United States Patent [19]

Cavallo

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[54] **CONTROL DEVICE FOR A RESPIRATORY APPARATUS**

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[52] **U.S. Cl.** **128/145.8,** 128/145.5

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

[58] **Field of Search** ..... 128/145.8, 146.3, 146.4, 128/146.5, 145.5, 142.2, 142.3, 420, 424, DIG. 17; 137/624.14, 487.5

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Assistant Examiner—Henry J. Recla
Attorney, Agent, or Firm—Karl F. Ross; Herbert Dubno

[57] **ABSTRACT**

Respiratory apparatus having an electromagnetically operated valve for controlling the flow of respirable gas from a source thereof to a mouthpiece has a control arrangement for opening and shutting the valve in accordance with pressure changes appearing during periods of inhalation and exhalation by a patient using the apparatus. Alternatively, the valve can be opened and shut according to a predetermined cycle.

10 Claims, 3 Drawing Figures

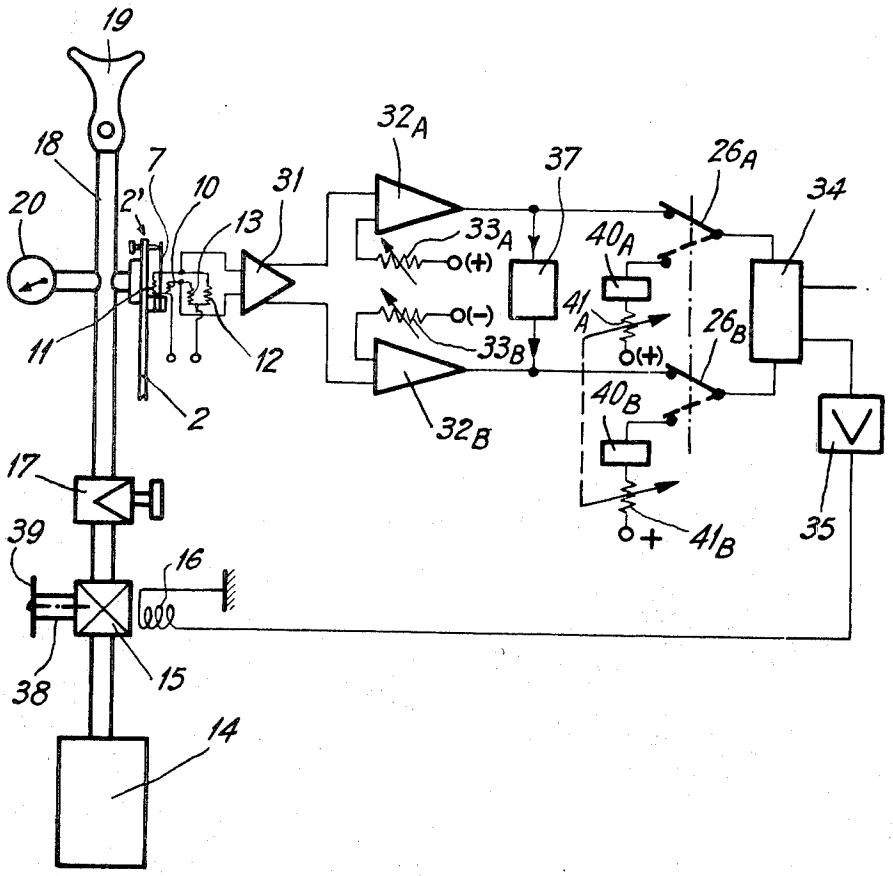


Fig. 1

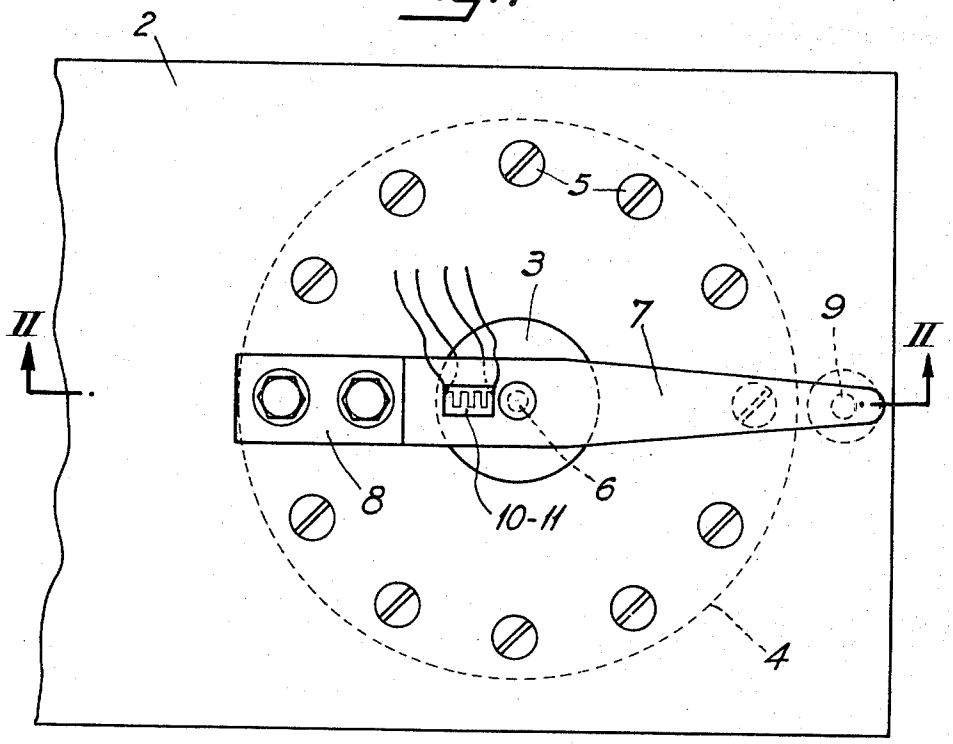


Fig. 2

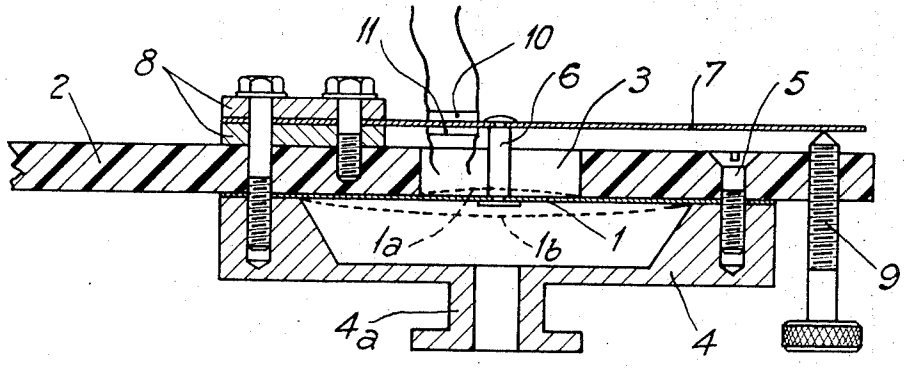
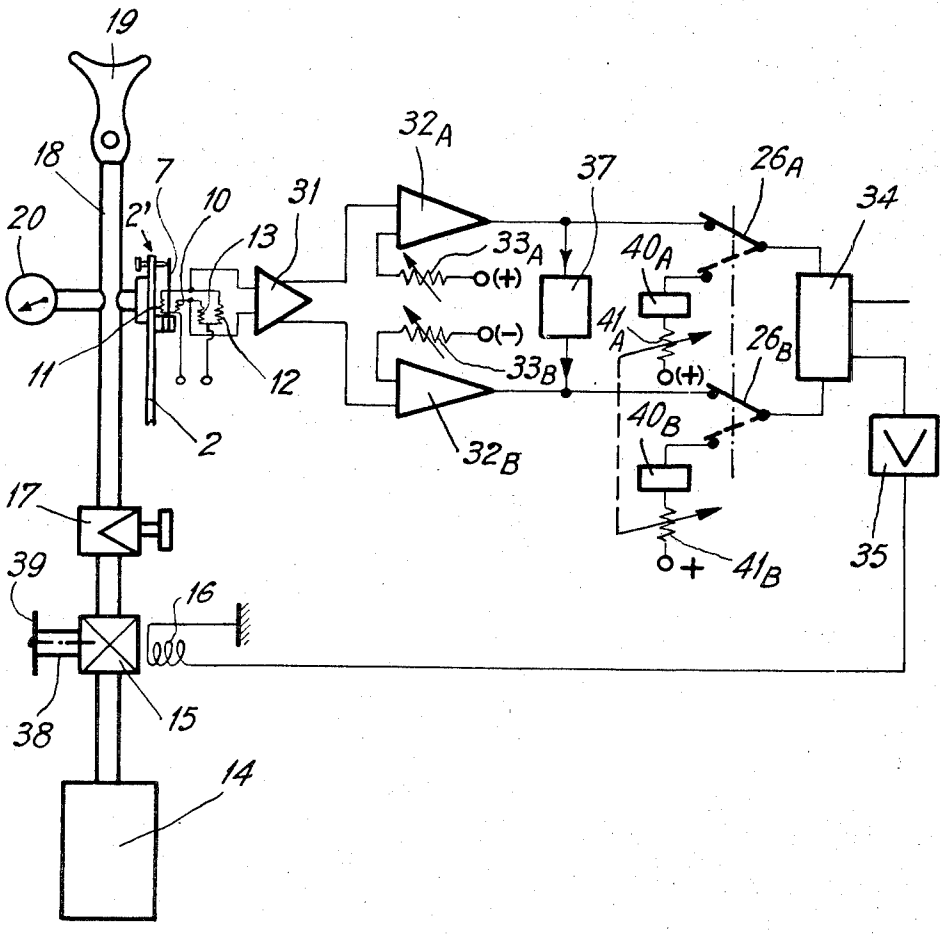


Fig. 3


19
18
7
2'
10
31
32A
37
26A
34
20
13
33A
40A
(+)
(−)
41A
26B
11
12
33B
(+)
2
32B
40B
17
39
16
35
41B
38
15
14

CONTROL DEVICE FOR A RESPIRATORY APPARATUS

This invention relates to control devices for respiratory apparatus. Respiratory apparatus for assisting natural respiration is normally controlled to operate at a fixed frequency or rhythm by a clock mechanism operated electrically or pneumatically but this is not satisfactory when the respiratory rhythm of a patient to be treated is irregular.

The present invention concerns means for supplying air to patient according to the demand of his lungs, in other words means to control the apparatus by shutting air supply as soon as the lungs are full of air and by opening the air supply as soon as patient begins an inhalation.

A control device for a respiratory apparatus comprising a source of respirable gas connected to a mouthpiece by a conduit provided with a control valve, according to the invention includes a pressure sensor connected to said conduit between said valve and mouthpiece, said sensor comprising a housing closed by a membrane, the outer face of which exposed to ambient air is partly applied against a rigid sustaining member, a first detector of a predetermined outward distortion of said membrane for controlling closing of said valve and a second detector of a predetermined inner distrotion of said membrane for controlling opening of said valve. Thus owing to the membrane outer sustaining member, outward displacement of a given point on the membrane due to gas over pressure inflating the lungs and prevailing in the housing may be of the same order as inward displacement of the same point due to under pressure in said housing produced by the inhalation effort of the patient.

