

[54] **CYCLICALLY OPERATED MEDICAL RESPIRATORS**

[75] Inventor: **Barry John Kipling**, Cambridge, England

[73] Assignee: **Pye Limited**, Cambridge, Cambridgeshire, England

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[58] Field of Search..... 128/140, 145.6, 145.8, 128/188, 145.5, 145.7; 137/624.12, 625, 624.47

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Primary Examiner—Richard A. Gaudet

Assistant Examiner—G. F. Dunne

Attorney—Watson, Cole, Grindle & Watson

[57] **ABSTRACT**

For a medical respirator, a pneumatic drive circuit is provided which operates the respirator inspiratory and expiratory control valves in accordance with any one or more of the three modes of cycling, viz. time cycling, volume cycling or pressure cycling. Separate mode selection is provided for terminating the inspiratory and expiratory periods, each period being terminated at an instant determined by the selected parameter or the first one of the selected parameters.

6 Claims, 2 Drawing Figures

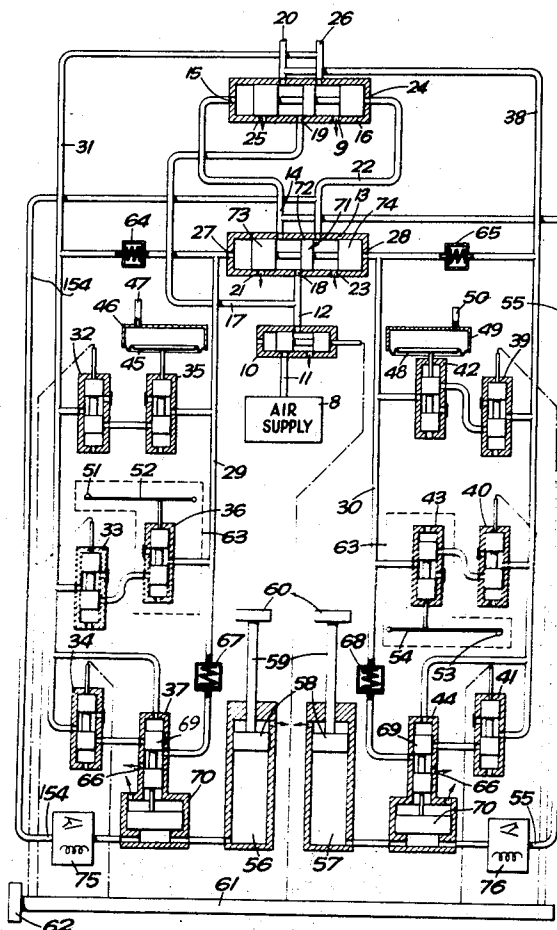
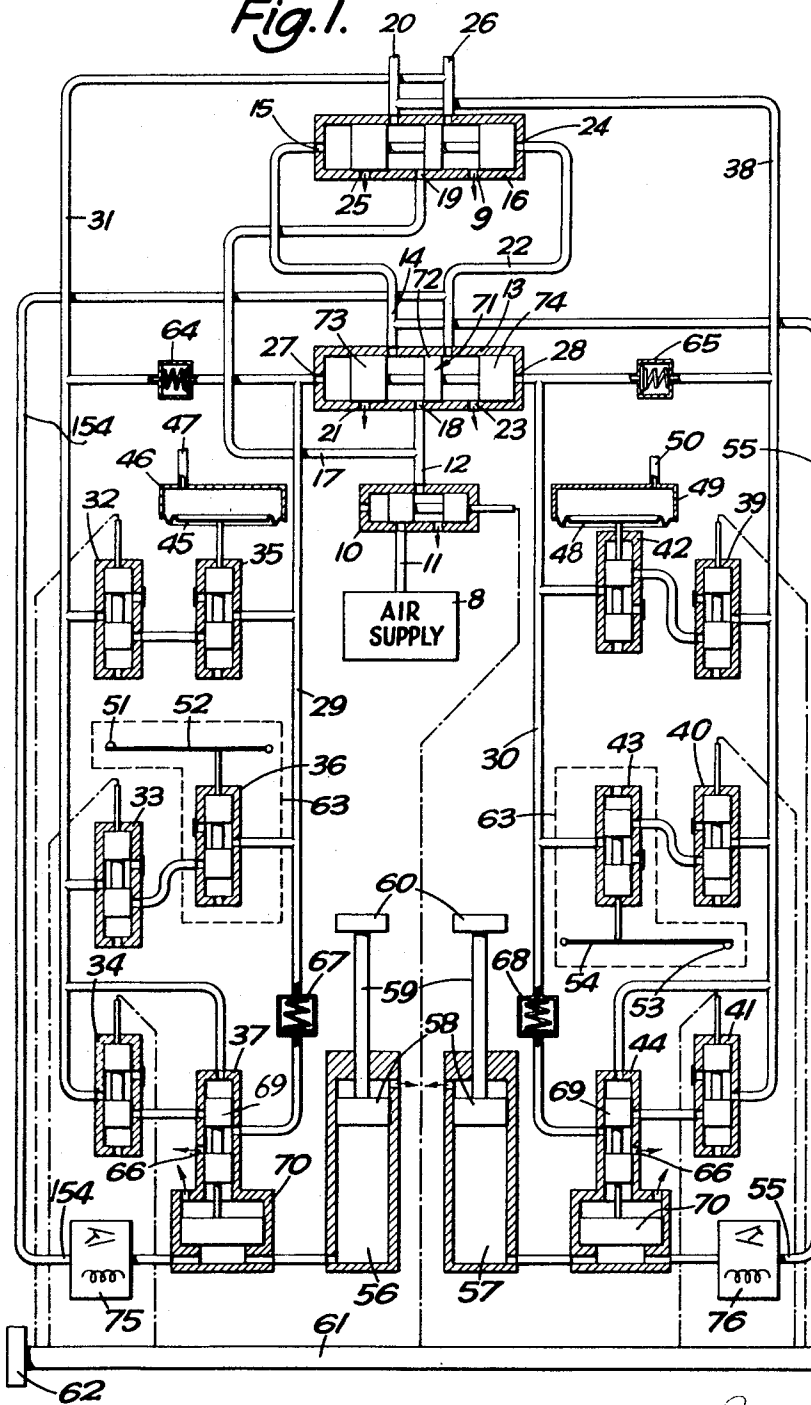


