

[54] ARTIFICIAL RESPIRATION SYSTEM

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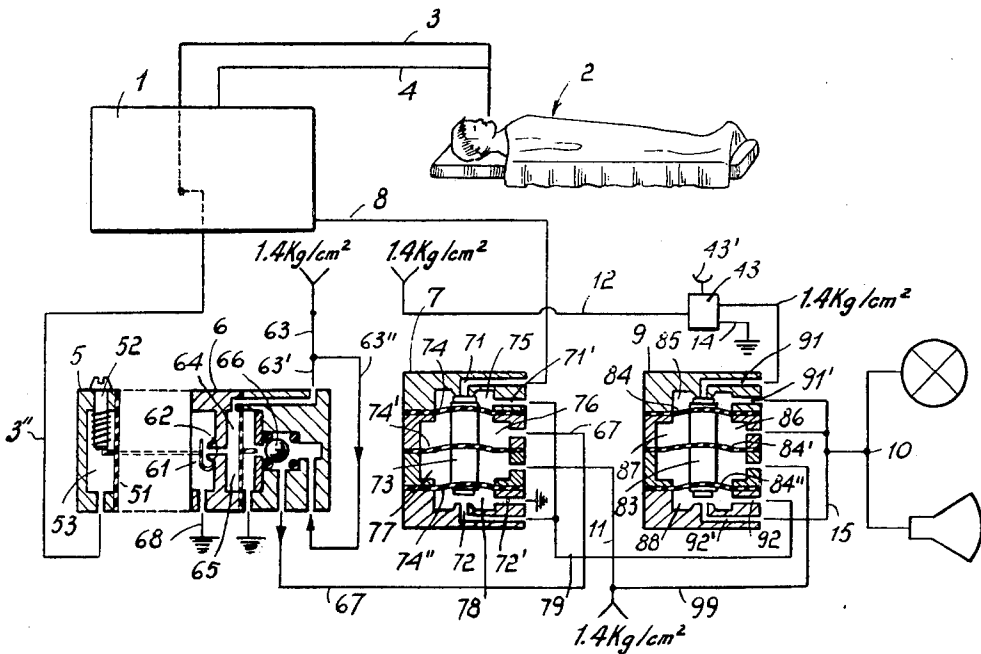
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