Preferably an adjustable flexible flat member is connected to a point of the flexible membrane, so as to respond to the flexure of the latter and both faces of the member are provided with strain gauges which are connected in a Wheatstone bridge with reference resistors. Hence by adjusting the initial shape of the member, the bridge may be exactly equilibrated when the same pressure prevails on both faces of the membrane, so that an over pressure in the housing provides a current of one direction in the bridge detecting diagonal and an under pressure a current of the other direction, in the same diagonal.

Thus the bridge arrangement is a part of the first and second detectors.

By comparison of each of both currents with respective adjustable thresholds, control of a flip-flop at predetermined amplitudes of the currents (i.e. definite levels of membrane distortions) may be obtained for the alternate control of the valve.

In one particular form of the control device according to the invention the the flow control valve is electro-magnetically operated by one output of a flip-flop device triggered by signals derived from the strain gauges.

For reasons of security after control of the valve to close position, the flip-flop is again triggered to control open position of the valve by the output of a timing device a predetermined time after closing of the valve.

For allowing the weak inhalation effort of the patient to entail a negative pressure in the conduit portion the flow control valve is adapted, when in its closed position, to place the pipe in communication with atmosphere via a light exhaust valve.

In a further embodiment of the apparatus, means are provided for operating the flip-flop according to a predetermined time cycle. Such means may comprise resistorcapacitor combinations of which the resistors are variable.

By way of example only, an embodiment of the invention will now be described in greater detail with reference to the accompanying drawing in which:

FIG. **1** is a plan view of part of one embodiment,

FIG. **2** is a section on the line II—II of FIG. **1**, and,

FIG. **3** is a circuit diagram partly in block or schematic form of the respiratory apparatus.

The component shown in FIGS. **1** and **2** is a pressure change detector and it comprises a flat circular membrane **1** attached to a plate **2** concentrically with an aperture **3** in the latter. The membrane is clamped between the plate and a cup-shaped housing **4** attached to the plate by screws **5** which also pass through the membrane adjacent its periphery.

The membrane **1** is made of metal or of a plastic material, for example that known as "Stabilene."

The plate **2** is of laminated glass/resin construction and is extended to provide support for other components described below.

Extending externally of the housing **4** and centrally from the base thereof is a coupling **4***a* by means of which connection is made to a pipe supplying a patient with respirable gas.

Connected to the center of the membrane **1** is one end of a bolt **6** whose other end is fixed to a flexible strip **7** clamped cantilever fashion between small clamping plates **8** bolted to plate **2**. The free end of the strip **7** rests resiliently on an adjusting screw **9**, which sets the zero position of the strip **7**, and of the membrane.

To the upper and lower faces of the strip **7** are fixed strain gauges **10, 11** respectively. The gauges are connected in a Wheatstone bridge including reference resistors **12, 13** (FIG. **3**) for supplying control signals.

Increase of pressure within the housing **4** causes the central part only of the membrane **1** to flex upwardly as indicated by the dotted line **1***a* whereas a reduction in pressure below atmospheric causes the membrane to flex downwardly over a much greater area as indicated by the dotted line **1***b*. In this way, a pressure reduction which is only one tenth of the maximum pressure to which the membrane is likely to be exposed produces, in the strip **7** a flexure equal in amplitude but opposite in sense to that produced by that maximum pressure.

The respiratory apparatus shown in FIG. **3** includes a source **14** providing respirable gas under pressure. The gas may be air with enriched with oxygen or pure oxygen for example. The source is connected by a pipe **18** to a mouthpiece **19** for supplying the gas thereto.

The supply of gas is controlled by a three-way, electromagnetically operated valve **15** whose energizing winding is shown at **16**. The valve **15** is normally closed and is in series connection in the pipe **18** with a throttle valve **17** regulating the gas flow.

A manometer **20** is joined to the pipe **18** as shown and the latter also has a branch connection to the housing **4** via the coupling **4***a*.

