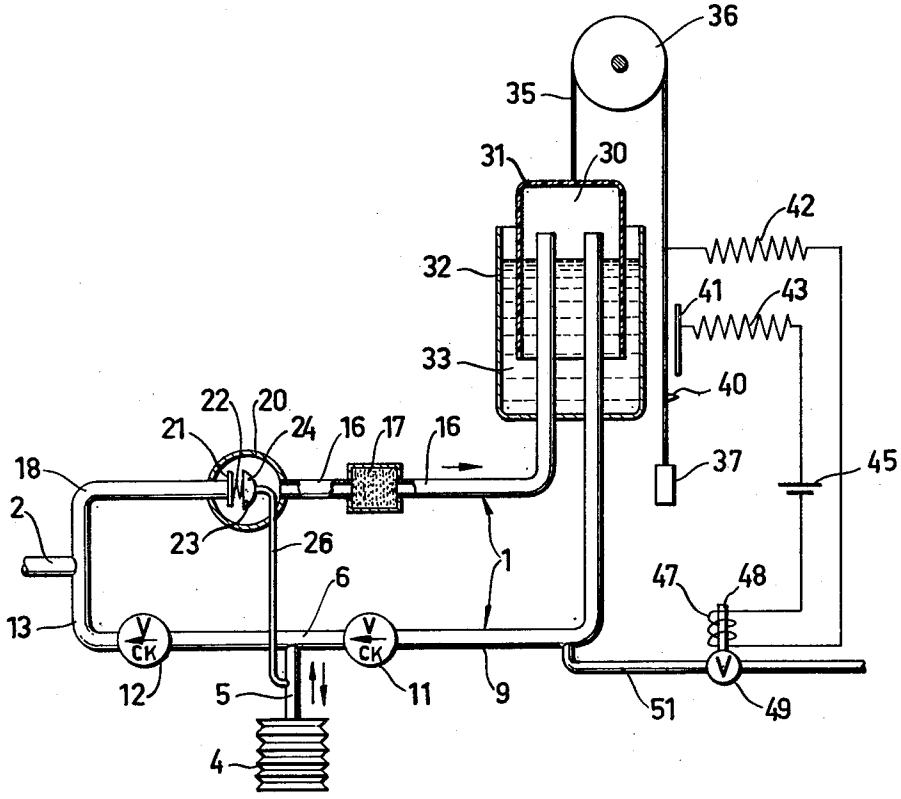
March 24, 1964 CARL-GUNNAR D. ENGSTRÖM 3,126,001

