

[54] **VALVE AND CIRCUIT FOR
INTERMITTENT POSITIVE PRESSURE
BREATHING APPARATUS**

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[58] Field of Search 137/102, 63; 128/145.6, 145.7, 128/145.5, 145.8, 188

[56] **References Cited**

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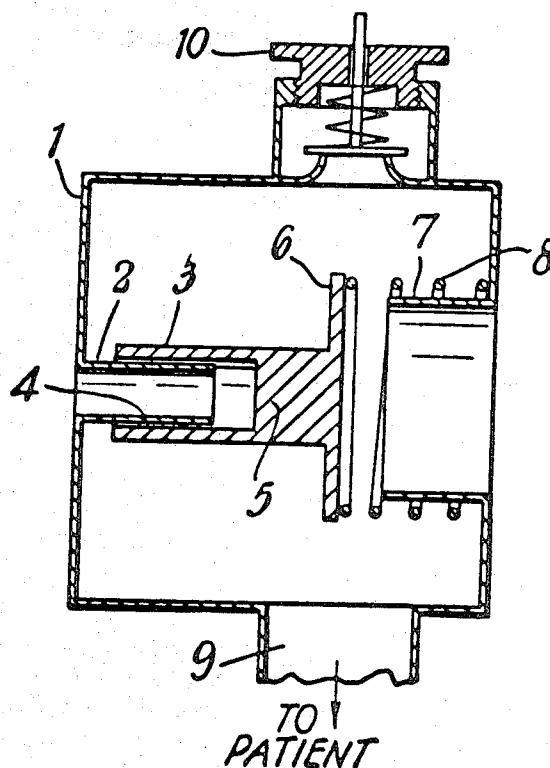
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[57] **ABSTRACT**

An apparatus for producing intermittent positive pressure comprises a high-pressure nutrient gas supply, a valve device connected to the supply and operable by the gas, and a conduit connected downstream of the valve device to lead gas under low pressure towards a patient or a space between a breathing bag and a surrounding casing. The valve device controls gas flow through the conduit and opens and closes with relatively sudden pressure change. The valve device can include a housing having a tubular, high-pressure gas inlet and a low-pressure gas outlet, a member in the housing co-axial with the inlet and longitudinally movable thereon with clearance, a valve closure at one end of said member movable therewith between a first position closing the outlet end of the inlet and leaving open the inlet end of the outlet and a second position closing that inlet end and leaving open that outlet end, a compression spring urging the valve closure into the first position, and a duct communicating with the housing interior and the clearance, and with the open outlet, and leading to outside the housing.