Fig. 1.



Inventor
 Barry John Kipling
 Watson, Cal. Grindle & Watson

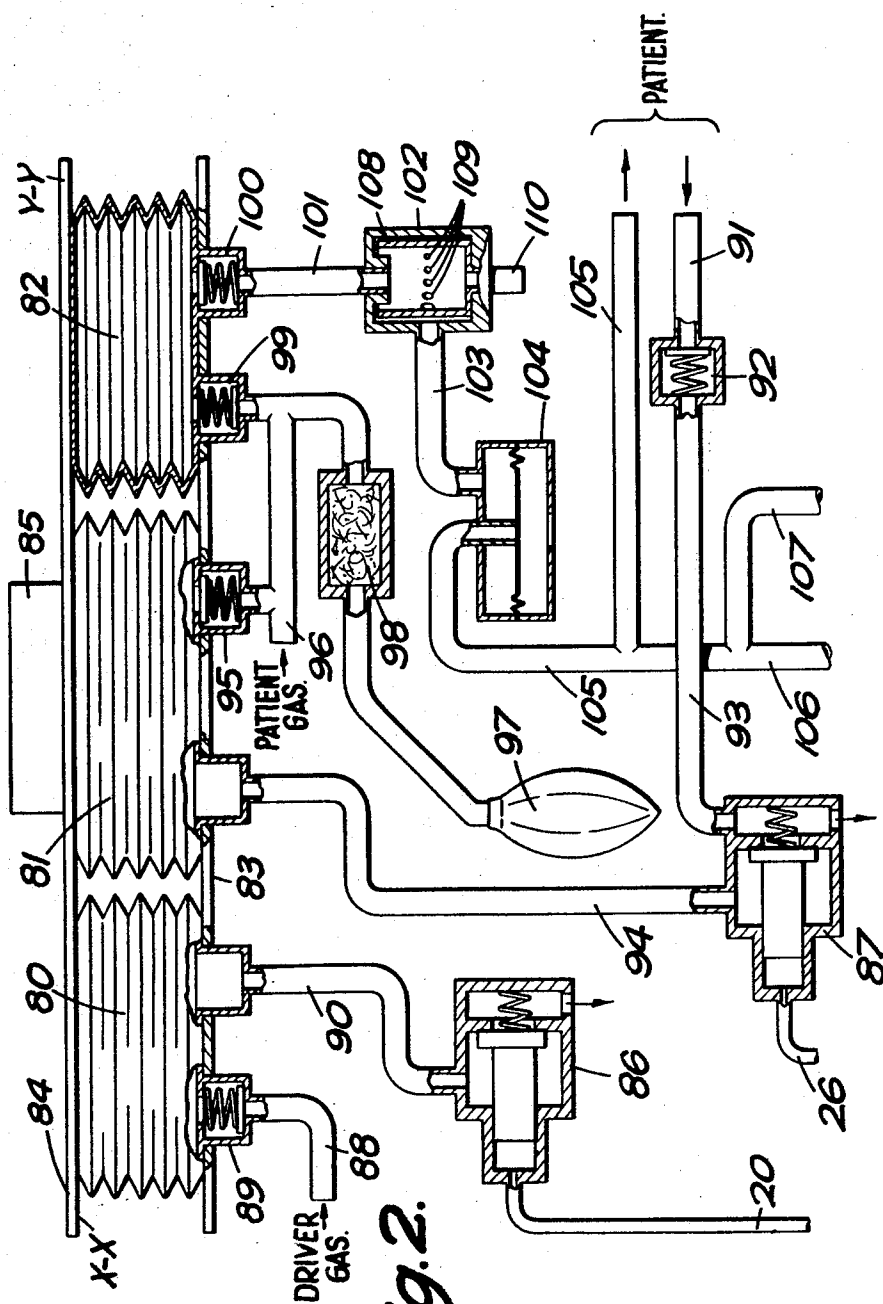


Fig. 2.