ARRANGEMENT IN RESPIRATORS

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Fig. 1

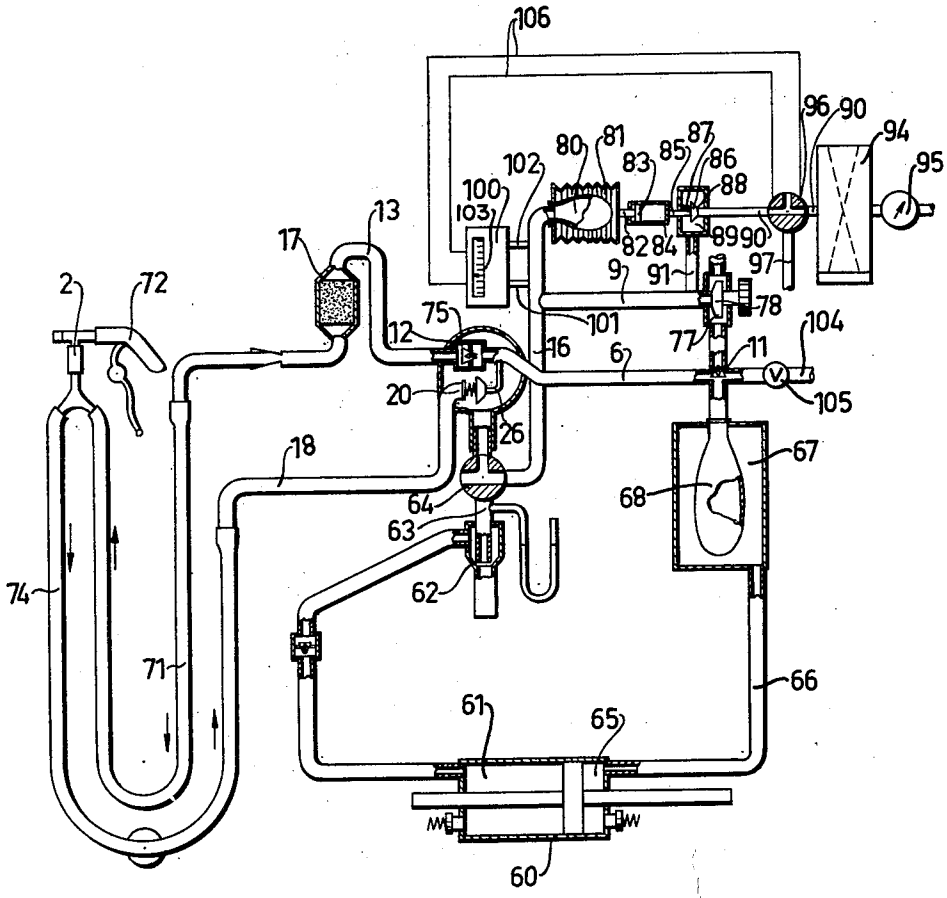


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Fig.2



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Fig. 3

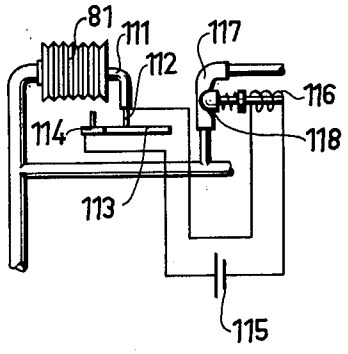


Fig. 4

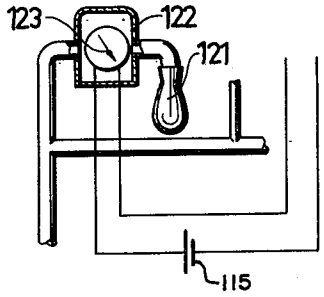


Fig. 5

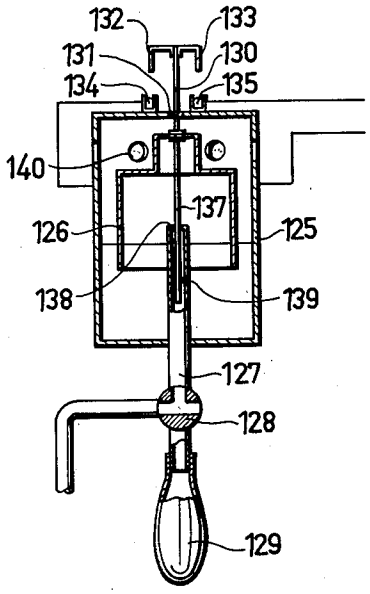
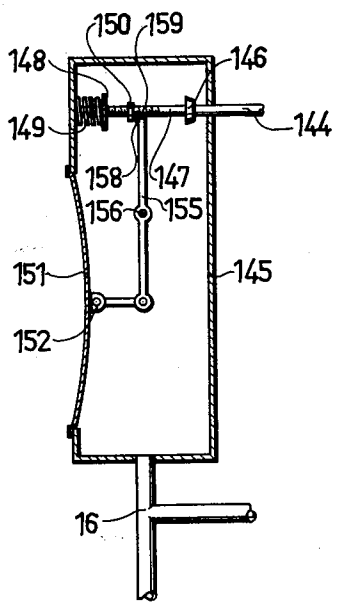


Fig. 6



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3,126,001

ARRANGEMENT IN RESPIRATORS

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Claims priority, application Sweden Sept. 16, 1959
11 Claims. (Cl. 128—29)

