

[54] **OXYGEN POWERED VOLUME CYCLED RESPIRATOR WITH OXYGEN AIR MIX**

[75] Inventor: **Lyndon S. Cox**, Silver Spring, Md.

[73] Assignee: **The United States of America as represented by the Secretary of the Army**, Washington, D.C.

[22] Filed: **July 26, 1972**

[21] Appl. No.: **275,373**

[52] U.S. Cl. **128/145.8, 137/815**

[51] Int. Cl. **A61m 16/00**

[58] Field of Search..... 128/145, 145.5, 145.6, 128/145.7, 145.8, 188; 137/805, 806, 807, 814, 825, 826, 830

[56] **References Cited**
UNITED STATES PATENTS

3,339,545	9/1967	Burchell.....	128/145.8
3,556,095	1/1971	Ismach.....	128/145.8
3,659,598	5/1972	Peters.....	128/145.8

3,730,180 5/1973 Davison 128/145.6

OTHER PUBLICATIONS

Automatic Ventilation of the Lungs by W. W. Mushin, et al., 1969, Chapter 54.

Automatic Ventilation of the Lungs by W. W. Mushin et al., 1969, Chapter 87.

Primary Examiner—Richard A. Gaudet

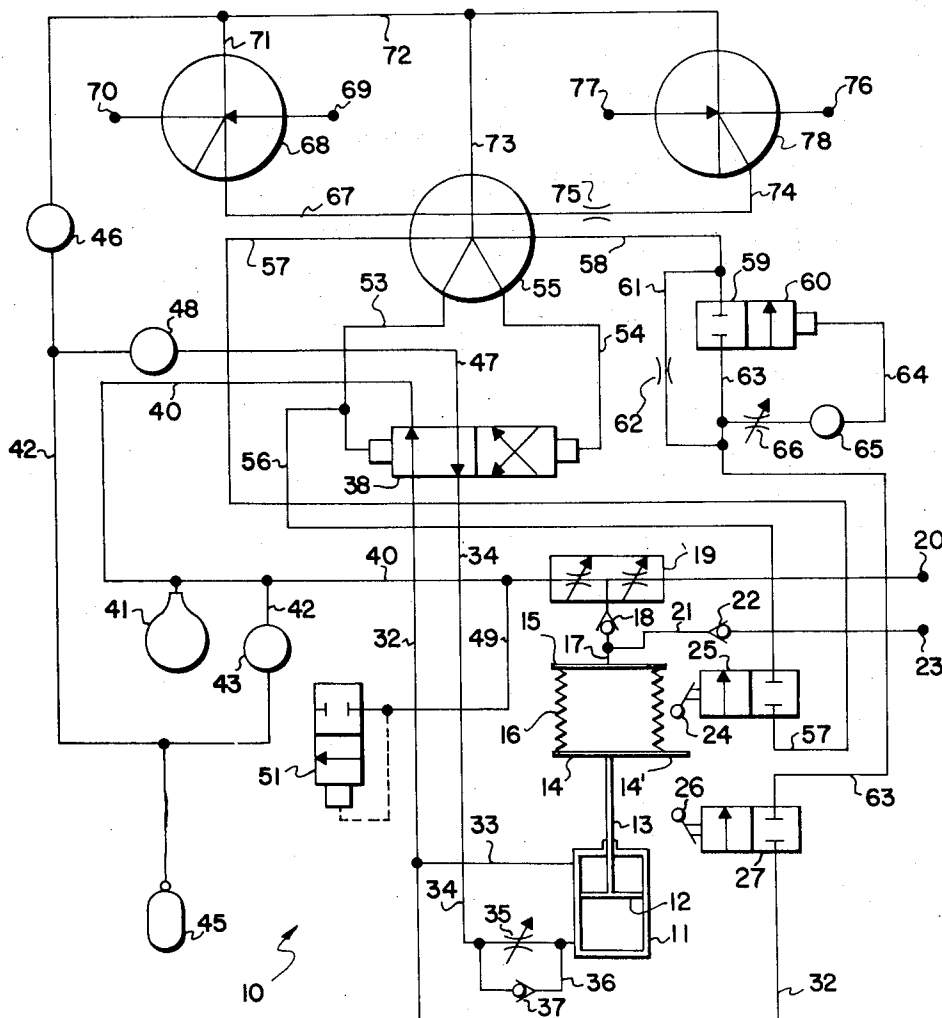
Assistant Examiner—G. F. Dunne

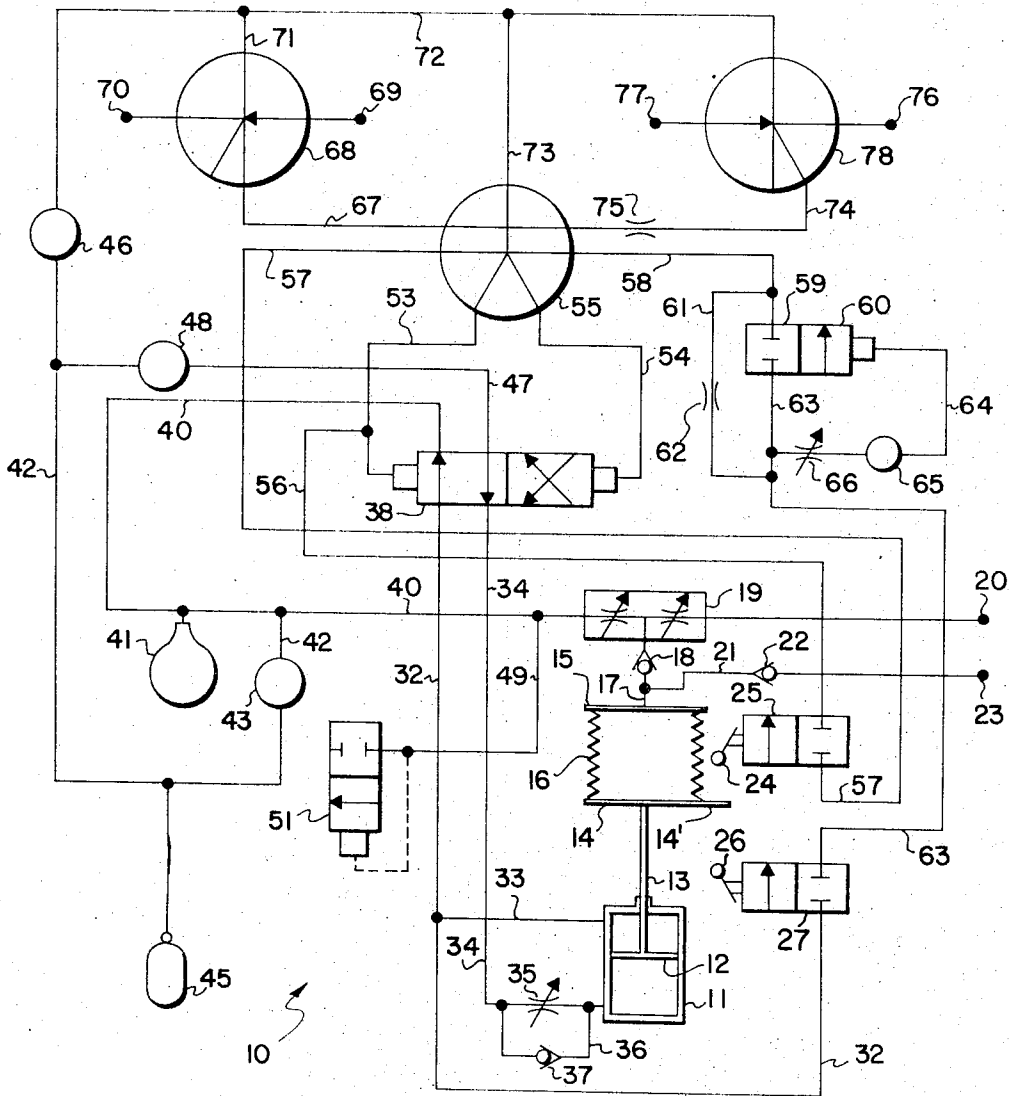
Attorney, Agent, or Firm—Saul Elbaum

[57] **ABSTRACT**

A solely oxygen-powered respirator using oxygen-powered controls and an oxygen-powered driving mechanism, the flueric controls cyclically controlling the driving mechanism through a four-way, two position interface valve. The flueric controls include over-pressure and inspiratory sensing at the patient to interrupt the basic volume cycle.

10 Claims, 1 Drawing Figure





OXYGEN POWERED VOLUME CYCLED RESPIRATOR WITH OXYGEN AIR MIX

The invention described herein may be manufactured, used and licensed by or for the United States Government for governmental purposes without the payment to me of any royalty thereon.

This invention relates to a unique volume cycled respirator which utilizes a conventional source of oxygen for both breathing gas and as an operating medium for its control system.

A basic innovation of the instant device is the use of oxygen-powered flueric devices to accomplish the control logic needed to run the system. The exhaust from these flueric controls, as well as the exhaust from the driving piston is utilized as part of the oxygen portion of the breathing gas for the patients. The system includes an assist mode in which flueric sensing of the pressure drop produced when the person starts to inhale triggers the controls to start pumping breathing gas to the patient, thereby reducing inspiratory effort.

