art. Also, it is apparent that additional or fewer valves may be stacked in serial relationship to allow for the opening or closing of other ports as desired. Further, the valve assembly may be used either alone or in combination with the above-described fluidic circuit or other pneumatic circuits. Additionally, any structure which would control the alternation of modes of operation, such as a demand valve and fluidic control arrangement, may be employed; for example, a demand valve may replace the Schmitt Trigger.

Having described my invention, what I now claim is:

1. A ventilator for controlling the flow of a fluid to a user, which comprises:

a. means to deliver a ventilating fluid to a user, including at least one conduit communicating with the user;

b. switching means operable between a first mode to place the ventilator in a demand ventilation mode and a second mode to place the ventilator in a controlled ventilation mode, said switching means responsive to a signal from the conduit to effect its changes between modes;

c. a first fluid amplifier responsive to the switching means in its first mode and in communication with the conduit to provide the ventilating flow to the user in the demand ventilation mode;

d. at least one tidal volume restrictor downstream of the first fluid amplifier to control the volume of the ventilating fluid flowing to the user in either the controlled or demand ventilation mode; and

e. a controlled ventilation mode circuit responsive to the switching means in its second mode and in communication with the means to provide the ventilating flow to the user, said ventilation mode circuit including:

i. means responsive to the switching means in the second mode, said means actuatable between first and second states; and

ii. first and second timing means in combination with the means responsive to the switching means, the first timing means in communication with the means responsive to the switching means in its first state, and the second timing means in communication with the means responsive to the switching means in its second state to control the rate at which the ventilating fluid flows to the user.

2. The ventilator of claim **1,** wherein means responsive to the switching means includes a flip-flop actuatable between first and second states; and

wherein the first and second timing means include first and second time-delay relays and at least one coordinated pair of restrictors, the restrictors in communication with the first and second time-delay relays respectively such that when the flip-flop is in its first state it communicates with the first time-delay relay and its associated restrictor and when the flip-flop is in its second state it communicates with the second time-delay relay and its associated restrictor.

3. The ventilator of claim **2,** which includes a second fluid amplifier responsive to the switching means in its second mode, the second fluid amplifier adapted to provide a signal to the flip-flop while the switching means is in its second mode.

4. The ventilator of claim **3,** wherein the flip-flop in its first state provides a signal to and opens the first fluid amplifier and in its second state stops the signal to and closes the first fluid amplifier.

5. The ventilator of claim 2, which includes a plurality of coordinated pairs of restrictors, each pair of restrictors of a different value to establish a plurality of BPM's and I/R ratios; and

means to select which coordinated pair of restrictors is placed in communication with the first and second time-delay relays.

6. The ventilator of claim 5, wherein the ventilator includes a plurality of tidal flow restrictors and the means to select a coordinated pair of restrictors includes means to select one of said tidal flow restrictors.

7. A ventilator for controlling the flow of fluid to a user, which comprises:

a. means to deliver a ventilating fluid to a user, including at least one conduit communicating with the user;

b. a Schmitt trigger in combination with a first time-delay relay responsive to the pressure in the conduit and actuatable between first and second states, the Schmitt trigger when in its first state actuating a first fluid amplifier, which amplifier allows flow of the ventilating fluid to the user in a demand ventilation mode, the trigger when in its second state actuating the first time-delay relay;

c. a second fluid amplifier responsive to a signal from the first time-delay relay, the signal provided when the Schmitt trigger is in its second state for a time longer than the preestablished time of the first time-delay relay to provide a controlled ventilation mode; and

d. a controlled ventilation mode circuit including bistable means responsive to the second fluid amplifier, second and third time-delay relays in communication with the bistable means, at least one coordinated pair of restrictors in communication with the second and third time-delay relays respectively, the bistable means when in its first state in communication with the second time-delay relay and its associated restrictor adapted to provide a signal to the first fluid amplifier to allow flow of fluid to the user, the duration of the first state controlled by the second time-delay relay and its associated restrictor, the bistable means when in its second state in communication with the third time-delay relay and its associated restrictor adapted to terminate the signal to the first fluid amplifier to stop the flow of fluid to the user, the duration of the second state controlled by the third time-delay relay and its associated restrictor, the alternation between states of the bistable means continuing until the Schmitt trigger in response to a pressure change in the conduit switches to its first state.

8. The ventilator of claim 7 wherein each of the restrictors of the pair is of a different value.

9. The ventilator of claim 8 which includes a plurality of coordinated pairs of restirctors, each pair of restrictors of different values whereby a plurality of BPM's and I/R ratios are established; and

means to select which coordinated pair of restrictors is placed in communication with the second and third time-delay relays.

10. The ventilator of claim 9 which includes at least one tidal flow restrictor downstream of the first fluid amplifier to control the flow rate of fluid to the user.

11. The ventilator of claim 10, which includes a plurality of tidal flow restrictors and the means to select a coordinated pair of restricotrs includes means to select one of said tidal flow restrictors.

12. The ventilator of claim 9, wherein the means to select which coordinated pair of restrictors is placed in communication with its associated time delay relay includes:

A. a plurality of non-electric switches;

B. at least one valve responsive to the actuation of each switch, each said valve in communication with each set of coordinated restrictors;

C. means to close mechanically one of said valves by actuation of its corresponding switch; and

D. means to prevent actuation of a second switch when the first switch is engaged.

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