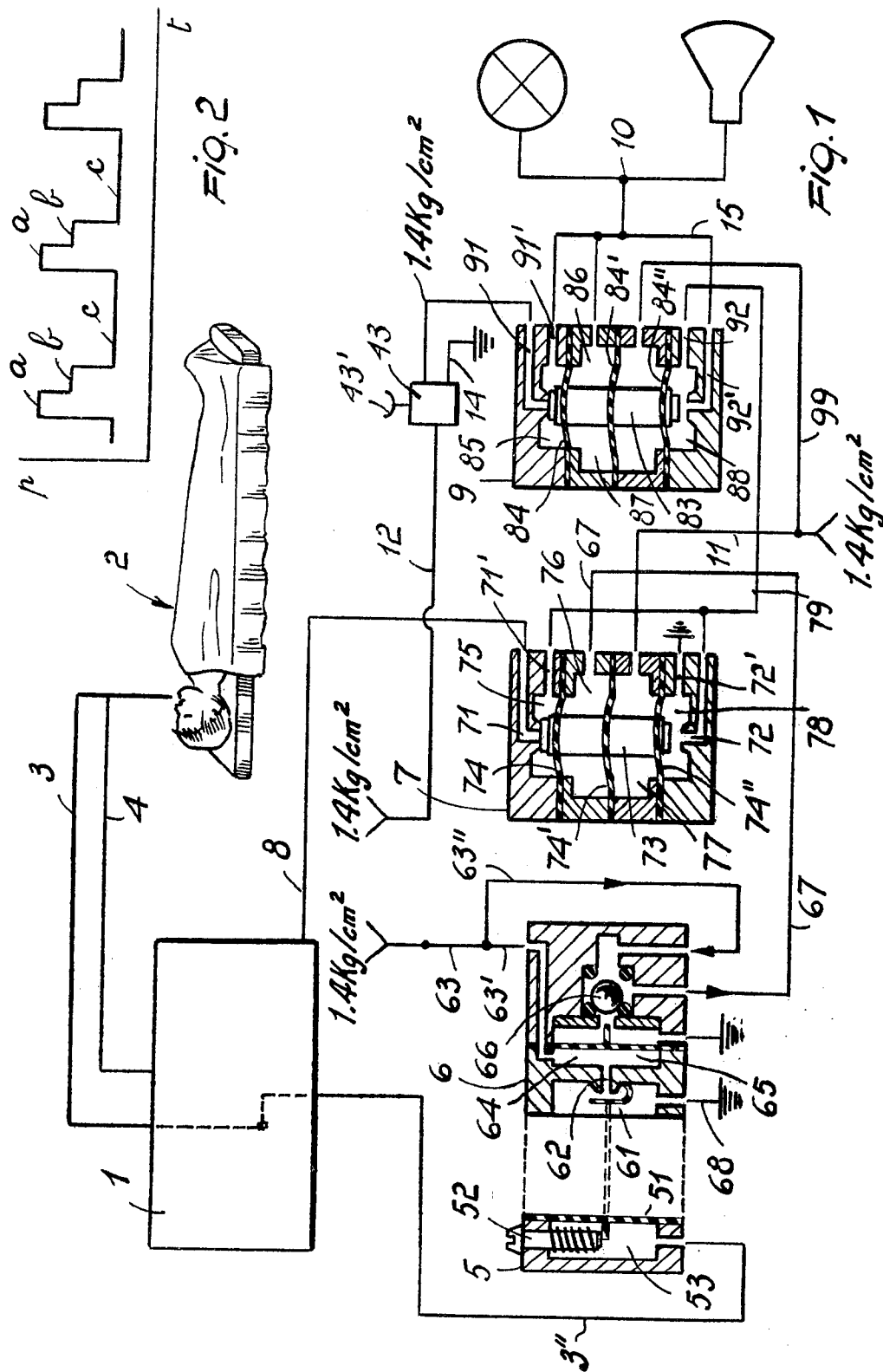
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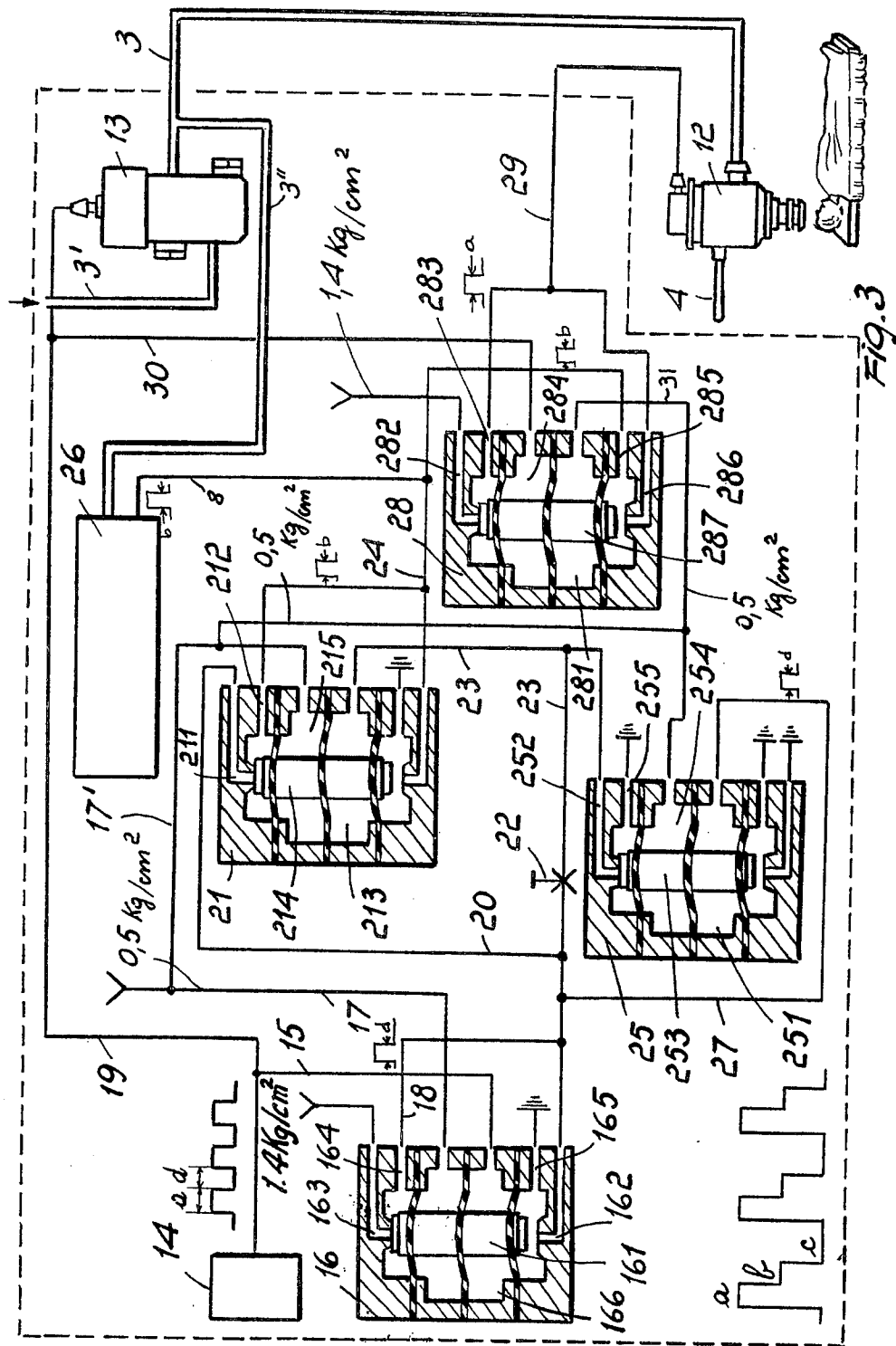
[57] ABSTRACT