In use, flexure of the strip **7** causes signals to be transmitted from the bridge whose amplitude and polarity depend upon the extent to which and the direction in

which the strip is flexed and thus, this flexure indicates the pressure in the housing **4** and so in the pipe **18.** Owing to the screw **9** output of the bridge is adjusted to zero when both faces of the membrane are submitted to the same pressure.

The bridge output is applied to an amplifier **31** having thus one output on which appear positive signals representing positive pressure in housing **4** and another output on which appear negative signals representing negative pressures in that housing. The two outputs are connected to respective differential amplifiers 32_A, 32_B each with a reference input controlled by the respective potentiometers 33_A, 33_B.

Amplifier 32_A and its potentiometer 33_A are adapted to deal with positive pressures and by adjustment of the potentiometer 33_A can be set to deal with a range of from 0 — +100 mb as indicated by the manometer **20.** This range is selected so that a supply pressure can be selected which suffices to fill the lungs of a patient without smothering him.

Amplifier 32_B and its potentiometer 33_B are adapted to deal with negative pressures and by adjustment of the potentiometer 33_B can be set to deal with a range of pressures of from −1 mb to −10 mb which pressure can also be indicated by manometer **20.** In practice, the pressure is determined by the comfort of the patient in that a signal is emitted when the latter breathes undue without effort.

By means of the contact arms 26_A, 26_B of a doublepole changeover switch, the outputs of the differential amplifiers 32_A, 32_B can be applied to the inputs of an electronic flip-flop circuit represented by block **34.** The flip-flop has a single output corresponding with the output of amplifier 32_B which is used, after amplification by power amplifier **35,** to energise the winding **16** and so open valve **15.**

The output of differential amplifier **32A** is also applied to a timing device **37** which, in response to an input, produces an output after a predetermined delay within the range of from **2** to **5** seconds, for example **3** seconds. The output of timing device **37** is connected to the output of differential amplifier 32_B.

The general arrangement is such that when the predetermined positive pressure is reached pipe **18,** a signal is sent to the flip-flop **34** which responds by a change in its other stable state and as a result valve **15** is closed. At the same time, the timing device **37** is set into operation.

The patient then exhales and after a certain time inhales again providing a negative pressure in housing **4** and this produces a signal that is applied via amplifier 32_B to the flip-flop **34** which switches to its other stable state with the result that valve **15** is opened.

In inhaling is insufficient to produce the necessary negative pressure or if the latter appears after the end of the predetermined delay to which device **37** is set, the latter produces a signal at the end of the delay and this causes flip-flop **34** to switch to its other state and valve **15** opens. The cycle then repeats, timing device **37** being ready then to receive a further signal from amplifier 32_A when the pressure in pipe **18** again rises to the predetermined positive value.

It has already been stated that valve **15** is a three-way valve. In the open position of valve **15,** pipe **18** is placed in communication with source **14** only while in the closed position source **14** is shut off from pipe **18** but the latter is placed in communication with the atmosphere via an outlet **38** normally closed by a light exhaust valve **39,** for example a flexible elastomeric disc with a central fastening positioning the valve over outlet **38.** Thus, when valve **15** closes, the positive pressure then existing in pipe **18** flexes valve **39** away from the outlet **38** and the pressure rapidly drops to ambient pressure. As the patient inhales exhaust valve **39** is closed and negative pressure appears in pipe **18** and housing **4.**

The double pole switch can be manually actuated to disconnect the amplifiers 32_A, 32_B from the flip-flop **34** to connect the latter to capacitive devices 40_A, 40_B which with their respective potentiometers 41_A and 41_B convert the flip-flop into a multivibrator.

The setting of the potentiometers 41_A, 41_B is such that the ratio of the switching times of the multivibrator is 2:1 so that the valve **15** is open and shut cyclically, the closed time being twice the open time, this giving a time period for expiration that is twice the time period for inhalation.