Inventor
 Barry John Kipling
 Watson, Cal., Grindle & Watson

CYCLICALLY OPERATED MEDICAL RESPIRATORS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to cyclically operated medical respirators and to control apparatus therefor.

2. Description of the Prior Art

In medical respirators used to assist respiration or in anaesthesia, the duration of the inspiratory and expiratory periods may be controlled by inspiration and/or expiration valves operated by the elapsing of a preset time or by the attainment of a preset level of pressure or volume of gas passing to or from the patient. Such respirators in which periods of inspiration and/or expiration are controlled in dependence on at least two of the parameters time, pressure and volume are hereinafter referred to as multiple mode respirators. A multiple mode respirator with electronic control of the inspiration and expiration valves is described in British Pat. specification No. 1162151 (and in the corresponding U.S. application Ser. No. 617,305 filed Feb. 20, 1967 and entitled Electronically Controlled Variable Mode Respirator, now U.S. Pat. No. 3,523,527.

SUMMARY OF THE INVENTION

According to one aspect of this invention, pneumatic control apparatus for a multi mode respirator having an inspiration control valve comprises a gas flow path for operating said inspiration control valve, a change-over valve device for adjusting the gas flow in said gas flow path at the end of each of the inspiration and expiration periods and at least two switch devices for controlling the flow of gas to operate the change-over valve device, which switch devices are each responsive to a different one of the parameters time, pressure of gas flowing to the patient or volume of gas flowing to the patient and switch device selector means operable to select switch devices to be effective to control the gas flow to the change-over switch so that the inspiration control valve is controlled in accordance with any selected one or more of the said parameters.

In the form of apparatus described above, multi-mode control of the termination of the inspiration period is obtained by selection of the appropriate switch devices so that this period is terminated in accordance with one selected parameter or in accordance with the first condition to occur of two or more selected parameters. The expiration period may be terminated in the known manner by a time control.

More generally, however, multi-mode control of the termination of both inspiration and expiration periods may be provided.

According to this invention, there is provided a pneumatic control apparatus for a multiple mode respirator having an inspiration control valve and an expiration control valve which comprises gas flow paths for operating said inspiration and said expiration control valves, a change-over device for adjusting the gas flow in said gas-flow paths at the end of each of the inspiration and expiration periods and at least two switch devices for controlling flow of gas to operate the change-over valve device at the end of an inspiration period and at the end of an expiration period, which switch devices are each responsive to a different one of the parameters time, pressure or volume of gas flowing to or from the patient and switch device selector means operable to select

switch devices to be effective to control gas flow to the change-over switch so that at least one said control valve is controlled in dependence on any selected one or on more than one of the said parameters.

With this form of control apparatus, the selector means enable one or more switch devices to be made effective to terminate an inspiration or expiration period. Thus the period is terminated when the first of the selected switches operates. Each of the switches controls the flow of gas to operate the change-over valve and thus the subsequent operation in that cycle of a second switch is of no effect. The control apparatus is pneumatic thereby avoiding the hazards which can arise with the use of electricity in the administration of certain anaesthetic gases.

Preferably two sets of switch devices are provided for operating the change-over valve device, one set being arranged to operate the change-over valve device at the end of the inspiration periods and the other set being arranged to operate the change-over valve device at the end of the expiration periods. Thus the control of both inspiration and expiration periods can be effected in accordance with a selected parameter or parameters.

Each set preferably includes three switch devices responsive respectively, for the switch devices operating at the end of the inspiration period, to time, pressure of gas flowing to the patient and volume of gas flowing to the patient and, for the switch devices operating at the end of the expiration period, to time, pressure of gas flowing from the patient and volume of gas flowing from the patient.

The switch devices of each set may control three gas passages connected in parallel between a control inlet to said change-over valve and a source of gas pressure controlled by said valve.

In one convenient form of construction, the change-over valve device comprises a valve change-over member movable in dependence on the gas pressure applied to one or other of two control inlets and operable to connect a main inlet from a source of gas pressure to either of one or other of two outlets, each of said outlets being connected either directly to said gas flow circuit or indirectly to control gas supply to said gas flow circuit and also to one of the control inlets through one set of said parallel connected switch controlled passages whereby two sets of switch devices, control respectively the flow of gas to said control inlets. Thus the operation of any switch device of the appropriate set to terminate an inspiration or expiration period will cause gas to flow through one of the parallel connected passages to the control inlet to cause the change-over valve member to move. It will be seen that with the arrangement flow through inspiration period switch devices can only occur if the change-over valve is set to a position corresponding to an inspiration period and vice versa as this flow comes from one or other of the two outlets of the change-over valve.