Air is alternately forced into the lungs of a patient during an inhalation period and permitted to flow out of the lungs of the patient during a subsequent exhalation period. A synchronizing signal is generated indicative of the time intermediate the inhalation period and the exhalation period. A warning unit is provided for generating a warning signal. The pressure of air in the lungs of the patient is detected to determine whether or not such pressure falls below a predetermined value or overcomes a predetermined maximum value. If the detected pressure in the patient's lungs falls below or respectively overcomes such predetermined value during the time of generation of one of said synchronizing signals, that is, during the specific time period intermediate the inhalation and exhalation periods, then the warning unit generates a warning signal.

9 Claims, 3 Drawing Figures







ARTIFICIAL RESPIRATION SYSTEM

CROSS-REFERENCES TO RELATED APPLICATIONS

The present application is a continuation-in-part of my prior copending application Ser. No. 239,977, filed on Mar. 31, 1972, now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to methods and systems for the artificial respiration of a patient, and furthermore relates to means and methods for determining insufficiency of the artificial respiration operation being performed.

It is known to operate mechanical respiration machines in such a manner as to blow gas into the lungs of a patient through a pipe inserted into the patient's trachea, thus expanding the patient's chest by the pressure of the introduced respiration gas, and then permitting the patient to exhale. However, with the known techniques, it is possible that the patient's lungs may not be sufficiently ventilated, due for example to a leakage in a gas line, or due to an obstruction in one of the gas lines, or for other reasons. Simple measurement of the pressure of gas delivered to the patient is not sufficient to indicate the ventilation condition of the patient's lungs, because it is possible that a proper operating pressure may be measured although the lungs are in fact not being properly ventilated. This could happen, for example, if there were an obstruction in the gas delivery line downstream of the point where the gas pressure is measured. In the same manner it may be desirable to control the pressure value into the patient's lungs to limit it below a maximum value that could be dangerous for the patient.

SUMMARY OF THE INVENTION

The present invention has for its object the provision of a method and an apparatus for signalling insufficient lung ventilation which avoids the above-mentioned disadvantage by measuring the gas pressure during the interval between inhalation and exhalation, and by determining insufficient lung ventilation when the measured gas pressure at such time is less than a predetermined value. This results in a safer check, since the pressure measured at the end of the inhalation stage is more directly dependent upon the amount of gas blown into the patient's lungs.

This object, and others which will become more understandable from the following description of a preferred embodiment, can be met, according to one advantageous concept of the invention by providing an artificial respiration system which includes respirating means for alternately forcing air into the lungs of a patient during an inhalation period and permitting outflow of air from the lungs of the patient during a subsequent exhalation period. Synchronizing means is provided for generating a synchronizing signal indicative of the time intermediate the inhalation period and the exhalation period. Warning means is provided for issuing a warning signal. Pressure-detecting means is provided for detecting when the pressure of air in the lungs of the patient falls below a predetermined value. Activating means is connected to said synchronizing means for receipt of said synchronizing signal and is connected to said pressure-detecting means and is operative for causing the warning means to issue a warning

signal if the pressure detected by the pressure-detecting means falls below the predetermined value during the time of receipt by the activating means of said synchronizing signal.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 depicts an artificial respiration system according to the invention;

FIG. 2 depicts in graphical form certain aspects of the operation of the artificial respiration system shown in FIG. 1; and

FIG. 3 depicts the structure of the schematically depicted respirating unit 1 shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 depicts an automatic respirating machine for respirating the lungs of a patient 2. A conduit for air is inserted into the trachea of the patient 2, and has two branches 3 and 4. The respirating machine pumps air into the patient's lungs through inhalation conduit 3 during the inhalation period *a* (see FIG. 2). The air pumped through inhalation conduit 3 expands the patient's chest, filling the lungs of the patient with air.

Subsequent to the inhalation period *a*, the pumping of air through inhalation conduit 3 is terminated, and an exhalation conduit 4, previously blocked, is opened, permitting the air in the patient's lungs to escape through conduit 4, and permitting the air pressure which has built up in the patient's lungs to fall towards atmospheric pressure. Such exhalation is permitted to occur during the exhalation period designated *c* in FIG. 2.

Intermediate the inhalation period *a* and the exhalation period *c* is a short-lasting pause *b*, having a duration on the order of about 200/1000 of a second. The time duration of pause *b*, relative to the time durations of the inhalation period *a* and the exhalation period *c*, has been greatly exaggerated in FIG. 2, for the sake of clarity.

One of the principal features of the invention is the determination of the pressure in the patient's lungs during the short-lasting pause *b* occurring intermediate the inhalation period *a* and the exhalation period *c*.

To this end, the respirating machine schematically depicted in FIG. 1 generates, on synchronizing line 8, a pneumatic synchronizing signal contemporaneously with the occurrence of the short-lasting pause *b*. The pressure in the patient's lung is monitored during this interval *b* and, if during the interval *b* the pressure of air in the patient's lungs is lower than a preselected minimum sufficient value, acoustical and/or visual alarm signals will be issued.

The illustrated embodiment will now be described in greater detail.

FIG. 3 shows essential portions of the respirating machine 1. In particular, the machine 1 comprises two pneumatically controlled valves 13 and 12. The valve 13 has an inlet 3' into which is pumped the respiration

air to be pumped into the patient's lungs. The valve 13 has an outlet 3 which passes to the inlet of valve 12. Valve 13 can be made to either permit air flow from its inlet 3' to its outlet 3, or can be made to block such air flow. The control of valve 13 is effected by the application thereto of pneumatic control signals, via a control line 19, in a manner described below.