27 Claims, 12 Drawing Figures



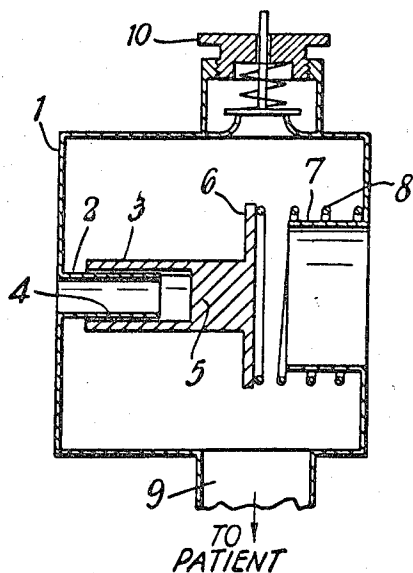


FIG. 1

FIG. 2

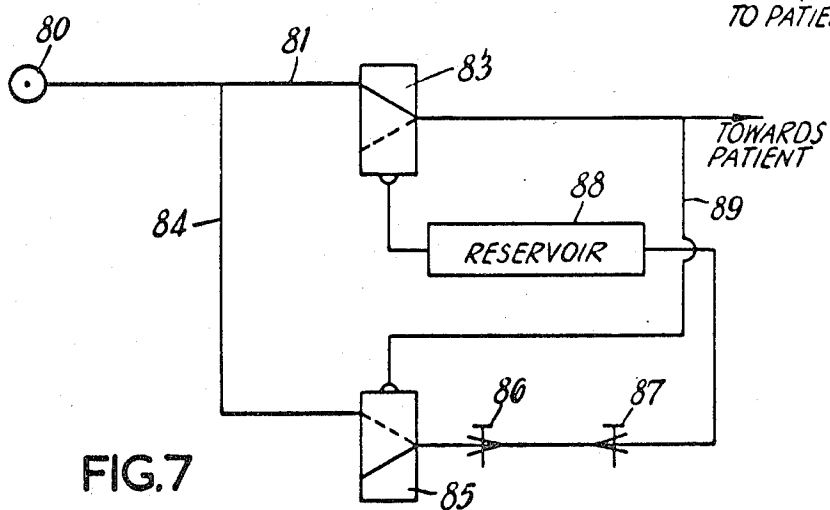
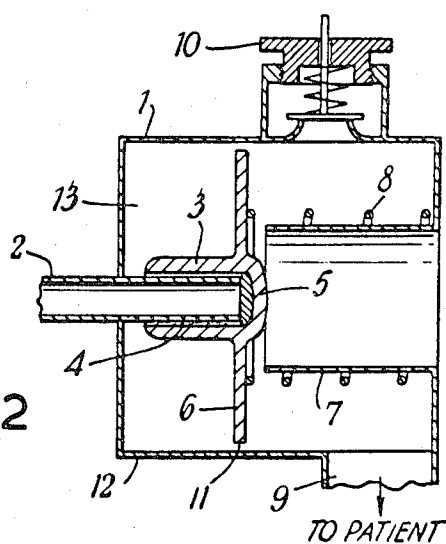


FIG. 7

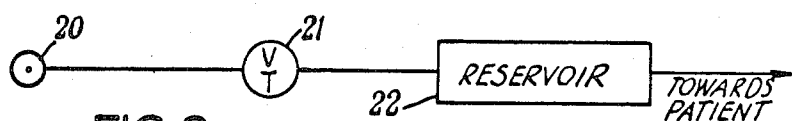


FIG. 3

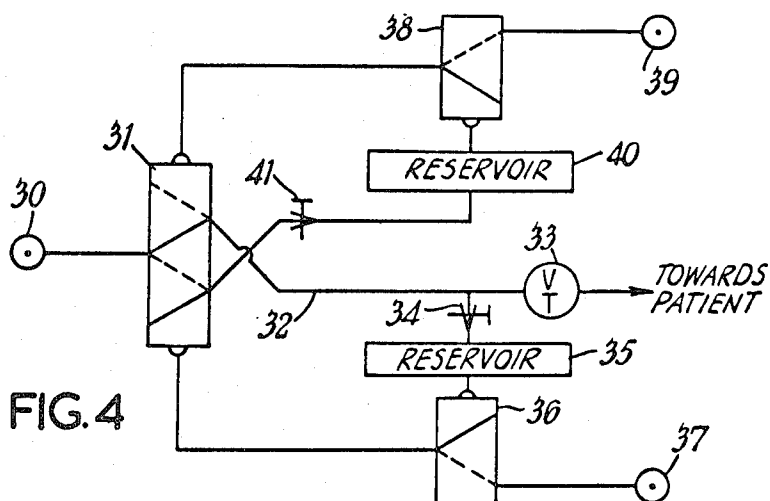


FIG. 4

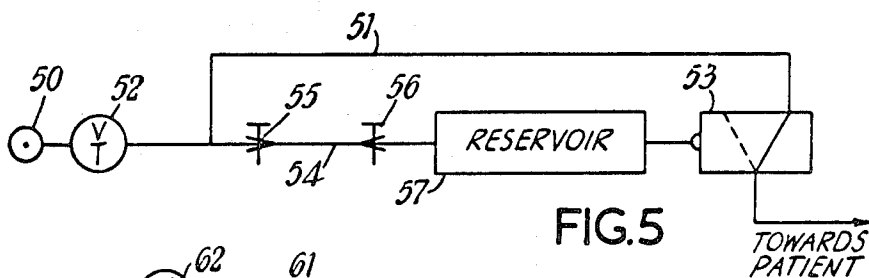


FIG. 5

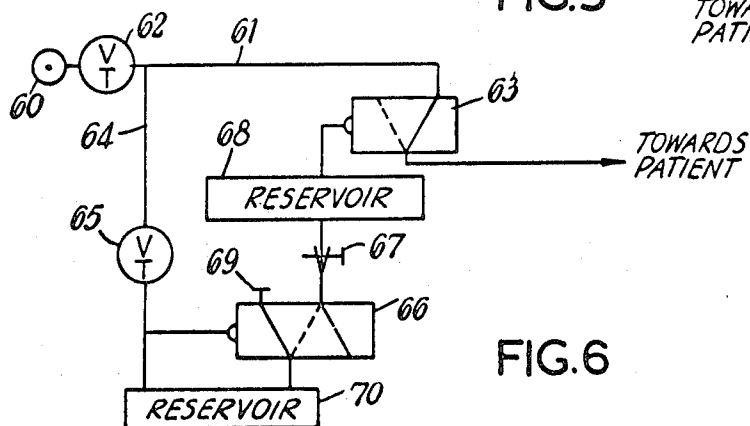


FIG. 6

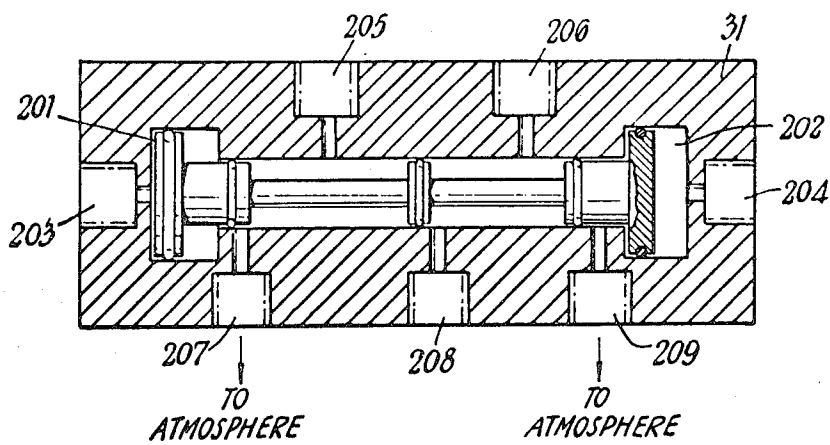
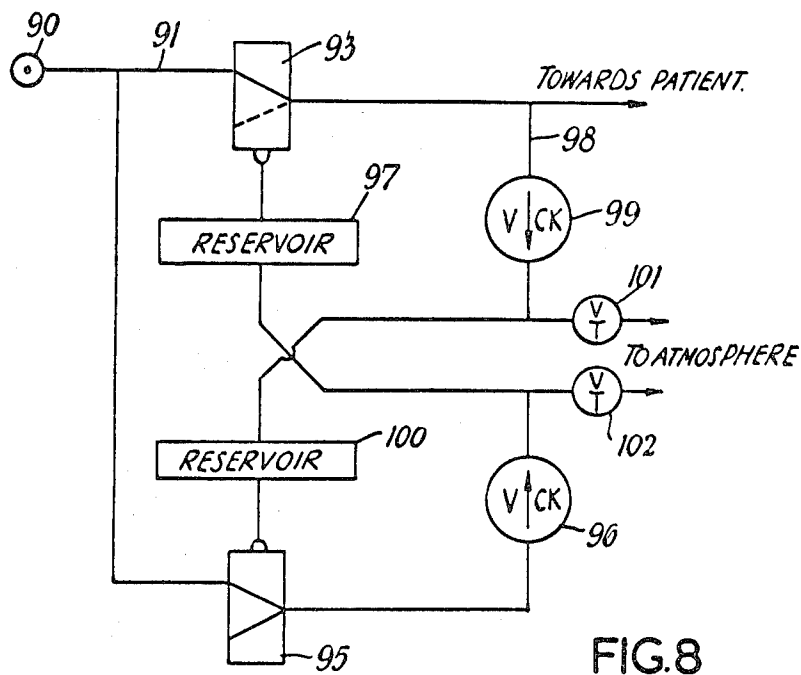
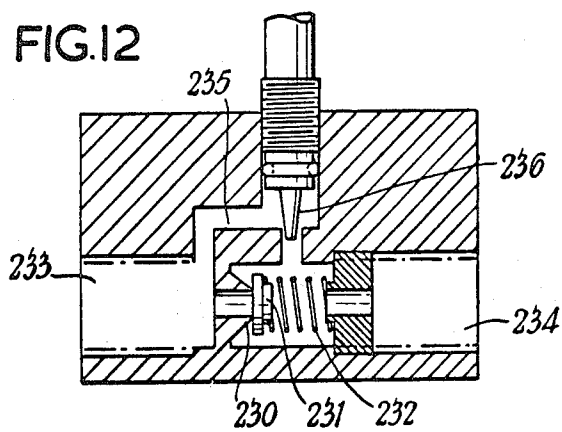
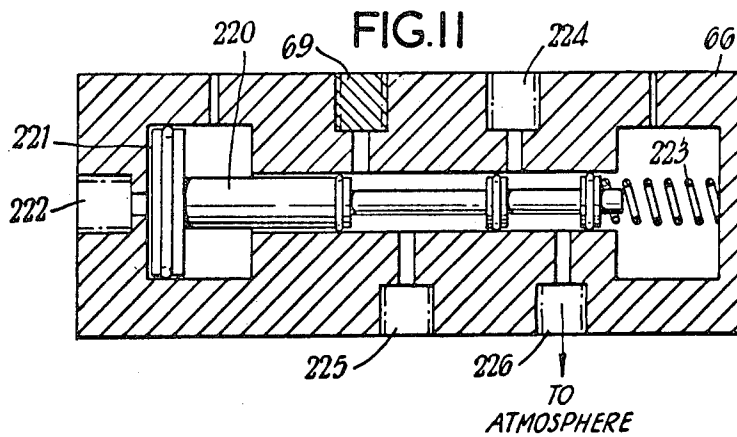
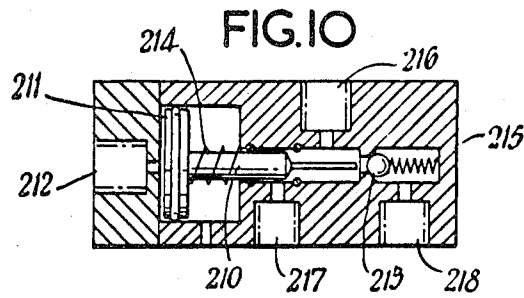


FIG. 9



VALVE AND CIRCUIT FOR INTERMITTENT POSITIVE PRESSURE BREATHING APPARATUS

According to one aspect of the present invention, there is provided a valve device comprising a housing, a high-pressure gas inlet part of said housing of tubular form, a member in said housing co-axial with said inlet part and longitudinally movable relatively to said inlet part, portions of said inlet part and said member defining radial clearance therebetween, a low-pressure gas outlet part of said housing, valve closure means connected to said member at one end of said member and movable, with said member, between a first position in which said means closes the outlet end of said inlet part and the inlet end of said outlet part is open, and a second position in which said means closes said inlet end and said outlet end is open, biasing means urging said valve closure means into said first position, and a duct communicating with the interior of said housing and thus with said clearance, and with said inlet end when the latter is open, and leading to a location outside said housing.

According to another aspect of the present invention, there is provided an apparatus for producing intermittent positive pressure, comprising supply means for supplying gas under high pressure, conduit means connected downstream of said supply means for leading gas under low pressure, and a valve device interposed between said supply means and said conduit means, and operable by gas from said supply means, said valve device controlling gas flow through said conduit means and opening and closing with relatively sudden pressure change.

In order that the invention may be clearly understood and readily carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

FIG. 1 is a diagrammatic sectional view of a valve device of a respiratory apparatus,

FIG. 2 is a view similar to FIG. 1 of a valve device of a modified version of the respiratory apparatus,

FIG. 3 is a diagrammatic view of another part of the apparatus of FIG. 2,

FIGS. 4 to 8 are respective diagrammatic views of various apparatus for producing intermittent positive pressure and each capable of use with the apparatus of FIG. 1, and

FIGS. 9 to 12 are diagrammatic axial sections through various valves of the apparatuses.

Referring to FIG. 1, the valve device includes a housing 1 having a high-pressure nutrient gas inlet 2 of tubular form. A sleeve 3 encircles the inlet 2 with clearance 4 and is movable longitudinally relatively thereto. The sleeve 3 has integral therewith a member 5 which closes the inner end of the sleeve 3 and is movable towards and away from the outlet end of the inlet 2. Integral with the member 5 is a valve closure member 6 arranged to close a low-pressure gas outlet 7 of the housing 1 leading to atmosphere or to a negative pressure zone. A heavy spring 8 acting between the housing 1 and the member 6 tends to urge the member 5 towards the inlet 2 and to open the member 6. A duct 9 communicating with the interior of the housing and thus with the clearance 4, and with the outlet 7 when the member 6 is open, leads to the patient. A positive pressure relief valve 10 is also mounted on the housing to prevent the occurrence of excess pressure in the interior of the housing. Instead of or additionally to having the gas leaked through a clearance 4, the gas can be leaked through an orifice controlled by any suitable valve means. In any case, it will be appreciated that the minimum throughflow area for gas flowing from the inlet to the duct 9, even when the member 6 is fully open, is small compared to the minimum internal cross-sectional area of the inlet 2 itself.