The valve change-over member may comprise a shuttle member connected between two piston devices slidable within a cylinder, the shuttle member being arranged to move across the said main inlet between the two outlets to connect the main inlet to one or other of the two outlets, and two venting outlets are provided in the cylinder and controlled by movement of the two piston devices respectively.

Preferably each control inlet is connected through a non-return valve to a controlled vent to atmosphere.

The aforementioned change-over valve may, from two outputs, control respectively inspiration and expiration valves of the respirator. Preferably however this is done indirectly, these two outputs controlling a further change-over valve which provides two alternative outputs which control respectively inspiration and expiration valves. This enables a constant air pressure to be rapidly established in the pipes between the two control valves (which pipes can be relatively short) irrespective of any use made of the output from the second change-over valve.

In a construction having a switch device responsive to time, for inspiration period control and/or expiration period control, the or each switch device may comprise an adjustable pneumatic delay including a piston operated through a restricted orifice. Preferably with two change-over valves as described above, this switch device is fed from the appropriate output of the first change-over valve so that the full pressure is applied quickly to the time delay after operation of the change-over valve. The paths through the switch devices however are preferably fed from the appropriate output of the second change-over valve. This prevents any leakage in the switch devices and assorted parts of the apparatus from having any effect on the time delay.

The invention includes a multiple mode respirator having pneumatic control apparatus as described above.

BREF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows diagrammatically a pneumatic control apparatus for a medical respirator, and

FIG. 2 shows a medical respirator to which the pneumatic control apparatus of FIG. 1 is connected.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In this example the pneumatic control apparatus is entirely pneumatic with no electrical parts. It is designed to be used in medical respirators having a valve or valves controlling gas flow to or from a patient, e.g. such as that described in the specification of the aforementioned British Pat. No. 1162151; the pneumatic drive replacing the electrical drive circuit described in that specification, for operating the inspiration and expiration control valves of the respirator.

In the pneumatic control apparatus of FIG. 1 air at a constant pressure, e.g., 60 p.s.i., from a source 8, such as a compressed air cylinder with a pressure regulator is applied to a manually operated valve 10, acting as an ON/OFF switch, through a pipe 11. The valve 10 is shown in the OFF position. When operated to the ON position by movement of the valve member to the left in the drawing, air pressure is applied through a pipe 12, previously vented to atmosphere, to a main inlet port 18 of a five port change-over valve 13, such as Type KV9/025 as manufactured by Kay pneumatics of London Road, Dunstable, Bedfordshire, England. This change-over valve 13, in its first position (shown), directs the air pressure to a first air pipe 14 which is connected to a control port 15 of a second change-over valve 16, to maintain that valve in the position shown. A pipe 17 connects pipe 12 to a main inlet port 19 of the second change-over valve 16, so that, in the position shown, an air pipe 20 receives pressurised air. In the alternative second position of valve 13, air pipe 14 is vented to atmosphere through a port 21 and a second

air pipe 22, previously vented through a port 23, receives pressurised air, so applying pressure to another control port 24 of valve 16. As air pipe 14 is vented, the pressure at port 24 operates valve 16 to its second position in which air pipe 20 is vented through a port 25 of valve 16 and in which an air pipe 26, previously vented through a port 9 of valve 16, receives pressure. The inclusion of valve 16 assists in the rapid establishment of a constant air pressure in air pipes 14 and 22 irrespective of the manner in which pressure in air pipes 20 and 26 is used.

Pressure applied to a first control port 27 of valve 13 causes valve 13 to take up its first position (as shown) and pressure applied to a second control port 28 operates the valve 13 to its second position, provided that the circuit connected to the control port 27 or 28 not receiving pressure allows the discharge of entrained air.

The change-over valves 13 and 16 employed do not require air pressure to be continuously applied to a control port to maintain a particular position; the valve remains in a position determined by a pulse of pressure applied to one control port until again operated by a pulse of pressure applied to the other control port.

Pressure is applied to control ports 27 and 28 by first and second control pipes 29 and 30 respectively. Pressure for these control pipes is obtained as follows. Pressure from air pipe 26 is passed through a pipe 31 to three inspiratory mode selection switches 32, 33 and 34 shown in their OFF position and, from the selection switches, may be passed via respective mode switches 35, 36 and 37 also shown in their non-operated OFF position, to control pipe 29. Pressure from air pipe 20 is similarly passed along a pipe 38 to expiratory mode selection switches 39, 40 and 41 and thence via respective mode switches 42, 43 and 44 to control pipe 30, these expiratory mode selection switches and mode switches also being shown in their OFF or non-operated position.

The inspiratory pressure mode switch 35 is operated to establish an air passage by outward movement of a diaphragm 45 of a positive pressure sensor 46 connected to the patient gas circuit of the medical respirator by a line 47. The expiratory pressure mode switch 42 is operated similarly by inward movement of a diaphragm 48 of a negative pressure sensor 49 connected to the patient gas circuit of the medical respirator by a line 50.