Usually, the tidal volume delivered to the patient is determined by a device such as the bellows or piston with a controlled stroke. Therefore, the volume delivered to the patient is fixed and is delivered once inspiratory triggering occurs. The instant system utilizes such tidal volume control and in addition pressure sensing in which the pressure delivered to the patient is sensed. If this pressure exceeds a preset level, the delivery of breathing gas to the patient is halted. Such a feature is used for patient protection and safety but also pressure cycles the respirator.

The instant system also incorporates planned delay devices to control the rate at which the cycle repeats in the absence of inspiratory trigger signals.

The instant invention features the use of oxygen-powered flueric controls, an oxygen-powered driving mechanism, and the collection of exhaust from the oxygen-powered flueric driving mechanism for use in the breathing gas. This collected oxygen is available to an air-oxygen mixing valve which sets the mixture level to be supplied to the patient. It is shown that if all of the driving and control exhaust were collected and put into the breathing mixture, the enriched mixture could be substantially low in oxygen content, e.g. 30 percent. Air is 20 percent oxygen.

Additional oxygen is supplied by a demand valve to enrich it above this level, and exhaust oxygen can be spilled to the hospital room if a level lower than 30 percent is needed or desired.

The system utilizes a volume-cycle respirator in which a bellows is stroked to pump the breathing gas, the bellows being driven by a pneumatic cylinder.

Another basic feature of this invention is the use of interface valves operated by flueric amplifiers to control the oxygen flow to and from the driving cylinder. The use of such valves to control the operation reduces the total power requirement and in particular reduces the gas-flow requirement. The use of flueric amplifiers to drive the pistons directly would call for an excessive quantity of oxygen to be exhausted at all times.

The operation of the system from the oxygen supply requires a pressurized supply of oxygen. Directly or indirectly, this comes from a bottle of pressurized gas. The instant system utilizes the stored energy of compression in the gas to both power and control the deliv-

ery of the breathing gas and permits mixing to intermediate levels of oxygen in the breathing mixture.

The instant device then has the advantages of being able to be powered from a convenient oxygen wall receptacle and to be used in an ambulance with a pressurized bottle of oxygen. The reliability of the flueric controls is enhanced by the use of clean gas and the system has lower power requirements than existing apparatus.

Accordingly, it is an object of the present invention to provide a unique oxygen-powered respirator.

It is a further object of this invention to provide an oxygen-powered respirator having no power source other than pressurized oxygen.

It is another object of this invention to provide an oxygen-powered respirator utilizing flueric controls.

A still further object of this invention is to provide an oxygen-powered respirator incorporating Schmitt triggers, a fluid amplifier, and interface valves in its control system.

These and other objects of the invention will become apparent when reference is made to the accompanying specification and drawings in which:

FIG. 1 is a fluid schematic diagram of the basic control system and breathing gas supply system utilized in the instant respirator.

The system is designated generally as 10 and comprises an air cylinder 11 having a double-acting piston 12 to which is attached one end of a piston rod 13. The other end of rod 13 is attached to one of two plate portions 14 of a bellows 16. The other plate portion 15 is held stationary. The piston, through the admittance and exhaust of oxygen (O_2) through lines 33 and 34 operates the bellows. When the bellows 16 is compressed, it drives an air and oxygen mixture through line 21, check valve 22 to outlet 23. Any suitable arrangement of hose and mask can be connected to outlet 23, i.e., the mixed air and oxygen are provided to the patient through outlet 23.

When the piston 12 moves downwardly through the introduction of oxygen under pressure through line 33, it expands bellows 16, thus drawing air and oxygen through mixing valve 19 and check valve 18. The mixing valve 19 contains individual valves which are adjustable to control the percentages of oxygen and air.

Check valve 18 prevents the expended mixture from bellows 16 from re-entering the mixing valve 19 and the mixture flows out line 21, through check valve 22 to outlet 23.

The system, as described, is conventional. However, to control the operation of the bellows 16, the power source for moving piston 12 as well as the power for control of flow to cylinder 11 is provided by the oxygen supply itself, i.e., the energy stored by maintaining the oxygen under pressure is employed to operate the respirator itself. A separate source of energy, such as compressed air or other fluid power supply is not needed. To facilitate this, fluid amplifiers with small jets are used to reduce the flow and power dissipation associated with using fluid amplifier outputs to drive a piston. A much greater driving pressure is available via valves operated by the fluid amplifiers than from fluid amplifiers operated at the same input pressure, hence the driving piston can be smaller and total gas and power consumption is reduced.

Referring again to FIG. 1, the plate 14' of bellows 16 projects outwardly to engage a pair of excursion triggers, 24 and 26, at the upper and lower ends of its reciprocating movement respectively.

Triggers 24 and 26 are coupled to valves 25 and 27. Valves 25 and 27 provide outputs to control the operation of a fluid bistable amplifier 55 which controls the four way valve 38.

Valve 25 is connected, via lines 56 and 57, to one input of a fluoric four input bistable amplifier 55 and constitutes a circuit for ending the delivery cycle. The amplifier 55 delivers oxygen to operate a two-position four-way valve 38 whereby oxygen flows to line 34, adjustable flow restrictor 35 and to the chamber of cylinder 11 to force a delivery stroke of piston 12, thus causing the air and oxygen mixture within bellows 16 to be delivered to the patient via outlet 23.

Oxygen is supplied to four-way valve 38 through line 47 from oxygen supply 45, line 42, and regulator 48.

Valve 27 is connected to one input of fluid bistable amplifier 55 through line 63, a delay circuit and line 58. The delay circuit consists of valve 60, control line 64, adjustable flow restrictor 66, volume 65 and flow restrictor 62 in line 61. The delay circuit gives the patient a chance to exhale or rest before the next breath, and sets the pace of breathing when patient is unable to breathe for himself. The delay can be varied by adjusting restrictor 66, i.e., the time delay function of the circuit is adjustable. As stated, the line 58 connects the time delay circuit with bistable fluid amplifier 55 which is adapted to switch at the end of a refill.

The bistable fluid amplifier is also controlled by the pressure of the source of oxygen 45, line 42, regulator 46 through fluoric Schmitt triggers 68 and 78.

Trigger 68 functions to operate the bistable fluid amplifier 55 by reversing its output to end the delivery cycle. The trigger is connected, via 69, to a bias pressure setting, i.e., a predetermined allowable overpressure is set into connection 69. The input 70 of the trigger senses the pressure at the patient communicated by a tube from either output 23 or the mask on the patient, i.e., excess pressure to the patient triggers the apparatus to switch bistable amplifier 55 and start the refill cycle. Line 67 connects output of trigger 68 to input of bistable amplifier 55.

Schmitt trigger 78 is attached, via 77, to a bias or inspiratory predetermined setting. At 76, the trigger is connected to the patient for inspiratory sensing. A partial vacuum produced at 76 activates the trigger 78 which, in turn, via line 74 and flow restrictor 75, activates the bistable amplifier 55. Hence, it triggers delivery to the patient prior to the time of delay mechanism operation and assists the patient when he is ready to breathe.

Thus, either overpressure or the end of the delivery stroke will then switch the bistable amplifier, operating valve 38 and refilling the bellows.

The driving circuit consists of supply 45, lines 42, regulator 48, valve 38 and lines 32 and 34. While the oxygen under pressure in line 32 is driving piston 12 in a downward direction, oxygen is being exhausted via line 34 and directed by valve 38 into line 40 where it will be drawn into bellows 16 via the mixing valve 19 and check valve 18. A relief valve 51 is connected via line 49 to line 40 to prevent excessive pressure in line 40.

Bladder 41 serves as a temporary storage medium to avoid pressure rise when oxygen is stored in line 40. If insufficient oxygen is available from cylinder 11, the required flow is supplied via regulator 43 and line 42.

Piston 12 in air cylinder 11 is driven, during the delivery stroke, by oxygen supplied through regulator 48, line 47, valve 38 and line 34. A rate of delivery adjustment is provided by an adjustable flow restrictor 35. Bypass line 36 and check valve 37 are provided for rapid refill of bellows 16. Restrictor 35 controls the rate of delivery of the oxygen and air mixture to the patient. During the delivery stroke, oxygen is exhausted via lines 33 and 32, valve 38 and line 40 to supply oxygen to the mixing valve 19.

The fluoric bistable amplifier 55 is a four-input device which is thus made to respond to overpressure and partial vacuum at the patient and to the end of the delivery stroke and, after a delay, at the end of the refill stroke.

Thus, it can be seen that one basic feature of this invention is the use of oxygen-powered fluoric controls to accomplish the control logic of the system.

The pressure in the patient circuit operates one of the Schmitt triggers 68 and 78 which drives the bistable amplifier 55. The amplifier, in turn, operates valve 38 which determines in which direction piston 12 is driven. Output from the inspiratory trigger 78 causes the valve 38 to drive the bellows 16 to produce outflow to the patient. Either overpressure or the end of the delivery stroke will then switch the bistable amplifier 55, reversing the valve 38 and refilling the bellows 16 via oxygenair mixing valve 19. Upon reaching the end of the refill stroke, the oxygen flow to cylinder 11 can be stopped by using a four-way, three-position blocked center valve instead of the four-way, two-position valve 38. This, of course, would require two fluoric amplifiers or flip-flops 55. In any event, with oxygen flow through valve 38 and line 32, the bellows 16 is refilled until the excursion trigger 26 then starts the time delay. Upon completion of the delay by components 60, 61, 62, 63, 64, 65 and 66, the valve 60 sends flow to operate bistable amplifier 55 and initiates the next cycle. If the inspiratory trigger 78 precedes the completion of the delay, the cycle is restarted. If trigger 78 is switched to line 74, the flow can switch bistable amplifier 55 by itself. By placing suitably selected restrictors, such as 75, on bistable amplifier inputs, both the end of refill and the patient inspiratory signals can be required together, preventing restart of the cycle before the end of the time delay.

While only one embodiment of the invention has been shown and described, it is obvious that many changes and modifications may be made by those of ordinary skill in the art without departing from the scope of the appended claims.

What is claimed is:

1. An oxygen-powered respirator utilizing only pressurized oxygen as its power source, said respirator comprising:

- a. means for supplying oxygen to power said respirator and mixing a predetermined percentage of said oxygen with air to form breathing gas;
- b. delivery means having a delivery stroke and a refill stroke for supplying a predetermined amount of said breathing gas to a patient; and

- c. control means operatively associated with said pressurized oxygen power source and said delivery means and adapted to cyclically and reciprocally stroke said delivery means to provide said breathing gas to a patient during alternate predetermined periods of an inspiratory cycle, said control means comprising:
1. fluid amplifier means and interface valve means, said fluid amplifier means being operatively associated with and controlled in whole or in part by said delivery means and adapted to activate said interface valve means to reciprocally stroke said delivery means;
 2. first Schmitt trigger means adapted to control said fluid amplifier means together with said delivery means, said first Schmitt trigger means including means for receiving a predetermined allowable overpressure setting, means for sensing the pressure of said breathing gas at the patient, and means for providing a first output signal whenever said sensed pressure at the patient exceeds said predetermined allowable pressure setting, said first output signal causing said fluid amplifier means to activate said interface valve means to interrupt the delivery stroke and to commence the refill stroke of said delivery means; and
 3. second Schmitt trigger means adapted to control said fluid amplifier means together with said delivery means and said first Schmitt trigger means, said second Schmitt trigger means including means for receiving a predetermined inspiratory pressure setting, means for sensing the inspiratory pressure of said breathing gas at the patient and means for providing a second output signal whenever said sensed inspiratory pressure drops below said predetermined inspiratory pressure setting, said second output signal causing said fluid amplifier means to activate said interface valve means to interrupt the refill stroke and to commence the delivery stroke of said delivery means.
2. A respirator as in claim 1 wherein said interface valve means is a four-way, two position valve.
 3. a respirator as in claim 1 wherein said control

means additionally includes a time delay means which causes said fluid amplifier to pause a predetermined amount of time before activating said interface valve means to cause a delivery stroke at the conclusion of said refill stroke, said second trigger means adapted to override said delay upon sensing inspiration at the patient.

4. A respirator as in claim 1 including a relief valve means associated with said oxygen supply means and adapted to prevent a pressure build-up beyond a predetermined amount.

5. a respirator as in claim 4 and including a bladder means for the temporary storage of oxygen.

6. A respirator as in claim 1 wherein said delivery means includes a bellows in communication with said mixing means, check valve means adapted to admit said breathing gas mixture into said bellows upon said refill stroke and deliver it to a patient during said delivery stroke.

7. A respirator as in claim 6 wherein said delivery means additionally includes a double acting cylinder and piston means, said piston means being operatively connected to said bellows, said interface valve means adapted to provide pressurized oxygen to said double acting cylinder means to power said piston means and said bellows in alternative delivery and refill strokes.

8. A respirator as in claim 1 and including a pair of excursion trigger means associated with said delivery means and adapted to cause said control means to cause said delivery means to change from a refill stroke to a delivery stroke at the end of said refill stroke and vice-versa.

9. A respirator as in claim 1 wherein said fluid amplifier means has four input signal receiving means for receiving said first and second output signals from said first and second Schmitt trigger means and for receiving two signals from said delivery means indicative of the commencement and termination of the delivery stroke.

10. A respirator as in claim 1 wherein said first and second Schmitt triggers are directly connected to said fluid amplifier so that said first and second output signals are delivered directly to said fluid amplifier.

* * * * *

50

55

60

65