The present invention relates to respirators for artificial respiration and/or giving narcosis and is more particularly concerned with respirators having a closed gas system. In such respirators the body of respiratory gas is circulated in a closed circuit, including the lungs of a patient, by means of a propelling member which intermittently forces a given quantity of the gas in a high pressure portion of the circuit at superatmospheric pressure into the patient's lungs thus forming an active inhalation or inspiration phase. In the lungs the gas mixture is deprived of a part of its contents of oxygen and, as the case may be, of anesthetic gas, such as laughing gas, and instead takes up some carbon dioxide. This gas mixture in the following exhalation or expiration phase is passed back into the respirator system either passively by the natural compression of the lungs or actively by a negative pressure created in the respirator, as by the action of the intermittently working propelling member, or both passively and actively. The gas mixture having thus completed one respiratory cycle will then be forced into the lungs again, and the gas body performs a pulsating movement in the respirator circuit. In a respirator with closed gas system and at steady state a substantial part of the gas circulates without being appreciably altered as to its amount, and this is especially the case in regard to such constituents that are not absorbed in the lungs such as laughing-gas when the body of the patient is saturated therewith, while oxygen is absorbed by the lungs and thus leaves the gas system. It is true that in lieu of oxygen carbon dioxide released from the lungs is introduced into the gas system correspondingly, but this is only temporary, since the gas mixture is conveyed through an absorber in which carbon dioxide is absorbed. As a consequence the gas quantity in the system is reduced in each breathing-cycle and, therefore, the respiratory gas body has to be replenished.

It is an object of the present invention to provide means for automatic compensation of the amount of oxygen or, if desired, any other gas consumed in the system, while the pumping members of the respirator force the respiration gases pulsating through the system. A special object of the present invention is to attain a high degree of accuracy in such compensation. It is also an object of the invention to provide a simple and reliable device for dosage of gas into a gas pulsating in a closed gas system. A further object is to provide means well adapted for simultaneous measuring and control of the oxygen consumption.

The respirator according to the invention comprises a closed circuit for circulating respiratory gas, which circuit comprises a high pressure portion and a low pressure portion, an attachment for alternatingly connecting said high pressure portion and said low pressure portion with the lungs of a patient, an inlet for respiratory gas opening into said circuit, a member controlling said inlet, a propelling member adapted intermittently to press a portion of the gas in said high pressure portion into the patient's lungs, thereby creating an inhalation phase, valve means arranged to close the connection between the patient's lungs and said low pressure portion of the circuit during said inhalation phase and to permit opening of said connection to the low pressure portion during the exhalation phase following said inhalation phase thus permitting the expiration gas to enter said low pressure portion, valve

means controlling one way gas flow from the low pressure portion to the high pressure portion, said propelling member causing the respiration gas to circulate in a pulsating manner, and an impulse member connected to said low pressure portion responsive to variations of the gas quantity in said low pressure portion, said impulse member being connected to the control member for said inlet for respiratory gas so as to actuate said control member and thus govern the supply of gas through the inlet. This supply governor or supply control member consists suitably of a valve or a pumping device, which is actuated by impulse from a member, such as a bellows, bladder or membrane, connected to the system with the pulsating gas and adapted to follow the pulsations. The respirator may, if desired, be provided with a gas meter or another device for recording the amount of gas streaming to and/or from said governor. Said valve may be a pure cut-off valve, but it may as well be a throttle-valve or a regulation-valve. Respiration gas, such as oxygen, may be supplied to any portion of the closed circuit from any suitable source of such gas. If the gas is obtained under super-pressure a valve may be used to control the gas inlet, whereas a pump is required if the gas source is of atmospheric pressure. The gas, such as oxygen, is preferably supplied from a spirometer or a gas meter, for example, according to the Patent No. 3,075,384 if measuring of the oxygen consumption is concerned.

According to a preferred embodiment of the present invention the governor, i.e. the valve or the pumping device is electro-magnetically operated and the pulse-following member (which is influenced by the pulsating gas), is provided with an electric contact member oscillating in time with the pulses therein and arranged to close the circuit for the governor, when due to the reduction of the gas volume in the closed system, the gas volume enclosed in the pulse-following member, or supplied thereto at the pulsation, reaches a predetermined minimum.

According to another embodiment the operation is carried out mechanically in such manner that a part of the pulse-following member oscillates in time with the pulses with relatively large amplitudes in different portions of a path according to the amount of gas passing to and from the pulse-following member, said portion being mechanically connected with the closing part of the valve so that said part opens the valve when the above mentioned predetermined minimum volume is reached.

The invention will now be explained in more detail by reference to some embodiments illustrated on the attached drawings, it being understood, however, that the invention is not limited thereby.

In the drawings FIGS. 1 and 2 are diagrammatic views of respirator assemblies comprising dosage devices according to the present invention and in FIGS. 3–6 there are shown different embodiments of impulse and controlling members for such devices.

A quite simple and therefore particularly illustrative embodiment is shown in FIG. 1. A pipe system generally designated by the reference numeral **1** forms a closed circuit for the respiratory gas and has an attachment **2** connecting it to the lungs of a patient. A propelling member in the form of a bellows **4** is connected by means of a pipe **5** to a pipe **6** constituting a high pressure portion of the closed circuit. The high pressure portion **6** is separated from a pipe **9** of the low pressure portion by a non-return valve **11** permitting passage only from the low pressure to the high pressure portion. Another non-return valve **12** is provided between pipe **6** and a conduit **13** connecting pipe **6** with the attachment **2**, this valve permitting pressure gas introduced by bellows **4** to pass into the lungs but preventing expiration gas from the lungs from entering the pipe **6** when there prevails a negative pressure at the suction stroke of the

bellows. The low pressure portion of the circuit also comprises a pipe 16 containing a carbon dioxide absorber 17. This pipe 16 is connected to attachment 2 by a pipe 18 and is provided with a special non-return valve 20 preventing passage of gas from pipe 16 to pipe 18 but normally permitting passage from pipe 18 to pipe 16, i.e. permitting expiration gas to pass into the low pressure portion (16) by moving valve disk 21 against the pressure of spring 22 mounted on a membrane 23 covering the opening of the box 24. This box communicates through the thin pipe 26 with pipe 5, so that the superatmospheric pressure caused by the pressing of bellows 4 will be transferred to the box 24 with the result that membrane 23 is bulged out so as to compress spring 22 and thus press disc 21 hard against the opening of pipe 18, thereby preventing inspiration gas from being pressed from pipes 6, 13, and 18 into the low pressure portion 16 when bellows 4 is compressed.

The low pressure portion pipes 9 and 16 open in the gas space 30 of a gasometer 31 vertically movable in the tank 32 filled up to a suitable height with a liquid 33. The gasometer 31 hangs on one part of a wire 35 passed over a small wheel 36, and a counterbalancing weight 37 hangs at the end of the other part which also carries a contact pin 40 cooperating with a contact rod 41. Electrical conductors 42 and 43 connect wire 35 and contact pin 40 on the one hand and contact rod 41 on the other hand with an electric current source 45. In the circuit is also an electromagnetic coil 47 arranged to attract the stem 48 of a needle valve 49 positioned in and controlling the inlet pipe 51 for respiratory gas. Pipe 51 opens in pipe 9, but it may, as a matter of principle, open anywhere in the closed circuit of the respirator. The control member 47–49 may, of course, be replaced by equivalent means obvious to those skilled in the art.

When operating the respirator of FIG. 1 bellows 4 is compressed and pulled out in time with the desired breathing rhythm by hand power or by any mechanical means. Thereby gas is pressed through pipes 6 and 13 and attachment 2 to the patient's lungs at the compression phase, valve 12 being opened and valve 20 as well as valve 11 being closed by the action of the pressure. As soon as the pulling starts the pressure in box 24 is released and the lungs can press the gas mixture back through pipe 18 and valve 20 to pipe 16 and gasometer 31 which is inflated and raised to some extent. The pulling of bellows 4, however, will cause the gas to be sucked back into the high pressure portion 6 so that the gasometer 31 will sink again. The gasometer and consequently the contact pin 40 will thus perform a rocking or oscillating movement in accordance with the pulsations caused by the actuation of the bellows. The total quantity of gas in the system will be gradually reduced as oxygen and possibly other gases are consumed in the lungs and carbon dioxide is removed in the absorber 17. Therefore, apart from the oscillations, the gasometer will gradually sink and the pin 40 gradually rise, namely until contact is established between pin 40 and rod 41. At that moment impulse is given to the governor valve 49 which is opened so that fresh gas can be admitted to replenish the system.