The valve 12 is a three-port valve. In the first of the two positions thereof, valve 12 permits the pressurized gas in inhalation pipe 3 to enter the lungs of the patient, during the inhalation phase *a*. In the second of the two positions thereof, valve 12 establishes communication between the lungs of the patient and the exhalation pipe 4, to permit the air under pressure in the patient's lungs to flow out of the patient's lungs through exhalation pipe 4, during the exhalation phase *c*. The control of valve 12 is effected by the application thereto of pneumatic control signals, via a control line 29, in a manner described below.

The cyclical control of the valves 13 and 12, considered from a purely functional point of view, is as follows:

During the inhalation phase *a*, the valves 13 and 12 are both opened. Accordingly, the ventilation gas entering inlet conduit 3' passes through valve 13, through inhalation pipe 3, and through valve 12 into the lungs of the patient.

During the phase *b*, intermediate the inhalation phase *a* and the exhalation phase *c*, the valve 13 is closed and the valve 12 is in the first position thereof wherein it establishes communication between the lungs of the patient and the inhalation pipe 3. The pressure in the inhalation pipe 3 will now be established not by the action of the (non-illustrated) pressure-creating means connected to ventilation gas inlet 3'; instead, the pressure in the inhalation pipe 3 will be established by reason of the pressure build-up in the lungs of the patient and by reason of the compressive force exerted by the patient's thorax.

During the exhalation phase *c*, the valve 13 is closed and the valve 12 is in the position thereof wherein it establishes communication between the interior of the patient's lungs and the exhalation pipe 4, so that the pressure build-up in the patient's lungs can be relieved by an outflow of air through the exhalation pipe 4.

The means which establishes this sequence of valve openings and valve closings is depicted in FIG. 3.

A pressure pulse generator 14 continuously generates a pneumatic square-wave comprised of pressure pulses having a pulse-duration equal to the duration of the inhalation phase *a*, but separated from each other by a time interval *d*. The duration of the time interval *d* is equal to the duration of the exhalation phase *c* plus the duration of the intermediate phase *b* ($d = b + c$). Evidently, the pulse-repetition frequency of the pulse train generated by pulse generator 14 establishes the respiration frequency for the artificial respiration of the patient. The generator 14 can, for example, comprise a source of pressure having an outlet provided with a solenoid-operated valve, with the electrical input of the solenoid-operated valve being connected to and controlled by an astable multivibrator having a first unstable state lasting a time interval corresponding to the duration of the inhalation phase *a* and having a second unstable state lasting a time interval corresponding to the duration *d*.

The cycle of operation of the means which control the opening and closing of the valves 12 and 13 will now be described.

INHALATION PHASE *a*

The pressure pulse generated by pulse generator 14 is transmitted through control-pulse conduit 19 and is applied to the control input of valve 13, thereby opening the valve 13. As a result, the valve 13 permits passage of pressurized gas from the inlet 3' thereof to the outlet 3 thereof.

That same pressure pulse generated by pulse generator 14 is furthermore transmitted through conduit 30 to the upper chamber 284 of a pneumatic repeater device 28, causing the valve member 287 thereof to assume its lowermost position, by reason of the pressure in chamber 284 exceeding the normal biasing or operating pressure of 0.5 kg/cm² established in the chamber 281 by way of biasing-pressure conduit 31. Once the valve member 287 has been pushed in this manner to the lowermost position thereof, it unblocks the pressure inlet 282, which is connected to a pressure source of 1.4 kg/cm². This pressure of 1.4 kg/cm² passes in through the conduit 282 and then out through the conduit 283, and then through the control-pulse conduit 29 to the control input of the two-position valve 12. When this 1.4 kg/cm² control pulse is applied to the control input of valve 12, it causes valve 12 to assume the position thereof wherein communication is established between the interior of the patient's lungs and the inhalation pipe 3.

Thus, the valve 13 is in the open position thereof, and the valve 12 is in the position establishing communication between inhalation pipe 3 and the interior of the patient's lungs. Accordingly, the respiration gas introduced into inlet 3' enters the patient's lungs.

This situation prevails for the entire duration of the pressure pulse, i.e., for the entire duration of the inhalation phase *a*.

THE INTERMEDIATE PAUSE *b*

At the end of the pressure pulse generated by pulse generator 14, the valve 13 reassumes its normal closed position.

Furthermore, at the end of the pressure pulse generated by pulse generator 14, the pressure established in chamber 284 or repeater 28 terminates, and as a result the valve member 287 reassumes its illustrated uppermost position. With valve member 287 in its illustrated position, the inlet 282 is blocked, and the 1.4 kg/cm² valve-control pressure cannot pass into the conduit 282 and out the conduit 282 and through the conduit 29 to the control inlet of the valve 12 to maintain the latter in the first position thereof. However, as will be clear from the foregoing functional description of the operation of valve 12, valve 12 must be maintained in its first position (establishing communication between inhalation pipe 3 and the interior of the patient's lungs) during the intermediate pause *b*. The valve 12 is maintained in the first position thereof in the following manner.