For medical use, the frequency of the multivibrator can be set to a value within the range 10–60 exhalations and inhalations per minute. However, for veterinary use, a wider range of variation may be required and in practice, the respiratory rhythm is adjustable within the range of from to 100 per minute.

What I claim is:

1. A device for the control of a respiratory apparatus comprising:

a source of a respirable gas connected to a patient through a conduit provided with an electrically operated control valve;

control means for operating said valve, said control means including a housing communicating with said conduit between said valve and the patient, a flat membrane spanning said housing and having an outer face exposed to the atmosphere and an inner face exposed to the breathing air supplied to said patient, a flat generally rigid member disposed proximal to said outer face for securing said membrane and provided with a central aperture of a surface area substantially less than the area of said membrane, a rigid element connected to a central portion of said membrane, and a distortion detector connected to said element; and

electrical means connected to said detector and to said valve for supplying a valve-closing signal to said valve upon distortion of the membrane in the direction of said central aperture and; for supplying a valve-opening signal to the latter upon distortion of the membrane in the other direction.

2. The device defined in claim **1,** further comprising a flexible member overlying said membrane, said distortion detectors being formed as strain gauges applied to opposite faces of said flexible member and a wheatstone bridge circuit having reference resistors and said strain gauges connected therein.

3. The device defined in claim **2** wherein said flexible member is a blade, further comprising means for clamping said blade at one end to said housing, adjustment means for varying the position of the opposite end of said blade with respect to the housing, and means connecting an intermediate location on said blade between said ends to said rigid element.

4. The device defined the claim **3** wherein said rigid member is a wall of electrically insulating material carrying said detectors and said blade.

5. The device defined in claim 1 wherein the first-mentioned and second electrical means are respective differential amplifiers having respective adjustable thresholds of opposite polarity, and a bistable flip-flop responsive to said differential amplifiers.

6. The device defined in claim 1 wherein said valve is a three-way valve and in its closed position connects said conduit to the atmosphere through an adjust valve.

7. The device defined in claim 6, further comprising a timing device for operating said valve independent of at least one of said detectors.

8. The device defined in claim 1, further comprising means for indicating visually the pressure in said conduit.

9. A device for the control of a respiratory apparatus comprising:

a source of a respirable gas connected to a patient through a conduit provided with an electrically operated control valve;

control means for operating said valve, said control means including a housing communicating with said conduit between said valve and the patient, a flat membrane spanning said housing and having an outer face exposed to the atmosphere and an inner face exposed to the breathing air supplied to said patient, a flat generally rigid member disposed proximal to said outerface for securing said membrane, a rigid element connected to a central portion of said membrane, and a distortion detector connected to said element;

electrical means connected to said detector and to said valve for supplying a valve-opening signal to the latter upon distortion of the membrane in one direction;

a second distortion detector connected to said element for sensing deflection of said membrane in the opposite direction, and second electrical means responsive to said second detector and connected to said valve to apply a valve-closing signal to the latter, said control valve is electromagnetic, said detectors are strain gauges, and said electrical means include respective differential amplifiers having adjustable thresholds and connected to said strain gauges, a bistable flip-flop connected to said differential amplifiers and having an output applied to said valve, two resistor-capacitor combinations, each associated with said flip-flop, and switching means for selectively applying said resistor-capacitor combinations and said differential amplifiers to said valve for constituting a multivibrator from the flip-flop upon connection of a resistor-capacitor combination therewith.

10. The device defined in claim 9, further comprising variable resistors in said resistor-capacitor combinations for determining the switching time of the multivibrator.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,831,596

DATED : 27 August 1974

INVENTOR(S) : Roger Paul Charles CAVALLO

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading, after line /21/ insert:

-- /30/ Foreign Application Priority Data

10 November 1971 FRANCE 71 40291

17 October 1972 FRANCE 72 36666 --

Signed and Sealed this

twenty-ninth Day of July 1975

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks