Aug. 27, 1963 K. R. PERRY ETAL 3,101,708

ELECTRONIC TIME CYCLED RESPIRATOR

Filed Feb. 1, 1960 2 Sheets-Sheet 1

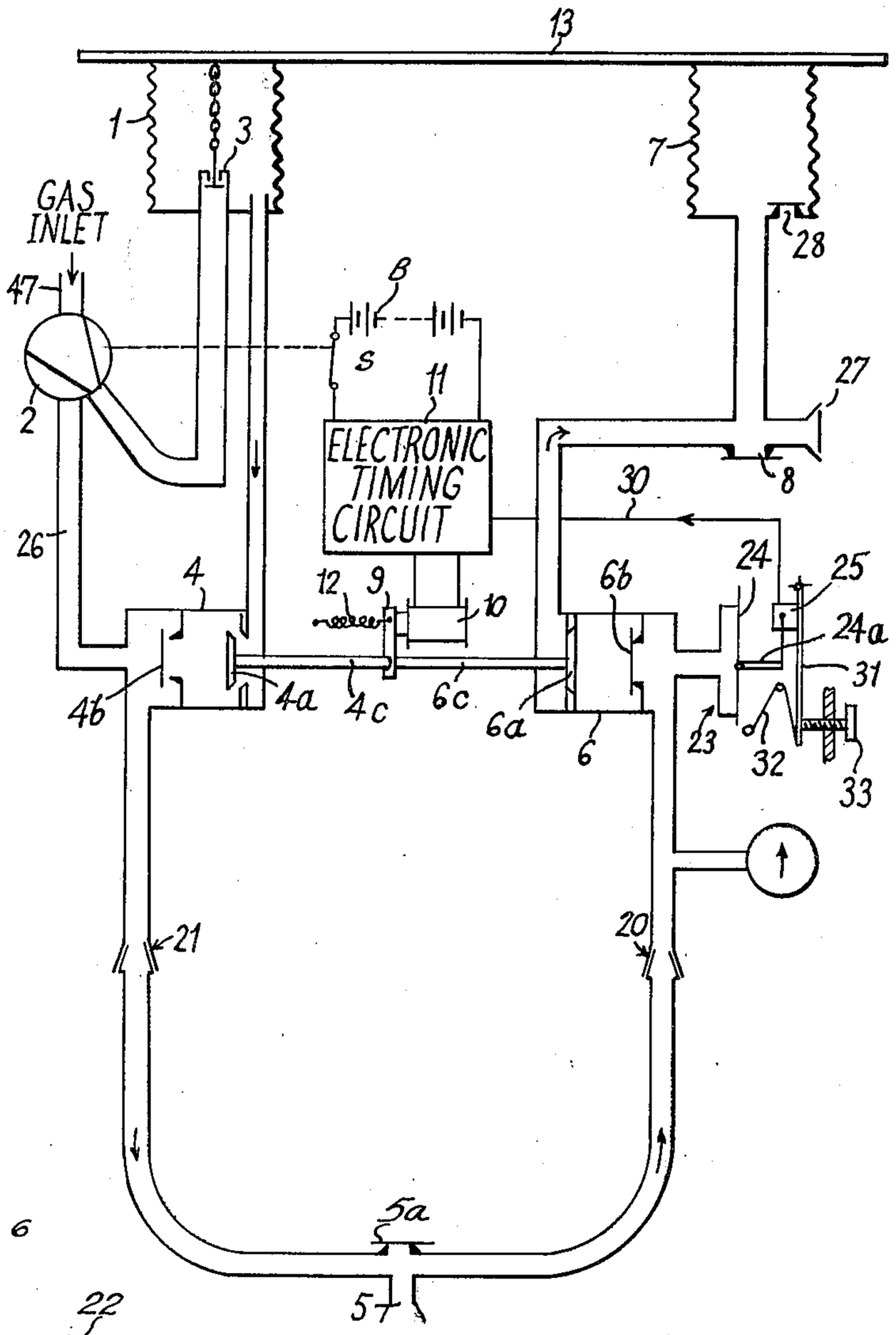


Fig.1

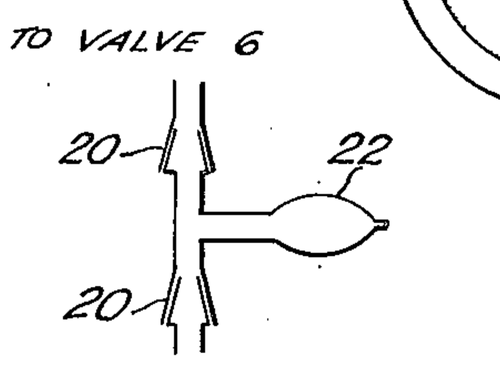


Fig.1A

Inventors
K. R. Perry
M. C. W. Andrews
By
Holcomb, Wetherill & Brisebois
Attorneys

Aug. 27, 1963 K. R. PERRY ETAL 3,101,708

ELECTRONIC TIME CYCLED RESPIRATOR

Filed Feb. 1, 1960 2 Sheets-Sheet 2

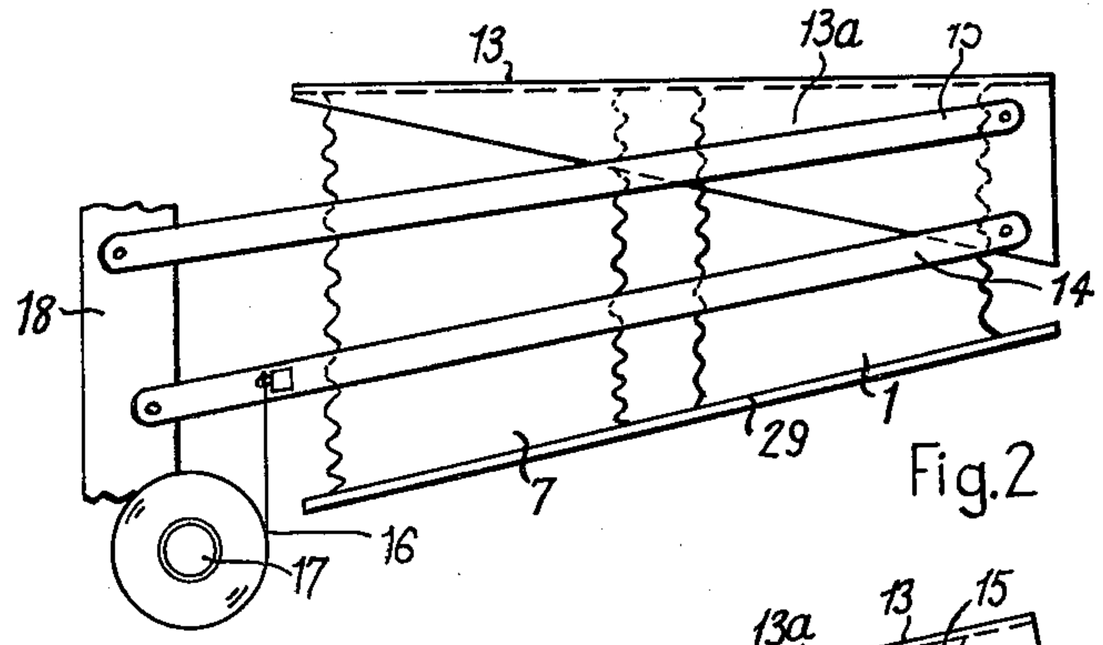


Fig.2

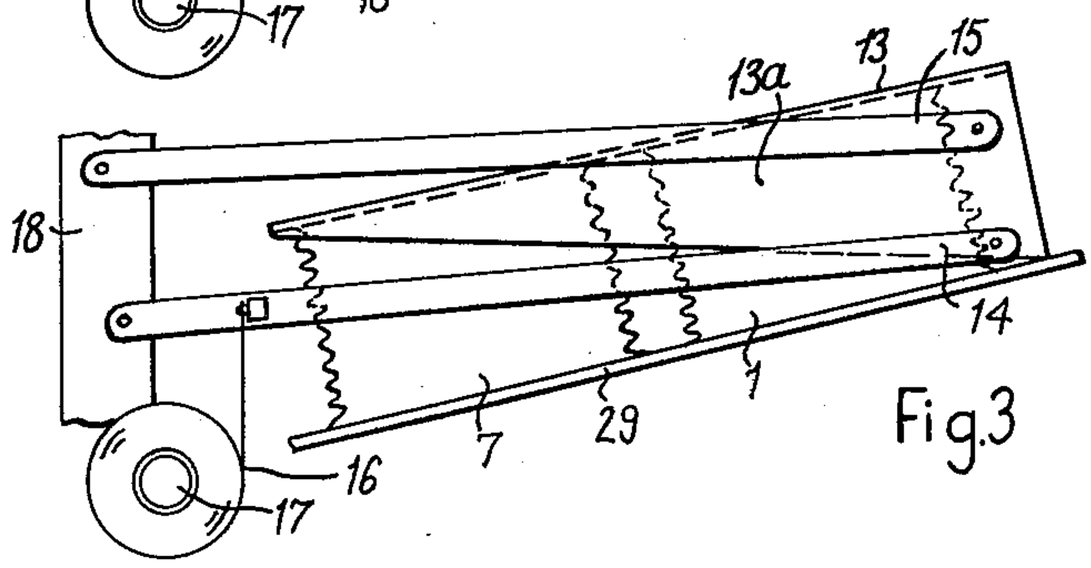
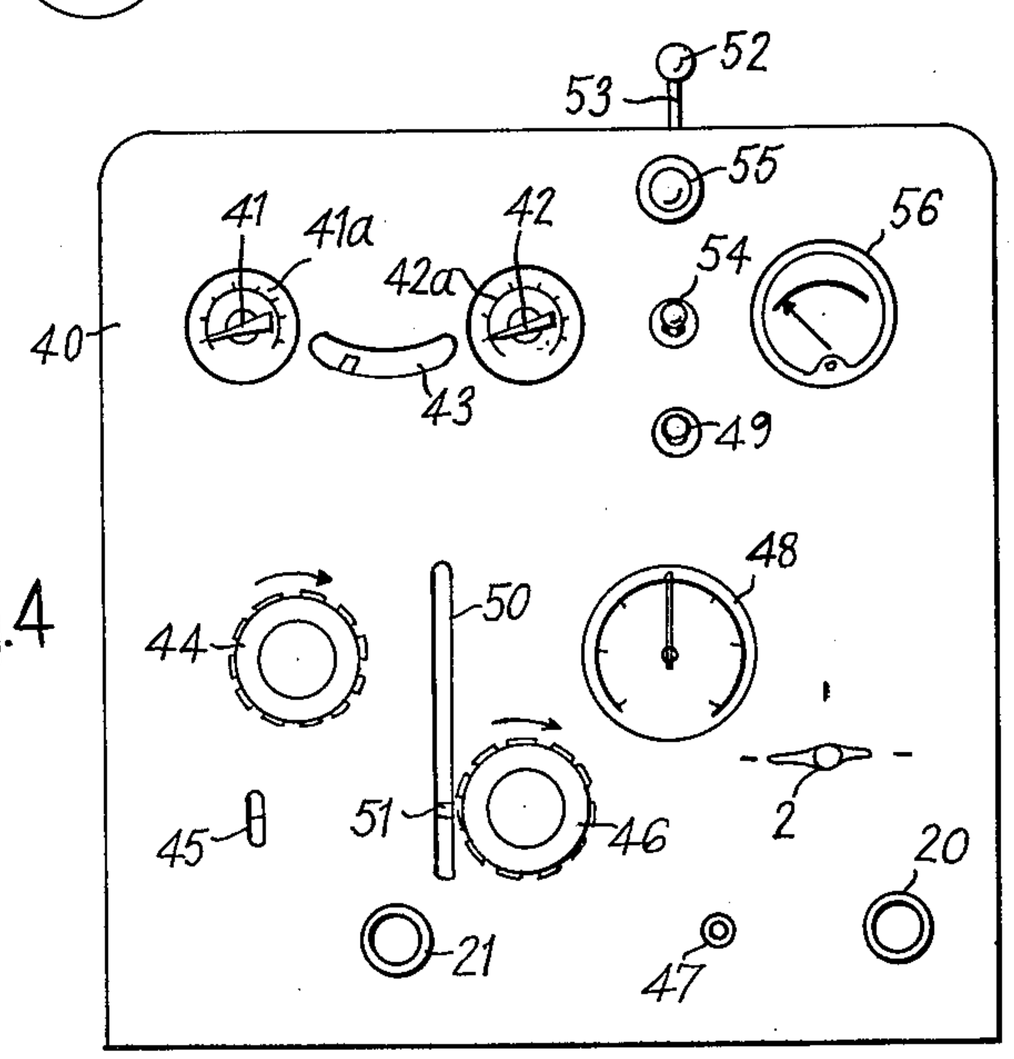


Fig.3

Fig.4



Inventors
K. R. Perry
M. C. W. Andrews
By Holcomb, Wetherill & Brisebois
Attorneys

United States Patent Office

3,101,708

Patented Aug. 27, 1963

3,101,708
ELECTRONIC TIME CYCLED RESPIRATOR

Kenneth R. Perry and Michael C. W. Andrews, Cambridge, England, assignors to Pye Limited, Cambridge, England, a company of Great Britain

Filed Feb. 1, 1960, Ser. No. 5,893
Claims priority, application Great Britain Feb. 6, 1959
16 Claims. (Cl. 128—29)

The present invention relates to an electronic timed cycled respirator for use in anesthesia and in the treatment of respiratory insufficiency.

Such a device basically consists of a gas circuit to which anesthetic or other gas is fed and includes electrically-operated valves controlling the inspiratory and expiratory periods of respiration, the operation of these valves being controlled by an electronic timing circuit, for example a form of multivibrator circuit.

From one aspect, the present invention provides an electronic time cycled respirator in which the inspiratory control valve and the expiratory control valve are actuated by a single electrically-operated device in combination with spring means arranged to urge the valves to the position in which the inspiratory control valve is open and the expiratory control valve is closed when the device is not energised, or should the power supply to the equipment fail. The electrically-operated device may be a solenoid connected to actuate the control valves. Preferably these valves both consist of a poppet valve controlled by the solenoid or other device in combination with a non-return valve which prevents gas flow in the reverse direction through the valve.

According to a feature of the invention the gas supply, fed for example from a Boyle's or similar machine, or direct from a cylinder, is fed through an inspiratory bellows to the inspiratory control valve and from thence to a face mask or other means for supplying the gas to a patient, the gases exhaled by the patient flowing through the expiratory control valve and an expiratory bellows to the gas outlet. The inspiratory bellows and expiratory bellows are connected to a control plate arrangement on which operates spring means providing the force to return the bellows to the collapsed position when necessary, means being provided for adjusting the pressure of the spring means. Two separate springs may be provided, the tension of both springs being adjustable simultaneously by a common tension control.

Means may be provided for changing over from automatic to manual operation including means for rendering the inspiratory bellows ineffective. Said means may consist of a changeover cock or valve which can be turned to a position in which the inspiratory bellows and inspiratory control valve are by-passed and the gas is fed direct to the face mask or the like. A manual control bag can be connected at a suitable point in the gas circuit to enable manual control of respiration to be effected. If the inspiratory bellows are rendered ineffective more sensitive manual control can be achieved.

If desired interlocking means can be provided in conjunction with the changeover valve and which operate upon moving the valve to the manual operation position to cut off the power supply to the apparatus, or at least de-energise the electrically-operated device controlling the inspiratory and expiratory control valves. Such interlocking means may also be arranged automatically to open a valve or port to which the manual control bag is connected. Alternatively this valve or port can be arranged so that it opens automatically upon connection of the bag thereto.

From another aspect, the invention provides an electronic time cycled respirator including a trigger mechanism connected in the circuit through which pass gases exhaled by a patient and which operates should a patient connected to the respirator try to inspire during the expiratory period of the time cycle to change the electronic timing circuit to the inspiration part of the cycle and means for adjusting the trigger device to alter the pressure value at which it becomes operative. Trigger mechanism may comprise a diaphragm which is sensitive to pressure changes and movement of which controls the operation of a microswitch which in turn controls the electronic timing circuit and means for adjusting the position of the microswitch relative to the diaphragm and hence altering the pressure value at which the trigger mechanism becomes operative.

From yet another aspect, the invention provides means for producing a negative pressure phase in the operation of the machine, said means comprising expiratory bellows, the stroke of which is made of sufficient length to provide the negative pressure desired, in combination with a variable orifice for adjusting the negative pressure between desired limits. Preferably a safety valve is also provided which allows air to enter if the negative pressure exceeds a certain desired value so as to avoid the possibility of excessive negative pressure being developed.

In order that the invention may be more fully understood reference will now be made to the accompanying drawings, in which:

FIGURE 1 is a diaphragm of one embodiment of an electronic time cycled respirator according to the invention.

FIGURE 1*a* is a fragmentary view of a modification to FIGURE 1.

FIGURE 2 is a diagram illustrating the mounting arrangement for the bellows showing them in the expanded condition.

FIGURE 3 is a similar diagram to FIGURE 2, showing the bellows in the collapsed condition, and

FIGURE 4 is a front view of one embodiment of apparatus.

Referring to the drawings, and in particular to FIGURE 1, gas from a Boyle's or similar machine, or a cylinder or pump, is fed to the inspiratory bellows **1** through a changeover valve **2** and a further valve **3** preventing over expansion of the bellows, and passes from the bellows to an inspiratory control valve **4** consisting of a poppet-type valve **4***a* and a non-return valve **4***b* and from thence to a face mask **5**, or other means for feeding the gas to the patient. The exhaled gas is fed from the face mask to the expiratory control valve **6** which is generally similar to the inspiratory control valve and consists of a poppet valve **6***a* and a non-return valve **6***b*. The output from the expiratory control valve is fed to the expiratory bellows **7** and to the non-return outlet valve **8**. The stems **4***c* and **6***c* of the two poppet valves are connected to the armature **9** of a solenoid **10** which itself is energised from the electronic timing circuit **11** which may be a free-running multivibrator, preferably employing transistors. The time cycle of the multivibrator **11** controls the time for which the solenoid **10** is energised and de-energised and hence the duration of the inspiratory period and the expiratory period of the respiration cycle. Thus when one part of the multivibrator is in the conducting state, the solenoid is energised and when the other part of the multivibrator is in the conducting state the solenoid is de-energised. The period for which each part of the multivibrator is conducting is determined by time constants of the circuit as is well known in the electronic art. The solenoid operates against the pull of a spring **12** and the arrangement is such that energisation of the solenoid allows the inspiratory control valve **4** to close and opens the expiratory control valve **6** and when the solenoid is de-energised this latter valve is allowed to close and the

inspiratory control valve 4 is opened, as shown in FIGURE 1. The spring 12 thus tends to restore the solenoid 10 to the de-energised position which ensures that the inspiratory control valve is left open in the event of any failure of the power supply to the equipment. Each of the poppet valves 4*a* and 6*a* includes a return spring (not shown) to close the valve. These return springs are overridden by the action of the solenoid 10 and spring 12. The connection between the solenoid armature and the poppet valves is such as to allow a slight free movement of each valve so that one can close before the other opens but securely holds the inspiratory valve closed when the solenoid is energised.

A volumeter and a manual control bag can be inserted in the circuit at connection 20, as will hereinafter be described.

As shown in FIGURES 2 and 3, the inspiratory bellows 1 and expiratory bellows 7 are connected to a common control plate 13 pivotally connected to the chassis or frame 18 of the apparatus by a pair of arms 14 and 15 at each end of the plate, only the pair of arms at one end being shown in the drawings. The other end of the bellows are attached to a fixed plate 29. The pairs of arms are each pivotally attached at one end to the frame 18 and at the other end to a flange 13*a* on the plate. A coil spring 16 is associated with each arm 14, one end of the spring being attached to the arm and the spring acting to urge the bellows to the contracted condition. A single tension control having a spindle 17 to which the other end of the springs are connected is provided for adjusting the pressure applied by the two springs simultaneously, by rotation of the spindle. FIGURE 2 shows the arrangement with the bellows in the expanded position and FIGURE 3 shows the arrangement of the bellows in the contracted position.

Associated with the expiratory control valve is a trigger arrangement 23 including a diaphragm 24 which is very sensitive to pressure changes and which is connected by an arm 24*a* to a microswitch 25 which is capable of controlling the electronic timing circuit 11 through connection 30. With this arrangement, should a patient attempt to inspire during the expiratory period of the time cycle, the changing pressure on the diaphragm 24 immediately closes the microswitch 25 which switches out of circuit a resistor forming part of one of the time constants in the multivibrator constituting the electronic timing circuit thereby causing the multivibrator to change its state to the inspiration part of the cyle, i.e. to the state in which the solenoid is de-energised and the inspiratory control valve is open. The microswitch 25 is pivotally mounted on a lever 31 which is urged away from the diaphragm by the spring 32. A set screw 33 bears against the end of the lever and adjustment of this controls the relative position of microswitch with respect to the diaphragm. When the screw 33 is unscrewed the spring 32 can push the lever 31 and hence move the microswitch 25 further from the diaphragm, and increase the sensitivity of the trigger mechanism. Movement in the reverse direction decreases the sensitivity of the trigger mechanism. A calibrated scale may be provided to enable the mechanism to be adjusted to a desired sensitivity.

If it is desired to operate the machine manually, the changeover valve 2 is turned to the position in which it bypasses the inspiratory bellows 1 and control valve 4 so that gas is fed directly to the face mask through bypass channel 26. The insertion of a manual control bag 22 into the circuit at connection 20, as shown in the modification of FIGURE 1*a*, enables manual control to be effected. The action of turning the changeover valve 2 may also operate the switch S to switch off the power supply to the apparatus or de-energise the solenoid. Thus, for manual operation the inspiratory contral valve 4 is permanently open and the expiratory control valve 6 is permanently closed. Squeezing of the control bag 22 will force gas into a patient's lungs to assist inspiration and during expiration the control bag is allowed to distend. The exhaled gas is vented through the outlet valve 5*a* on the face mask 5. The connections 20 and 21 constitute the inspiratory port and expiratory port respectively and allow for the face mask 5 or the like and its connecting tubes to be attached to the apparatus.

A negative phase can be produced with the apparatus by means of the expiratory bellows 7. As can be seen from a comparison of FIGURES 2 and 3, the expiratory bellows 7 expand to a greater extent than the inspiratory bellows 1, when the bellows 1 and 7 move together from the collapsed position (FIGURE 3) to the expanded position (FIGURE 2) under the control of the movement of the common control plate 13. Thus the expiratory bellows attempt to withdraw more gas as they expand than was admitted during the previous inspiratory period so generating a negative pressure. A variable orifice 27 is provided for adjusting the negative pressure between desired limits for example between zero and ten centimetres of water pressure. A safety valve 28 is also provided in the bellows 7 which is set at the desired maximum negative pressure, for example 8 centimetres of water pressure and allows air to enter if this pressure is exceeded, to ensure that there is no possibility of excessive negative pressure being developed. Moreover, if only a single bellows is provided as hitherto, gas is pumped into the patient and is forced out of the patient's lungs purely by the contraction of the chest muscles. By adding a second bellows according to the present invention to give a negative cycle, the gas is drawn from the patient's lungs during the negative phase by the expiratory bellows 7. This could have a deleterious effect on the cardio-vascular system, but with the provision of the variable orifice 27 and the safety valve 28 this danger is avoided. When the orifice is fully open there will be no effective negative phase at the face mask, but as it is closed the negative phase will become more and more effective.

Thus the function of the inspiratory bellows 1 is to control the supply of gas, and the stale gas is passed to atmosphere at intervals by the expiratory control valve 6. By fitting the bellows 7 and arranging a controllable negative phase it is possible to assist the patient's expiration and always ensure that the patient does not inspire stale gas. The extra length stroke of the bellows 7 is adapted to maintain the slight negative pressure at the end of the stroke and wihout this feature the pressure equalises before expiration is complete.

The power supply to the apparatus consists of a bank of batteries B to supply the electronic timing circuit and solenoid, rendering the machine portable and suitable for use on journeys. A mains supply is only necessary to charge the batteries. Alternatively the apparatus may be constructed to operate primarily from the mains supply, and should this fail during use of the apparatus, a bank of batteries automatically keeps the apparatus functioning without any interruption. The apparatus is designed to be intrinsically safe to permit the use of explosive anesthetic or in an explosive atmosphere. The machine can also be used to control a closed circuit type of system for anesthetic, if desired.

Referring now to FIGURE 4, the apparatus is housed within a casing having a front panel 40. The controls 41 and 42 adjust the timing of the electronic timing circuit 11 and hence the duration of the inspiratory period and of the expiratory period. These controls are provided with scales 41*a* and 42*a* which may be calibrated in seconds. 43 is an indicator for indicating the number of respirations per minute. This control and indicating arrangement may be constructed as described in our co-pending application No. 5,762, filed February 1, 1960, now Patent No. 3,072,327. The knob 44 controls the positive pressure and operates the common spindle 17 and hence varies the pressure of the springs 16 acting on the bellows. 45 is an indicator for giving an approximate indication of the pressure applied by the knob 44.

The knob **46** adjusts the orifice **27** and hence the amount of negative pressure. The inspiratory port and expiratory port for attaching the face mask or the like to the apparatus are shown respectively at **20** and **21**. The gas inlet is shown at **47** above which is located the changeover valve **2** for changing between automatic and manual operation. **48** is a pressure gauge calibrated in centimetres of water which is located adjacent the inspiratory port. Switch **49** is provided for rendering the trigger mechanism operative or non-operative to control the electronic timing circuit **11**. Behind the slot **50** is arranged an indicator **51** attached to the bellows mechanism to indicate the rise and fall of the bellows, this is also indicated by the knob **52** projecting from the top of the casing of the apparatus and carried by the rod **53** mounted on the plate **13**. This latter indicator **52** can be readily observed when the apparatus is in use in a hospital ward by any person on duty in the ward and avoids the necessity of closely approaching the apparatus to observe the indicator **51** which is primarily intended for use by anesthetist. A switch controlling the electrical and electronic circuits is shown at **54** together with an indicator light **55**, whilst a voltmeter is provided at **56** for monitoring the voltage of the battery from which the apparatus operates.

Besides its use in anesthesia, the respirator according to the invention may advantageously be employed in the treatment of patients suffering from poliomyelitis and other forms of respiratory deficiency. When used for treating a respiratory deficiency, the respirator is supplied from a simple air pump and in this case a flow meter should be included in the circuit as the volume of air is dependent upon a consistent flow.

Whilst a particular embodiment has been described, it will be understood that various modifications may be made without departing from the scope of this invention.

We claim:

1. An electronic time cycled respirator comprising an inspiratory control valve, an inspiratory bellows, means for feeding gas to the inspiratory bellows and from said inspiratory bellows to the inspiratory control valve, means for feeding gas from the inspiratory control valve to be inhaled by a patient, an expiratory control valve, an expiratory bellows, means for feeding gas exhaled by a patient through the expiratory control valve to the expiratory bellows, means for feeding gas from the expiratory bellows to a gas outlet, an electrically-operated device connected to operate said inspiratory control valve and said expiratory control valve, an electronic timing circuit for controlling the energisation of said electrically-operated device so that energisation of said electrically-operated device acts to close said inspiratory control valve and open said expiratory control valve, means operative to close said expiratory control valve and open said inspiratory control valve when said electrically-operated device is not energised, means for operating said respirator manually when the timing circuit is inoperative and means for rendering the inspiratory bellows ineffective during manual operation.

2. A respirator as claimed in claim 1, in which the means for rendering the inspiratory bellows ineffective during manual operation comprises a changeover valve which can be turned to a position in which the inspiratory bellows and inspiratory control valve are bypassed and the gas is fed direct to a patient, and the means for operating the respirator manually comprises a manual control bag inserted in the gas circuit.

3. A respirator as claimed in claim 2, including means interlocked with operation of the changeover valve to render the electrically-operated device inoperative.

4. An electronic time cycled respirator comprising an inspiratory control valve, an inspiratory bellows, means for feeding gas to the inspiratory bellows and from the inspiratory bellows to the inspiratory control valve, means for feeding gas fom the inspiratory control valve to be

inhaled by a patient, an expiratory control valve, an expiratory bellows, means for feeding gas exhaled by a patient through the expiratory control valve to the expiratory bellows, means for feeding gas from the expiratory bellows to a gas outlet, means connecting said inspiratory bellows and said expiratory bellows between two plate members, pivoted arm members for moving one of said plate members relative to the other plate member and spring means operating on said movable plate member to return the bellows to the collapsed position, an electrically-operated device connected to operate said inspiratory control valve and said expiratory control valve, an electronic timing circuit for controlling the energisation of said electrically-operated device so that energisation of said electrically-operated device acts to close said inspiratory control valve and open said expiratory control valve, and means operative to close said expiratory control valve and open said inspiratory control valve when said electrically-operated device is not energised.

5. A respirator as claimed in claim 4, in which means are provided for adjusting the pressure of the spring means.

6. An electronic time cycled respiratory comprising an inspiratory control valve, an inspiratory bellows, means for feeding gas to the inspiratory bellows and from the inspiratory bellows to the inspiratory control valve, means for feeding gas from the inspiratory control valve to be inhaled by a patient, an expiratory control valve, an expiratory bellows, means for feeding gas exhaled by a patient through the expiratory control valve to the expiratory bellows, means for feeding gas from the expiratory bellows to a gas outlet, means interconnecting said inspiratory bellows and said expiratory bellows so that they expand and contract together, an electrically-operated device connected to operate said inspiratory control valve and said expiratory control valve, an electronic timing circuit for controlling the energisation of said electrically-operated device so that energisation of said electrically-operated device acts to close said inspiratory control valve and open said expiratory control valve, means operative to close said expiratory control valve and open said inspiratory control valve when said electrically-operated device is not energised and a trigger mechanism connected in the circuit through which pass gases exhaled by a patient and which operates should a patient connected to the respirator try to inspire during the expiratory period of the time cycle to change the electronic timing circuit to the inspiration part of its cycle and thereby de-energise the electrically-operated device and open said inspiratory control valve.

7. A respirator as claimed in claim 6, including means for adjusting the trigger mechanism to alter the pressure value at which it becomes operative.

8. A respirator as claimed in claim 7, in which the trigger mechanism comprises a diaphragm which is sensitive to pressure changes and movement of which controls the operation of a microswitch which in turn controls the electronic timing circuit, and means for adjusting the position of the microswitch relative to the diaphragm and hence for altering the pressure value at which the trigger mechanism becomes operative.

9. An electronic time cycled respirator comprising an inspiratory control valve, an inspiratory bellows, means for feeding gas to the inspiratory bellows and from the inspiratory bellows to the inspiratory control valve, means for feeding gas from the inspiratory control valve to be inhaled by a patient, an expiratory control valve, an expiratory bellows, means for feeding gas exhaled by a patient through the expiratory control valve to the expiratory bellows means for feeding a gas from the expiratory bellows to a gas outlet, and electrically-operated device connected to operate said inspiratory control valve and said expiratory control valve, an electronic timing circuit for controlling the energisation of said electrically-

operated device so that energisation of said electrically-operated device acts to close said inspiratory control valve and open said expiratory control valve, means operative to close said expiratory control valve and open said inspiratory control valve when said electrically-operated device is not energised and said expiratory bellows having a stroke which is of sufficient length to provide a negative pressure and means for adjusting the negative pressure produced by the expansion of said expiratory bellows.

10. A respirator as claimed in claim 9, including a safety valve connected to the expiratory bellows which allows air to enter if the negative pressure exceeds a certain desired value thereby avoiding the possibility of excessive negative pressure being developed.

11. An electronic time cycled respirator comprising inspiratory bellows, expiratory bellows, means interconnecting said inspiratory bellows and said expiratory bellows so that they expand and contract together, spring means urging both said bellows to the contracted position, means for feeding gas to said inspiratory bellows during an expiratory period of said respirator cycle, an inspiratory control valve, means for feeding gas from the inspiratory bellows to the inspiratory control valve, a connection for feeding gas from the inspiratory control valve to a patient during an inspiratory period of said respirator cycle, an expiratory control valve, a connection for feeding gas from the patient to the expiratory control valve and from said expiratory control valve to the expiratory bellows during the expiratory period of said respirator cycle, a non-return outlet valve permitting gas to escape from said expiratory bellows during said inspiratory period of said respirator cycle, an electrically-operated device connected to operate said inspiratory control valve and said expiratory control valve, an electronic timing circuit defining said inspiratory periods and said expiratory periods and controlling the energisation of said electrically-operated device such that energisation of said electrically-operated device acts to close said inspiratory control valve and open said expiratory control valve, means operative

to close said expiratory control valve and open said inspiratory control valve when said electrically-operated device is not energised and pressure sensitive switch means connected to said expiratory control valve to control said timing circuit so as to terminate an expiratory period and initiate an inspiratory period if a patient connected to the respirator tries to inspire during said expiratory period.

12. A respiratory as claimed in claim 11, in which said inspiratory bellows and said expiratory bellows are connected between two plate members, pivoted link members for moving one of said plate members relative to the other plate member and arranged so that upon movement of said one plate member away from said other plate member said expiratory bellows expands more than said inspiratory bellows.

13. A respirator as claimed in claim 11, in which means are provided for adjusting the pressure of said spring means.

14. A respirator as claimed in claim 11, in which said electrically-operated device comprises a solenoid connected to operate said inspiratory control valve and said expiratory control valve.

15. A respirator as claimed in claim 11, including means for adjusting the pressure sensitive switch means so as to alter the point at which it becomes operative.

16. A respirator as claimed in claim 11, in which the pressure sensitive switch means comprises a diaphragm sensitive to pressure changes and a microswitch controlled by movement of said diaphragm and which in turn controls the electronic timing circuit.

References Cited in the file of this patent

UNITED STATES PATENTS

2,288,436	Cahan	June 30, 1942
2,391,877	Cahan	Jan. 1, 1946
2,593,774	Loredo	Apr. 22, 1952
2,907,322	Hay	Oct. 6, 1959
2,972,345	Spigel	Feb. 21, 1961