Immediately upon termination of the pressure pulse *a* generated by pulse generator 14, a pulse having a pulse-duration of for example 200/1000 sec. is transmitted through the inlet 285 of repeater 28, then through the outlet 286, then through the control-pulse conduit 29, to the control input of valve 12, thereby

maintaining valve 12 in its first position for an additional 200/1000 sec. subsequent to the termination of the inhalation phase *a*. The means for generating this supplemental pulse having a pulse-duration of for example 200/1000 sec. will be described below.

During this 200/1000 sec. time interval, the valve 13 is in closed position, and the valve 12 is in the first position thereof, i.e., in the position thereof wherein it establishes communication between the interior of the patient's lungs and the inhalation conduit 3. Clearly, the pressure now prevailing in the inhalation conduit 3 will be due exclusively to the pressure build-up in the patient's lungs and the compressive force of the patient's thorax. This pressure is applied to a pressure-monitoring device 26, via a communication conduit 3'. In a manner described in detail below, the pressure-monitoring device 26 evaluates the pressure prevailing in the patient's lungs during this pause period *b*, and determines whether it is within an acceptable range. In the event that the pressure just mentioned is not within such acceptable range a warning signal is generated.

The construction and operation of the pressure-monitoring device 26 of FIG. 3 will be explained in detail below. However, it is noted now that pressure-monitoring device 26 is operative to monitor the pressure in the patient's lungs specifically during the pause period *b*. To this end, pressure-monitoring device 26 is adapted to receive a synchronizing pulse, via the illustrated second inlet conduit 8 thereof. This synchronizing pulse has a pulse-duration equal to the duration of the intermediate pause period *b*. As a result, pressure-monitoring device 26 is informed of the fact that the intermediate pause period *b* is occurring and that the pressure in the patient's lungs should at this time be evaluated.

THE EXHALATION PERIOD *c*

The aforementioned pulse having a duration of 200/1000 sec. and applied to control-pulse line 29 via repeater inlet 285 and repeater outlet 286 terminates, and the exhalation period *c* commences. Specifically, upon termination of the 200/1000 sec. supplemental pulse, the valve 12 reassumes its normal position wherein it establishes communication between the interior of the patient's lungs and the exhalation conduit 4. Accordingly, the pressure build-up in the patient's lungs is relieved through the exhalation conduit 4, and the patient's thorax sinks in an exhaling manner.

THE GENERATION OF THE PULSE CORRESPONDING TO PAUSE *b*

The pulse train generated by pulse generator 14 is applied to the input conduit 14 of a pneumatic inverter device 16. Inverter 16 essentially is operative for producing at its outlet 18 a pressure pulse train inverted with respect to that generated by pulse generator 14. In other words, the inverter 16 produces at its outlet 18 a pressure pulse of duration *d* during the time interval between the pressure pulses produced by generator 14.

Inverter device 16 performs this function as follows. Inverter 16 receives a biasing or operating pressure of 0.5 kg/cm² via a biasing conduit 17. This 0.5 kg/cm² biasing pressure tends to move the valve member 161 of inverter 16 to the lowermost position thereof. A pressure of 1.4 kg/cm² is applied to the inlet 163 of the inverter 16. However, when the valve member 161 is in the illustrated uppermost position thereof,

the inlet 163 is blocked off. Valve member 161 will be in such blocking uppermost position during the existence of each pressure pulse generated by pulse generator 14. This is because the pressure pulse generated by generator 14 is applied to the inlet 15 of inverter 16 and enters the compartment 166 and overcomes the biasing pressure force of 0.5 kg/cm² applied via biasing conduit 17, to thereby move the valve member 161 to its illustrated blocking position.

However, during the time intervals *d* intermediate the pulses generated by pulse generator 14, no pressure in compartment 166 opposes the 0.5 kg/cm² biasing pressure applied via conduit 17, and accordingly valve member 161 moves to its lowermost, or unblocking position. As a result, the 1.4 kg/cm² pressure applied to inlet 163 will pass out through outlet 164 in the form of a pressure pulse of time duration *d* in conduit 18.

Inasmuch as device 16 produces at its outlet 18 pulses contemporaneous with the intervals between the pulses generated by pulse generator 14, device 16 has been referred to herein as an inverter. It is to be understood that a pulse appears at the output 18 of inverter 16 as soon as a pulse generated by pulse generator 14 ends.

The signal on inverter outlet 18 is applied simultaneously to conduits 20, 23 and 27.

The conduit 18 feeds this pressure pulse to the inlet 211 of a further pneumatic device 21. Device 21 is biased towards the lowermost position thereof by the action of a 0.5 kg/cm² biasing pressure applied to compartment 215 thereof by way of biasing pressure conduit 17'. The action of this biasing pressure is to normally maintain the valve member 214 of device 21 in the lowermost position thereof. As a result, the signal applied to inlet 211 passes out through outlet 212, and reaches conduit 24.

The same signal, i.e., the pulse appearing at output 18 of inverter 16, as mentioned before, is also applied to conduit 23. However, conduit 23 includes a manually adjustable throttling valve 22. The conduit 23 leads into the compartment 213 of the device 21. When the 1.4 kg/cm² pressure pulse appears at the outlet 18 of inverter 16, this pressure is transmitted via conduit 23 to the compartment 213 of device 21, but not instantaneously. Instead, there is a gradual build-up of the pressure in compartment 213 to the value 1.4 kg/cm², the gradualness of the build-up resulting from the provision of the throttle valve 22 in conduit 23.