The inspiratory volume mode switch 36 is opened to establish an air passage by downward movement of one end 51 of a lever 52, pivoted at its other end, under the control of the volume of gas passing to the patient. Similarly the expiratory volume mode switch 43 establishes an air passage on upward movement of one end 53 of a similarly pivoted lever 54 controlled by the volume of gas passing from a patient.

Operation and establishment of an air passage in time mode switches 37 and 44, which are of differential pressure type, is time dependent. These two switches are similar with the exception that they receive operating pressure from different points in the circuit. Switch 37 has its high pressure side supplied from pipe 31 and its low pressure side from a pipe 154 connected to air pipe 22 whereas the high pressure side supply for switch 44 is taken from pipe 38 and the low pressure side is supplied through a pipe 55 from air pipe 14. Alternatively the high pressure sides of switches 37 and 44 are fed from a constant source of pressure such as

pipes 11, 12 or 17. The low pressure input ports of each switch 37 and 44 contain means 75 and 76 respectively which restrict air flow inwards, e.g., a needle valve, but allows rapid egress of air from the low pressure side of the switch, e.g., a one way valve. Also connected to the low pressure side of each time switch 37 and 44 are variable volume cylinders 56, 57. The effective capacity of the cylinders 56, 57 can be altered by movement of pistons 58 controlled by rotation of respective screw threaded rods 59 by knobs 60 to determine the time lapse between application of pressure to the low pressure input port and switch operation.

The mode selection switches, 32, 33, 34, 39, 40 and 41 and ON/OFF switch 10 are lightly biased to the OFF position shown by spring means (not shown) and are manually operated. Such manual operation is facilitated by conversion of the small linear operation motion to rotary motion by the use of a cam having little difference between maximum and minimum radius. The switches are grouped along a shaft 61 carrying cams so that the switches may be controlled, and the mode of operation of each period of the respirator selected, by rotating a single knob 62 as indicated by the broken lines connecting the switches with the shaft 61.

In FIG. 1, for clarity, the movement of the diaphragm 45 and 48 of the sensors 46 and 49 is shown as being applied directly to operate the pressure mode switches 35 and 42. In practice, the movement has to be amplified; this may be done either by pneumatic amplifying means or by mechanical means or a combination of both. The predetermined pressure levels at which the pressure mode switches 35 and 42 operate is adjusted by altering the pneumatic amplification and/or the fulcrum point of a lever forming part of the linkage between the diaphragm and its pressure mode switch. Alternatively movement of a sensor relative to the linkage may form a part or the whole of the adjustment.

In the case of volume mode switches 36 and 43 the air pipes between these switches and their associated selection switches 33 and 40 and between the switches 36 and 43 and the control lines 29 and 30 are flexible, each switch 36 and 43 and lever 52, 54 being carried on a movable plate, indicated by a broken line 63 surrounding each switch and lever. The position of the levers relative to a striker bar, moving upwards during expiratory and downwards during inspiratory periods, may thus be adjusted to determine at what position the direction of travel of the striker bar is reversed by operation of one or other of the switches 36 or 43.

A very lightly spring loaded one way valve 64 is connected between pipe 31 and control port 27 of valve 13 so that, with pressure in pipe 31, the valve 64 is closed but, when the pipe 31 is vented via air pipe 26, pressure from the control line 29 and control port 27 may escape through the one way valve 64 and out through port 9 of valve 16. A similar valve 65 allows control port 28 and control pipe 30 to vent in the absence of pressure in pipe 38 through the one way valve 65 and port 25 of valve 16.

In this embodiment, time mode switches 37 and 44 are of a type, i.e., Kay Pneumatics' Type KTD/023, in which no provision is made for sealing switch port 66 shown as venting to atmosphere. One way valves 67 and 68 of a similar type to valves 64 and 65 are therefore inserted as shown between valves 37 and 44 and the respective control pipes 29 and 30, so preventing loss of pressure from a control pipe through a non-

operated time switch. The one way valves 67 and 68 are superfluous if the time switches are of a type in which the vent 66 is sealed.

The pipes 20 and 26 are connected to inspiration and expiration control valves in the respirator and alternate pressure in these pipes 20 and 26 controls the cycling of the respirator as will be described later with reference to FIG. 2. The operation of the pneumatic control apparatus is as follows when selection switches 34 and 41 are open and the rest closed.

With the ON/OFF switch 10 ON and the valve 13 in the position shown, valve 16 will be in the position shown and air lines 14 and 20 will be pressurised.

Compressed air from the high pressure source 8 passes along a pipe 11 through the ON/OFF switch 10 and the change-over valve 13 into pipe 14, along pipe 55 into the variable volume cylinder 57 through the low pressure inlet restriction 76 of mode switch 44. The pressure in the cylinder 57 gradually increases at a rate dependent on the volume of the cylinder and the size of the restriction. Compressed air from the source 8 also passes along pipe 17 and through change-over valve 16 into pipe 38 and provides a biasing pressure against a piston 69 in the expiration time mode switch 44. The piston 69 is connected to a piston 70 of larger area so that when the pressure in the cylinder 57 has built up to an amount which depends on the relative cross-sectional areas of the pistons 69 and 70, the switch 44 is operated and gas passes from pipe 38 through the switch 41 (which is open, although shown closed in FIG. 1) and switch 44 into the control pipe 30 for valve 13. The pressure in pipe 30 pushes a change-over member 71, comprising a shuttle member 72 connected between two piston devices 73 and 74 slidable within the body of valve 13, in the change-over switch 13 across to the left as seen in FIG. 1. Gas on the left side of the piston device 73 is forced out to atmosphere through port 27, one way valve 64, pipe 31, and port 9 of valve 16.

As soon as the change-over member 71 has changed over, gas passes from the source 8 through the valve 13 into pipe 22 to operate change-over valve 16 which is exactly similar to change-over valve 13. Gas can then pass from the source 8 along pipe 17 and through valve 16 to pipe 26, pipe 20 being vented to atmosphere through port 25.

Gas then also passes from pipe 22 along pipe 54 into the variable volume 56 through the restriction 75 in the entry to the low pressure side of the time mode switch 37.

The time mode switch 37 operates in the same way as time mode switch 44. When it operates, after a predetermined length of time has elapsed, gas passes from the source 8 along pipe 17, through valve 16 into pipes 26, along pipe 31, through selection switch 34, switch 37, one way valve 67, along control pipe 29 to the port 27 of the change-over valve 13 to push the change-over member 71 back to the right as seen in FIG. 1. Gas on the right side of piston device 74 is passed out to atmosphere through port 28, one way valve 65, pipe 38 and out through port 25 of change-over valve 16. This movement of member 71 then causes change-over switch 16 to change back again, the port 24 being vented to atmosphere through pipe 22 and port 23 of valve 13 to allow the change back. The sequence just described is then repeated and thus the pneumatic con-

trol apparatus cycles with the periods controlled by time.

If any of the other mode selection switches 32, 33, 39 or 40 are open as well or instead of selection switches 34 and 41, operation of their respective mode switches 35, 36, 42 or 43, will allow gas to pass from pipe 31 to control pipe 29 or from pipe 38 to control pipe 30 thus causing the valve 13 to change-over immediately followed by change-over valve 16 changing over.

The pipes 20 and 26 controlling the respirator are thus alternately pressurised and vented to atmosphere in accordance with the operation of the mode switches. For the pneumatic control apparatus to function at least one of each of the sets of selection switches 32, 33 and 34 and 39, 40 and 41 must be open. When more than one of either of these sets of selection switches are open, the first of the selected mode switches to operate controls the change-over of the valve 13 and hence the termination of an inspiration or expiration period of the respirator.

This pneumatic control apparatus may be used with any multiple mode respirator requiring or using alternate presence and absence of gas pressure to control patient gas flow; FIG. 2 shows an example of it being used with a respirator somewhat similar to that described in the aforementioned British Pat. specification No. 116215, working on closed circuit ventilation.

Three bellows 80, 81 and 82 have one side mounted on a fixed support 83 and the other side attached to a common movable striker bar 84 having a weight 85 on it biasing the bellows 80, 81 and 82 into their collapsed position. The pipes 20 and 26 from the pneumatic drive circuit of FIG. 1 are connected to an inspiration control valve 86 and an expiration control valve 87. These control valves are spring-biased to the open unless pressure is applied to the respective control pipe 20 or 26.

A driver gas is applied to a pipe 88 and passes via a one way valve 89 into bellows 80. This driver gas may be compressed air supplied from the same source 8 as that supplying the pneumatic control apparatus of FIG. 1. During an expiratory period with air pipe 20 pressurised, inspiration control valve 86 is closed and seals a pipe 90 connected to the exit port of bellows 80 so that the latter expands. Such expansion is transmitted to bellows 81, which is a negative pressure bellows, and also the third bellows 82 by the striker bar 84 to which all three bellows are attached. During such an expiratory period, air pipe 26 is vented (as previously described with reference to FIG. 1) and expiratory valve 87 is therefore open. Gas then flows from the patient via pipe 91, a one way valve 92, a pipe 93, a valve 87 and a pipe 94 into bellows 81. Gas will not flow into bellows 81 via its exit port due to a one way valve 95 therein. Patient gas at very low pressure applied to a pipe 96 initially charges a flexible walled reservoir bag 97 via a gas purifier 98 and during expiration gas will flow from the bag 97 into expanding bellows 82 through a one way valve 99 in its entry port, a one way valve 100 in the exit port of bellows 82 preventing gas entering therethrough. The connection between the exit port of bellows 82 and the patient comprises a pipe 101, a flow control 102, a pipe 103, a diaphragm valve 104 and a pipe 105 lead to the mask for the patient.

The flow control 102 consists of a cylinder 108 having an entry port into which gas flows through pipe 101 from bellows 82. Gas then passes out through an exit port of flow control 102 into the pipe 103 through one

or more of a series of holes 109 of differing diameter in the cylinder 108. Rotation of a shaft 110 rotates the cylinder 108 and determines the number and size of holes 109 exposed to the exit port and therefore the flow rate.

During an inspiratory period pressurising and venting of air lines 20 and 26 has been reversed, so that valve 86 is open and valve 87 is closed. Opening of valve 86 allows gas pressure in bellows 80 to drop and the weight 85 moves the three bellows towards a collapsed condition. The gas in bellows 81 passes through the one way valve 95 in its exit port to a branch of pipe 96 to recharge bag 97 through the purifier 98. At the same time gas in bellows 82 passes through the one way valve 100, pipe 101, flow control 102, pipe 103, diaphragm valve 104 and pipe 105 to inflate the lungs of the patient. As this inflation pressure is greater than that required to recharge bag 97, valve 99 is held closed so that no direct transfer of gas from bellows 81 to bellows 82 can occur and gas circulating from the patient passes through the purifier 98 twice, i.e., during charging and discharging of bag 97. As is normal for closed circuit work, the patient gas supply connected to pipe 96, after initial charging of the gas circuit, serves to make up any losses in the system due to leakage and/or absorption by the patient.

The pipe 96 is connected to the bellows 81 through a one way valve in a third port (not shown) of the bellows 81 by a pressure control valve (not shown) which allows gas to pass from the bag 97 into the negative bellows 81 during expiration to control the negative pressure developed.

Faces XX and YY on the striker bar 84 operate the levers 52 and 54 respectively of the volume mode switches 36 and 43. Pipes 106 and 107, branching from pipe 105, are connected to the pipes 47 and 50 of the positive and negative pressure sensors 46 and 49 respectively.

The one way valve 92 prevents gas flowing to the patient from the negative pressure bellows 81 should he attempt to inhale during an expiratory period. A lower pressure is more rapidly produced by the patient to operate the negative pressure sensor 49 connected to pipe 107, than if it was omitted. The one way valve 92, instead of being in pipe 91, may alternatively be in the entry port of bellows 81 connected to pipe 94.

Only the main elements of the patient gas circuits are shown in FIG. 2. Safety relief valves, flow meters, volume meters, controls for negative pressure, etc., are not shown.

The pneumatic control apparatus of FIG. 1 and valves 86 and 87 of FIG. 2 may be used with a respirator which has all the other patient and driver gas components of the respirator described in the aforementioned British Pat. specification No. 1162151 to provide a pneumatically driven respirator having facilities for multiple mode cycling and manual, open, or closed circuit working. The invention is not restricted to the details of the foregoing example.

Depending on the volume of air entrained within certain of the pipes of the drive circuit, which in turn is dependent on their lengths as determined by the physical arrangement or positioning of associated valves, and on the use of pressure available in air pipes 20 and 26 change-over valve 16 may be omitted, the first air pipe 14 then being directly connected to air pipe 20 and second air pipe 22 to air pipe 26.

It is conceivably possible, due to tampering with the pressure source supplying the pneumatic control apparatus, that change-over valves 13 and 16 could take up a position in which air pressure in pipes 12 and 17 could not pass through the valves due to the position of shuttles 72, and the respirator would then be in a stalled condition and incapable of operation on re-application of pressure. Such a condition may be rectified by a switch arrangement (not shown) that allows pressure from line 12 to be temporarily applied to one of the control ports 27 or 28. The switch arrangement is either arranged for manual operation or is mechanically linked to the switch 10 to provide an automatic pulse of pressure to a control port on switching ON.

I claim:

1. A multi-mode respirator having a pneumatically operated inspiration control valve, a pneumatically operated expiration control valve, bellow means in a patient gas path for measuring the volume of gas flowing to the patient and the volume of gas flowing from the patient, at least two of the following inspiratory and expiratory mode switches comprising: (a) inspiratory and expiratory volume mode pneumatic switches operatively connected to said bellow means to be operated by said bellow means respectively when the volume of gas flowing to the patient and the volume of gas flowing from the patient reaches predetermined magnitudes; (b) inspiratory and expiratory pressure mode pneumatic switches with pressure sensing means responsive to the pressure of inhaled and exhaled gas and operatively connected to said inspiratory and expiratory pressure mode switches to switch the inspiratory pressure mode switch when the pressure exceeds a predetermined value and to switch the expiratory pressure mode switch when the pressure falls below a predetermined value; and (c) inspiratory and expiratory time mode pneumatic switches each having a control input for pneumatic operation of the switch and each being connected to a separate pneumatic delay including a piston operated through a restricted orifice whereby each time switch operates it a time instant delayed after the application of pneumatic pressure to its control input, each of the mode switches controlling gas flow through a separate gas path, separate selector switches pneumatically in series each with one of the mode switches in said separate gas paths, selector switch operating means operatively connected to said selector switches to effect opening of any one or more of the selector switches in series with inspiratory mode switches and of any one or more of the selector switches in series with expiratory mode switches, a pneumatic change-over valve having an input and two alternative outputs and two control inputs, one control input being effective when pneumatic pressure is applied thereto to change-over the valve in one direction and the other control input being effective when pneumatic pressure is applied thereto to change-over the valve in the other direction, a pneumatic pressure source connected to the input of said first change-over valve, a first pneumatic control circuit for said change-over valve, said first pneumatic control circuit including a pneumatic patient gas path having the inspiratory mode switches each with its series selector switch in the respective gas flow paths connected in parallel to one control input of the change-over valve, pneumatic pressure supply means for said first pneumatic control circuit comprising a supply connection from one outlet of said change-

over valve or from a source controlled by that outlet, a second pneumatic control circuit for said change-over valve, said second control circuit including the expiratory mode switches, each with its series selector switch, connected in parallel to the second control input of said change-over valve, pneumatic pressure means for said second pneumatic control circuit comprising a supply connection from the second outlet of the change-over valve or from a source controlled by that outlet, means applying pressure from said first and said second outlets of said change-over valve to the inspiratory and expiratory time mode pneumatic delays respectively to initiate operation of the respective time delays when the change-over valve changes over to provide pressure at its first and second outlets, respectively, and means applying pressure from said first and said second change-over valve outlets to said expiratory and said inspiratory control valves respectively or to switch means controlling the application of pressure to said inspiratory control valves.

2. A multi-mode respirator having a pneumatically operated inspiration control valve, a pneumatically operated expiration control valve, bellow means in a patient gas path for measuring the volume of gas flowing to the patient and the volume of gas flowing from the patient, inspiratory and expiratory volume mode pneumatic switches operatively connected to said bellow means to be operated by said bellow means respectively when the volume of gas flowing to the patient and the volume of gas flowing from the patient reaches predetermined magnitudes, inspiratory and expiratory pressure mode pneumatic switches, pressure sensing means responsive to the pressure of inhaled and exhaled gas and operatively connected to said inspiratory and expiratory pressure mode switches to switch the inspiratory pressure mode switch when the pressure exceeds a predetermined value and to switch the expiratory pressure mode switch when the pressure falls below a predetermined value, inspiratory and expiratory time mode pneumatic switches each having a control input for pneumatic operation of the switch and each being connected to a separate pneumatic delay including a piston operated through a restricted orifice whereby each time switch operates it a time instant delayed after the application of pneumatic pressure to its control input, each of the six mode switches controlling air flow through a separate gas path, six selector switches pneumatically in series each with one of the mode switches in said separate gas paths, selector switch operating means operatively connected to said selector switches to effect opening of any one or more of the selector switches in series with inspiratory mode switches and of any one or more of the selector switches in series with expiratory mode switches, a pneumatic change-over valve having an input and two alternative outputs and two control inputs, one control input being effective when pneumatic pressure is applied thereto to change-over the valve in one direction and the other control input being effective when pneumatic pressure is applied thereto to change-over the valve in the other direction, a pneumatic pressure source connected to the input of said first change-over valve, a first pneumatic control circuit for said change-over valve, said first pneumatic control circuit including a pneumatic patient gas path having the inspiratory mode switches, each with its series selector switch in the respective gas flow paths connected in parallel to

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one control input of the change-over valve, pneumatic pressure supply means for said first pneumatic control circuit comprising a supply connection from one outlet of said change-over or from a source controlled by that outlet, a second pneumatic control circuit for said change-over valve, said second control circuit including the expiratory mode switches, each with its series selector switch, connected in parallel to the second control input of said change-over valve, pneumatic pressure means for said second pneumatic control circuit comprising a supply connection from the second outlet of the change-over valve or from a source controlled by that outlet, means applying pressure from said first and said second outlets of said change-over valve to the inspiratory and expiratory time mode pneumatic delays respectively to initiate operation of the respective time delays when the change-over valve changes over to provide pressure at its first and second outlets, respectively, and means applying pressure from the first and said second change-over valve outlets to said expiratory and said inspiratory control valves respectively or to switch means controlling the application of pressure to said inspiratory control valves.

3. The multi-mode respirator as claimed in claim 2 wherein said change-over valve comprises a cylinder having a main inlet and two outlets and a valve-change-

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over member including a shuttle member connected between two piston devices slidable within a cylinder, the shuttle member being arranged to move across said main inlet between the two outlets to connect the main inlet to one or other of the two outlets and wherein two venting outlets are provided in the cylinder and controlled by movement of the piston devices respectively.

4. The multi-mode respirator as claimed in claim 3 wherein each control inlet of the change-over valve device is connected through a non-return valve to a controlled vent to atmosphere.

5. The multi-mode respirator as claimed in claim 2 wherein there is provided a further change-over valve, the two outputs from the first change-over valve being applied to operate the second change-over valve which second change-over valve has two outlets connected to the pneumatic control operating inputs of the inspiration and expiration control valves respectively.

6. The multi-mode respirator as claimed in claim 5 wherein each said pneumatic delay includes a piston operated through a restricted orifice and wherein the appropriate output of the first change-over valve is fed to the time delay and wherein the outputs of the further change-over valve are connected to the appropriate switch devices to provide the flow therethrough.

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