In FIG. 2 a more perfect embodiment is illustrated, which shows an arrangement of the present invention applied to a respirator equipped also for the open gas system. The gas propelling member therefore consists of a double-acting compressor 60, the left cylinder chamber 61 of which operates a venturi-arrangement 62 by which suction is established in pipe 63. If the three-way valve 64 is turned to connect the respirator circuit with pipe 63 the negative pressure there will give rise to an active expiration of the lungs. However, with the valve 64 in the position illustrated, the repirator can be used according to the invention and then the right cylinder 65 of the compressor is used. In moving to the right the double-acting compressor 60 compresses the gas in the pipe 66 and the vessel 67 containing a bladder 68 filled with respiratory or breathing-gas. At the compression the bladder is fully pressed together, so that the breathing-gas therein is forced into the pipe 6 bringing about gas transport in the system through the non-return valve 12, the pipe 13 containing the carbon dioxide absorber 17 and then through the hose 71 to attachment 2 and the breathing-mask or the breathing-cannula 72 and thence to the lungs of the patient. From the lungs the expiration gas, generally by passive expiration only in operation with a closed system, will pass through the hose 74, the pipe 18 and the valve 20 to the housing 75. The valve 20 is constructed as described in connection with FIG. 1. The system being closed the exhalation gas then passes through the three-way valve 64 to pipe 16 and pipe 9 of the low pressure portion of the circuit. Pipe 9 has an opening in the chamber 77, which may be closed more or less by valve 78 so as to regulate the flow of gas when gas may be sucked into the conduit 6 through a non-return valve 11, when the compressor 60 performs a suction stroke.

Conduit 9 is in this case connected via conduit 16 with the bladder 80 in the bellows 81 both of which expand during the exhalation phase and contract when gas is sucked into conduit 6 during the suction phase of the compressor. By this means the quantity of gas in the system can be kept at a lower value than in case only a bellows is used, which is of importance particularly in case an automatic gas analyser is used. The bellows thus performs a pulsating movement which substantially follows the pulsation in the closed gas system of the respirator If the total gas volume in the system were constant the bellows should always perform practically identical pulsating movements and the rod 82 fixed at the end thereof would oscillate in a given path with its end plate 83 oscillating with identical amplitudes between fixed extremes in the cylinder 84. The rear end of this cylinder 84 is connected by a rod 85 to a valve disc 86, which is lightly pressed by the spring 87 against the opening 88 of the dosage pipe 90 opening in housing 89. If the gas volume in the system is reduced due to consumption of oxygen in the patient's lungs, the bladder 80 and bellows 81 will receive a smaller amount of gas in every pulsation, because they are the elastic member in the system which has to take up the volume changes in the system, and with a smaller amount of gas entering the bladder and bellows it will follow that the end plate 83 will perform its oscillating movements in another portion of the oscillation path than at greater filling of the bellows. At last, when the volume of the bellows has reached its minimum, the end plate 83 in the inhalation phase will abut against the end wall of the cylinder 84 and, against the pressure of the spring 87, move the disc 86 from the pipe 90, so that oxygen is admitted from there into the housing 89, and pipe 91 to pipe 9, whereby the oxygen consumption is compensated and that amount of gas becomes correct which is sucked into pipe 6 through the space 77 with the aid of the compressor 60.

The dosage pipe 90 may convey oxygen from an arbitrary oxygen source. The respirator according to the present invention, however, having special regard to medical investigations and surgical operations in which cases the oxygen consumption must be carefully controlled, pipe 90 may with advantage be connected to a spirometer or gas meter 94, preferably of the kind set forth in the Patent No. 3,075,384. By the use of such spirometer or gas meter the operator easily may control the oxygen consumption on a scale, for example, of a pressure gauge 95 By turning the three-way valve 96 the gasometer 94 when required, may be filled with oxygen from conduit 97, which may, for example, be connected with an oxygen container (flask).

It is often important that the operator of the respirator check the composition of the respiratory gas circulating in the system. Therefore, a conventional gas analysing

apparatus 100 may be connected to the circuit, for instance, to the pipe 16 by the tubes 101 and 102, or to the pipe 13 near the patient. The composition is indicated by the pointer 103. Supposing that oxygen is supplied through the meter 94 lack of, for instance, laughing-gas or nitrogen, indicated by pointer 103, can be compensated by manually attaching a source thereof, for instance, to pipe 104 and open valve 105.

It is also possible to keep the composition constant automatically by attaching, in addition to the gas source attached to pipe 90, the other gas source to the pipe 97, and with conventional means connect valve 96 to impulse members responsive to the position of the pointer 103, or generally to the analysis result obtained in the apparatus 100, such members being diagrammatically illustrated by the electrical wires 106.

The dosage assembly (30—49 and 80—90) described above may be replaced by equivalent means. Thus the governor may be actuated electromagnetically as shown in FIG. 3. In this figure there is shown a rod 111 mounted on the movable part of the bellows 81, preferably on the most movable part thereof. This rod carries a contact pin 112, which during the pulsating movements of the bellows oscillates along a path 113. On the critical point of said path, i.e. the point where the dosage is to be carried out, there is a contact bar 114 for an electric circuit. The contact pin 112 and the contact bar 114 are connected to a source of electricity 115 and in the electric circuit formed there is an electromagnetic operating instrument 116 for the opening of the valve consisting of a rubber hose 117 having a spring loaded clip 118. The valve can also be of the kinds shown in FIGS. 1 and 2.

As shown in FIG. 4 the electromagnetic device described above may be equipped with an elastic bladder 121, instead of the bellows, and a gas meter 122, known per se, in the conduit leading to said bladder. Pointer 123 of the gas meter constitutes the contact pin for the electrical circuit.

A further embodiment which is favourable in many respects is shown in FIG. 5. Also in this embodiment the governor in the inlet is actuated electromagnetically and may be constructed in the way described above. The actuating or pulse-following member comprises a tank 125 with a lightweight gas holder or gasometer 126, which may be made of plastic, and a conduit 127 opening in the gasometer and connected with the gas system of the respirator, more particularly with conduit 16 in FIGS. 1 and 2 via a three-way valve 128, by the aid of which the respirator may be connected with an expansion bladder 129 before the dosage assembly is to be used. The gasometer carries a vertical upright 130 which is inserted through an aperture 131 in the roof of the tank 125. The upright carries two downwardly pointing contact pins 132 and 133, which in a given adjustable position contact the mercury in the contact pockets 134 and 135, respectively, when the gasometer arrives at its lower level corresponding to the minimum volume in the closed gas system of the respirator at which fresh oxygen has to be introduced into the system. At the moment this contact is obtained the electric circuit is closed and the dosage valve opened so that oxygen is introduced into the system. For guiding the gas holder a rod 137 is fixed centrally in the roof thereof and passed through two slides 138 and 139 fixed to the tube 127. In the top part of the tank there is a number of openings 140 by which the interior of the tank communicates with the atmosphere so that an excess of air may be expelled from the system through the trap constituted by the gas holder, for instance, in case of a vigorous expiration.

A further embodiment of a wholly mechanical dosage assembly is illustrated in FIG. 6, which shows the principle for a device having a membrane as pulse-following member. The low pressure portion conduit 16, as well as the gas inlet pipe 144 (cfr. 51 and 90) open here into a valve housing 145. The opening of pipe 144 can be shut by the valve disk 146 having a stem 147 and a plate 148, engaged by a spring 149 in order to keep the disk 146 against the opening of the pipe and prevent inflow of gas, e.g. oxygen. On the stem there is also a nose 150. The housing 145 is provided with a large opening covered by a membrane 151 on the inside of which, preferably at the central part thereof, there is an attachment 152 for a lever 155 pivotally supported on a pin 156. The lever 155 obviously oscillates with the pulses of the gas body in the housing 145 and the abutment 158 thereof engages the nose 150, when due to the fact that the membrane 151 is forced inward as a consequence of the reduction of the gas volume in the system, the oscillating movements of the abutment 158 gradually approach the nose 150. If stem 147 and nose 150 are provided with threads 159 the critical opening position may be adjusted by moving the nose on the stem.

Although the invention has been described hereinabove with special reference to dosage of oxygen to the respirator other gases that may be contemplated for the operation of such a respirator may obviously be dosed in the same way. Thus narcotical cases may be dosed, which may be of interest in the period of time during which the system of the patient is getting saturated with narcotical gas.

It is obvious from the above description that the details of the devices of the invention can be varied within wide limits and combined in different ways. Thus the pulsation-following member directly communicating with the gas circuit may consist of a bladder or the like enclosed in a container with rigid walls and filled with, for instance, air which in turn is used for actuating the impulse members.

It will be understood from the above description that the lungs, the propelling member (bellows, bladder) and the impulse or pulsation-following member (bellows, bladder, gasometer) are the only parts of the closed gas circuit, apart from the gas itself, that are elastic, the rest of the circuit having rigid walls, in order that the accuracy of the impulse-giving shall be high.

What is claimed is:

1. A respirator for artificial respiration or narcosis comprising a system of conduits including an attachment adapted to be connected with a patient's lungs, said system comprising a high pressure portion and a low pressure portion, said attachment being adapted alternately to establish connection of said high pressure portion and said low pressure portion with the lungs of the patient, an inlet for respiratory gas fitted to and opening into a conduit of said system, a control member controlling flow of gas into said inlet, a propelling member adapted intermittently to press a portion of the gas in said high pressure portion through said attachment thereby creating an inhalation phase, valve means arranged to close communication between said attachment and said low pressure portion of said system of conduits during said inhalation phase and to permit opening of said communication to the low pressure portion during the exhalation phase following said inhalation phase thus permitting the expiration gas to enter said low pressure portion, valve means controlling one way gas flow from the low pressure portion to the high pressure portion, said propelling member causing respiration gas to circulate in a pulsating manner, and an enclosure comprising a gas space connected to said low pressure portion, walls defining said enclosure of an extendible character rendering the size of said enclosure responsive to variations of the gas quantity in said low pressure portion, an impulse member operatively connected to an extensible portion of said walls, said impulse member being connected to said control member to actuate it and thus govern the supply of gas through said inlet.

2. A respirator as claimed in claim 1 in which said impulse member comprises an inflatable container.

3. A respirator as claimed in claim 1 in which said control member is a valve.

4. A respirator as claimed in claim 1 in which said control member is a pumping device.

5. A respirator as claimed in claim 2, in which said impulse member comprises a bladder enclosed in a bellows provided with the means for actuating said control member.

6. A respirator as claimed in claim 1 in which said control member for the inlet of respiratory gas is provided with an electromagnetic actuating member including an electric circuit, and said impulse member is provided with a contact member arranged to move along a path according to the movements of the impulse member responsive to the gas variations and adapted to close said electric circuit when in a predetermined position in said path.

7. A respirator as claimed in claim 1 in which said impulse member is provided with an abutting member secured thereto and arranged to move along a path according to the movements of said impulse member responsive to the gas variations and adapted mechanically to actuate said control member when in a predetermined position in said path.

8. A respirator as claimed in claim 1 comprising at least two sources of respiratory gases alternatively attachable to a common impulse member over a multi-way gas

switch member which is connected to a gas analyser so as to be actuated by an indicator of said gas analyser responsive to the gas composition registered by said gas analyser.

9. A respirator as claimed in claim 6 in which said contact member of said impulse member is adapted to close said electric circuit when due to the reduction of the total amount of gas in the closed gas system the volume of the gas in said impulse member attains a predetermined minimum.

10. A respirator as claimed in claim 7 in which said abutting member is adapted mechanically to actuate said control member when due to the reduction of the total amount of gas in the closed gas system the volume of the gas in said impulse member attains a predetermined minimum.

11. A respirator as claimed in claim 8 in which said two sources of respiratory gases have a common control member.

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