When the pressure in compartment 213 has risen to the 1.4 kg/cm² value, after the exemplary time delay of 200/1000 sec., the pressure in compartment 213 overcomes the biasing pressure in compartment 215, causing the valve body 214 to move to its illustrated uppermost position. As a result, the pressure established via conduit 20 in inlet 211 of device 21 can no longer be communicated to the outlet 212 thereof. Accordingly, the duration of the 1.4 kg/cm² pressure pulse appearing at outlet 212 of device 21 will be equal to 200/1000 sec., in the illustrated embodiment, namely the duration of the intermediate pause *b*.

Finally, as mentioned above, the 1.4 kg/cm² pressure pulse appearing at the outlet 18 of inverter 16 is also applied to conduit 27 and therealong to the compartment 251 of the pneumatic device 25. A biasing pressure of 0.5 kg/cm² is maintained in the compartment 254 of the device 25. This biasing pressure normally maintains the valve member 253 in the lowermost posi-

on thereof. However, when the 1.4 kg/cm² pulse appears at outlet 18 of inverter 16, and is applied via conduit 27 to compartment 251, the pressure in compartment 251 overcomes the pressure in compartment 254, and as a result the valve member 253 moves to its illustrated uppermost position. This closes the inlet 252 communicating with the aforescribed conduit 23. As a result, the pressure in the conduit 23 cannot be relieved through the outlet 255. However, when the 1.4 g/cm² pressure established in compartment 251 is terminated, the 0.5 kg/cm² biasing pressure in compartment 254 moves the valve member 253 to its lowermost position, and the pressure in conduit 23 can be relieved through outlet 255.

It will be clear that the purpose of providing relief device 25 is to ensure that pressure cannot build up in compartment 213 of bistable device 21 except during the time interval *d* between two successive pulses generated by pulse generator 14.

As a result of all of the foregoing, a synchronizing pressure pulse of 200/1000 sec. duration is applied to the synchronizing inlet 8 of pressure-monitoring device 26 at the same time that the pressure applied to the inlet 3'' of device 26 is at a value corresponding to the pressure in the patient's lungs during the brief pause *b* intermediate the inhalation and exhalation phases.

The construction and operation of the pressure-monitoring device 26 of FIG. 3 will be explained with reference to FIGS. 1 and 2.

The many components and connections depicted in FIG. 3, except for the schematically shown box in FIG. 1, all correspond to the components 1, 3'', 3 and 4 of FIG. 1. In FIG. 1, reference numeral 1 generally designates the respiration machine shown in FIG. 3, with the inhalation and exhalation conduits 3 and 4 being shown somewhat more schematically. The remaining components in FIG. 1 correspond to the pressure-monitoring device 26 in FIG. 3.

The pressure-monitoring arrangement of FIG. 1 includes a pressure meter generally designated by reference numeral 5. The pressure meter 5 comprises a flexible diaphragm 51 which is pre-loaded by means of a screw 52, so that it will become deformed in a predetermined manner when the pressure entering chamber 53, via conduit 3'' explained with reference to FIG. 3, exceeds a predetermined minimum value. It is noted that a pressure corresponding to the pressure in the patient's lungs is applied via conduit 3'' to compartment 53 of pressure meter 5 not only during the pause period *b* but also during the inhalation period *a*, in the illustrative embodiment.

The diaphragm 51 is mechanically coupled (as represented by the broken lines) to a resilient shutter member 61. When the pressure in compartment 53 exceeds a predetermined minimum value, the diaphragm 51 moves towards the right, causing the shutter member to move rightwards and close off passageway 62.

A (non-illustrated) source of biasing pressure, here at a value of 1.4 kg/cm², has an outlet 63 which in turn has two branches 63' and 63'' which lead into two inlets of the minimum pressure detector 6. The branch 63' leads into a chamber 64. The chamber 64 is bounded on the left side by a wall through which passes the aforementioned passageway 62. The chamber 64 is bounded on the right side by a flexible diaphragm 65 which is operative, when urged in rightwards direction, for moving a spherical valve member 66 in rightwards

direction. It will be noted that, when shutter member 61 has not closed off passageway 62, pressure will not be able to build up in chamber 64, by reason of the communication of chamber 64 with the atmosphere, via passage 62 and outlet 68. Thus, when passage 62 is open, the pressure in chamber 64 will not build up to an extent sufficient to push diaphragm 65 in rightwards direction and thereby push spherical valve member 66 to its rightmost position. On the contrary, the spherical valve member 66 will be pushed to its illustrated leftmost position, under the action of the pressure in conduit 63''.

Inlet conduit 63'' communicates with outlet conduit 67, and when spherical valve member 66 is in the illustrated leftmost position thereof, the 1.4 kg/cm² pressure in conduit 63'' will be transmitted to outlet conduit 67.

It follows from what has been said that a pressure of 1.4 kg/cm² will appear in conduit 67 in the event that the pressure in compartment 53, i.e., the pressure in the patient's lungs during the inhalation phase *a* or during the pause *b*, falls below a predetermined minimum value. So long as the pressure in the patient's lungs is above the preselected minimum value, no 1.4 kg/cm² pressure signal will appear in conduit 67.

The conduit 67 leads into a compartment 76 of a pneumatic bistable device 7. The bistable device 7 is comprised of a housing having two principal inlets 71 and 72 and a cylindrical valve member 73 suspended by three flexible diaphragms 74, 74', 74'' for movement between uppermost and lowermost positions closing off one or the other of the inlets 71, 72. The flexible diaphragms 74, 74', 74'' divide the interior of the device 7 into four compartments 75, 76, 77, 78. It will be noted that the area of the diaphragm 74' exposed to the effects of pressure is considerably greater than the area of the diaphragms 74 and 74''.

The inlet 71 of the chamber 75 of device 7 is connected to conduit 8. As explained above, there appears on conduit 8 the 200/1000 sec. synchronizing pulse synchronized with the pause *b* between the inhalation phase and the exhalation phase.

A biasing-pressure conduit 11 leads into the compartment 77 of the bistable device 7 and establishes in compartment 77 a biasing pressure of 1 kg/cm², which normally maintains valve member 73 in its illustrated uppermost position. Accordingly, communication between inlet 71 and outlet 71' will be blocked, and when the synchronizing pressure pulses appear on synchronizing line 8 and are applied to the inlet 71 of device 7, no output signal will be developed at the outlet 71' thereof.

However, in the event that the pressure in the patient's lungs during either the inhalation period *a* or the pause period *b* falls between the predetermined minimum value associated with the units 5 and 6, then a 1.4 kg/cm² pressure signal will appear on line 67 (as explained before), and this 1.4 kg/cm² pressure will accordingly become established in compartment 76, overcoming the 1 kg/cm² pressure in compartment 77 and thereby moving the valve member 73 to its lowermost position. If the valve member 73 moves to the lowermost position during the existence of a 1.4 kg/cm² synchronizing pulse at inlet 71, then a 1.4 kg/cm² output pulse will appear at outlet 71'. Clearly, this will occur only if the pressure in the patient's lungs falls below the aforementioned minimum value during the

pause period *b*. If the pressure in the patient's lungs falls below the predetermined minimum during the inhalation period *a*, no output pulse will appear at outlet 71' because there will be no 1.4 kg/cm² synchronizing pulse at inlet 71.

The 1 kg/cm² biasing pressure established in compartment 77 is utilized solely to establish a biasing pressure. Accordingly, a simple biasing spring could be substituted for the use of the pressurized biasing gas. It will be understood by those skilled in the art that the 1.4 kg/cm² pressure of the synchronizing pulse at inlet 71 cannot of itself move the valve member 73 down, although it is higher than the 1 kg/cm² biasing pressure, because of the small area upon which the 1.4 kg/cm² pressure acts, compared to the area of diaphragm 74' upon which the 1 kg/cm² biasing pressure acts.

In any event, if the pressure in the patient's lungs should happen to be lower than the preselected minimum, and during the pause period *b* in particular, then an output pressure pulse will appear at outlet 71' and be transmitted by conduit 79 to inlet 92 of bistable device 9.

Incidentally, it is noted that this transmitting conduit 79 is connected to the inlet 72 of the device 7. Accordingly, when the valve member 73 of device 7 is in its illustrated position, conduit 79 communicates with the atmosphere via inlet 72 and outlet 72', the latter being open to the atmosphere. This positively prevents the development of a pressure pulse on the output line 79 so long as the valve member 73 is in its illustrated position.

The bistable device 9 is structurally similar to the bistable device 7 described before. The device 9 is comprised of a housing having inlets 91 and 92, with associated outlets 91' and 92'. The device has a valve member 83 mounted on three flexible diaphragms 84, 84', 84'', which divide the interior of the device 9 into four compartments or chambers 85, 86, 87 and 88. A biasing pressure conduit 99 leads into the compartment above diaphragm 84'' and maintains that compartment at a biasing pressure of 1 kg/cm². This biasing pressure serves to normally maintain the valve member 83 in its illustrated uppermost position.

The inlet 91 of the device 9 is connected to a source of 1.4 kg/cm² pressure, via a pressure conduit 12 and a three-port valve 43. Valve 43 has a port 14 which communicates with the atmosphere, and is provided with a pushbutton 43'. Normally, the pressure in conduit 12 is communicated to inlet 91. However, when pushbutton 43' is pressed, the position of the valve is changed, so as the conduit 12 is closed and the inlet 91 is communicated to the atmosphere.

It will be understood that, normally, valve member 83 maintains its illustrated position despite the greater pressure at its upper surface than at the supporting diaphragm 84', because the 1.4 kg/cm² acts upon a lesser surface area than the 1 kg/cm² biasing pressure.

Now, if the 1.4 kg/cm² pressure pulse discussed above appears on the conduit 79, and is established in the compartment 88, the pressure in outlet 92' will rise to 1.4 kg/cm² and will be transmitted via conduit 15 to an alarm system 10, comprised in this embodiment of a light bulb and a horn. The light bulb and horn may be provided with pressure-responsive electrical switches and may be electrically operated.

Moreover, a self-locking action occurs. Specifically, the 1.4 kg/cm² pressure in line 15 is communicated not

only to the warning system 10, but also to the compartment 86 of the device 9. The 1.4 kg/cm² pressure in compartment 86 overcomes the 1 kg/cm² biasing pressure in the compartment immediately below, and the valve member 83 moves downwardly. As a result, 1.4 kg/cm² pressure is established in compartment 85. Since the outlet 91' of compartment 85 communicates with the compartment 86 immediately below, the 1.4 kg/cm² pressure in compartment 85 will be maintained in compartment 86 immediately below, even in the event that the 1.4 kg/cm² pressure pulse on line 79 terminates, which of course it will at the end of the pause period *b*.

The energization of the alarm and the warning light will summon personnel to the installation to correct the malfunction or other difficulty. During this time it may be desired to terminate the warning signals, and for this purpose the pushbutton 43' is provided. When pushbutton 43' is depressed the 1.4 kg/cm² pressure in the inlet 91 is diverted to exhaust port 14, thereby terminating the self-locking action just mentioned.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of logic circuits and constructions differing from the types described above.

While the invention has been illustrated and described as embodied in an arrangement for monitoring the operation of an artificial respiration machine, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention. The same apparatus described in connection with FIGS. 1 to 5 can be used for the control of the pressure into the patient's lungs and in the pause *b* to avoid that said pressure overcomes the maximum pressure value dangerous for the patient, only by inverting the connections of pipes 11 and 67 to the device 7.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims:

1. An artificial respiration system comprising, in combination, respirating means for alternately forcing air into the lungs of a patient during an inhalation period and permitting outflow of air from the lungs of the patient during a subsequent exhalation period; synchronizing means for generating a synchronizing signal indicative of the time intermediate said inhalation period and said exhalation period; warning means for issuing a warning signal; pressure-detecting means for detecting when the pressure of air in the lungs of the patient falls below a predetermined value; and activating means connected to said synchronizing means for receipt of said synchronizing signal and connected to said pressure-detecting means and operative for causing said warning means to issue a warning signal if the pressure detected by said pressure-detecting means falls below said predetermined value during the time of

receipt by said activating means of said synchronizing signal.

2. The system defined in claim 1, wherein said synchronizing means comprises control means connected to said respirating means for controlling the sequence of operation of the same and operative for generating a first signal to cause said respirating means to force air into the lungs of the patient and operative for generating a second signal to cause said respirating means to permit outflow of air from the lungs of the patient and operative for generating said synchronizing signal intermediate said first and second signals.

3. The system defined in claim 1, wherein said respirating means comprises inhalation conduit means for carrying air into the lungs of the patient and a source of ventilation gas connected to said inhalation conduit means at one end of said inhalation conduit means and operative for establishing a predetermined pressure in said inhalation conduit means, and exhalation conduit means for carrying air out of the lungs of the patient, valve means for selectively establishing communication between the lungs of the patient and either said inhalation conduit means or said exhalation conduit means, said pressure-detecting means comprising means for detecting when the pressure of air in said inhalation conduit means falls below a predetermined value, and wherein said synchronizing means comprises control means connected to said respirating means for controlling the sequence of operation of the same and operative for generating a first signal to cause said valve means to establish communication between said inhalation conduit means and the lungs of the patient and cause said source to establish said predetermined pressure in said inhalation conduit means and operative for generating a second signal to cause said valve means to establish communication between said exhalation conduit means and the lungs of the patient and operative for generating said synchronizing signal intermediate said first and second signals to maintain communication between said inhalation conduit means and the lungs of the patient and simultaneously prevent said source from establishing said predetermined pressure in said inhalation conduit means so that the pressure established in said inhalation conduit means intermediate said inhalation and exhalation phases will be dependent upon the pressure in the patient's lungs.

4. The system defined in claim 1, wherein said pres-

sure-detecting means comprises means for generating an insufficient-pressure signal when the pressure of air in the lungs of the patient falls below a predetermined value, and wherein said activating means comprises an AND-gate having one input for receipt of said synchronizing signal and having another input for receipt of said insufficient-pressure signal and having an output connected to said warning means and being operative for activating said warning means when an insufficient-pressure signal and a synchronizing signal are concurrently present at said inputs of said AND-gate.

5. The system defined in claim 1, wherein said activating means comprises manually operable means for deactivating said warning means.

6. The system defined in claim 1, wherein said activating means comprises bistable means operative when in one of the two states thereof for causing said warning means to generate a warning signal and operative when in the other of the two states thereof for maintaining said warning means non-activated, and means for triggering said bistable means into said other of the two states thereof if the pressure detected by said pressure-detecting means falls below said predetermined value during the time of receipt by said activating means of said synchronizing signal.

7. The system defined in claim 1, wherein said activating means further comprises manually operable means for resetting said bistable means to said one state thereof.

8. A method of artificial respiration, comprising, in combination, the steps of first forcing respiration gas into the lungs of a patient during an inhalation period, then during a subsequent pause period terminating the forcing of air into the patient's lungs but without permitting exhalation by the patient during such pause period, and then permitting outflow of air from the patient's lungs during a subsequent exhalation period; generating synchronizing signals during the pause periods; and generating a warning signal if the gas pressure in the patient's lungs falls below a predetermined value during generation of one of the synchronizing signals.

9. The method defined in claim 8, wherein said step of generating a warning signal comprises generating a warning signal if and only if the gas pressure in the patient's lungs falls below a predetermined fixed value during generation of one of the synchronizing signals.

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