The version of FIG. 2 differs from that of FIG. 1 mainly in that the member 6 is longitudinally movable, with clearance 11, in a hollow cylindrical portion 12 of the housing 1, whereby a chamber 13 is formed between the housing 1 and the member 6 to that side of the member 6 remote from the outlet 7. A further difference is that the member 5 takes the form of a valve closure pad mounted inside the closed end of the sleeve 3, which acts to guide the movement of the mem-

bers 5 and 6. The valve device of FIG. 1 or 2 serves to reduce the pressure of the nutrient gas from a high positive pressure, i.e., a pressure above 5 lb./in.², to a low positive pressure, i.e., a pressure suitable for regular application to a patient.

With regard to FIG. 3, a high-pressure supply 20 of nutrient gas, for example a bottle or a mains point, supplies gas via an adjustable throttle 21 to a reservoir 22 which is connectable to the inlet 2 of the valve device of FIG. 2. The reservoir 22 need not be a specially provided chamber but could merely be the interior volume of the conduit connecting the throttle 21 to the inlet 2.

In operation of the combined respiratory apparatus of FIGS. 2 and 3, the nutrient gas is continuously supplied to the reservoir 22. When the pressure in the reservoir is sufficient to open the member 5 against the action of the spring 8, the gas leaks through the clearance 4 and the gas pressure builds up in the chamber 13 and acts on the member 6 to close the latter, the gas leaking through the clearance 11 to the patient. The flow into the reservoir 22 is less than the flow out of the reservoir. When the pressure in the reservoir 22 has fallen sufficiently, the spring 8 opens the member 6 and closes the member 5, thus permitting spontaneous or induced exhalation via the outlet 7. Because the area of the member 5 exposed to the pressure in the reservoir 22 when the member 5 is closed is much less than the area of the members 3, 5 and 6 exposed to the pressure in the reservoir 22 and the chamber 13 when the member 5 is open, the member 5 closes at a lower pressure in the reservoir 22 than that at which it opens. If the flow of the gas from the inlet 2 to the chamber 13 is arranged to be relatively constricted, there will be a relatively high pressure in the inlet 2 but a relatively low pressure in the chamber 13 when the member 5 has opened. However, if that flow is relatively free, there will be relatively high pressure in both the inlet 2 and the chamber 13.

With reference to FIG. 4, a high-pressure nutrient gas supply point 30 is connected via a per se known double-acting piston valve 31 to a conduit 32 leading via an adjustable throttle 33 to the inlet 2 of the valve device of FIG. 1 or 2. A branch conduit at a location upstream of the throttle 33 connects the conduit 32 via an adjustable throttle 34 and a reservoir 35 to the control chamber of a per se known spring-return relay valve 36, which can be a piston valve. The throttle 34 controls flow only in the direction from the conduit 32 to the reservoir 35, flow in the opposite direction being preferably uncontrolled. The throttle 34 preferably consists of a valve arranged to throttle flow in both directions, but by-passed by a non-return valve. The valve 36 can connect a gas supply point 37 to one of the control chambers of the valve 31. The other of the control chambers of the valve 31 can be connected, via a valve 38 corresponding to the valve 36, to a gas supply point 39. The control chamber of the valve 38 communicates with the ambient atmosphere via a reservoir 40, a throttle 41 corresponding to the throttle 34, and the valve 31.

In operation of the respiratory apparatus of FIG. 1 or 2 and FIG. 4, the nutrient gas is supplied to the patient via the conduit 32 until sufficient pressure has built up in the reservoir 35 to operate the valve 36 to produce a change-over of the valve 31. This change-over connects the conduit 32 and the reservoir 35 to the atmosphere and the reservoir 40 to the supply 30. Thereupon, the pressure in the inlet 2 drops to allow the spring 8 to open the member 6, thus producing exhalation via the outlet 7. Moreover, the supply point 37 is disconnected from the relevant control chamber of the valve 31 which is thus connected to atmosphere. The pressure in the reservoir 40 increases gradually under the control of the throttle 41 until it is sufficient to operate the valve 38 to connect the relevant control chamber of the valve 31 to the supply point 39, whereupon the valve 31 is again changed-over. The reservoir 40 then exhausts to atmosphere and the valve 38 is again operated, and the supply point 30 recommences supplying gas to the reservoir 35 and the patient.

In the version of FIG. 5, a high-pressure nutrient gas supply point 50 feeds gas via a conduit 51, containing an adjustable

throttle 52 and a per se known spring-return relay valve 53, to the inlet 2. Branching from the conduit 51 between the throttle 52 and the valve 53 is a branch conduit 54 leading to the control chamber of the valve 53. Connected in the conduit 54 are an adjustable throttle 55 controlling flow in one direction only, an adjustable throttle 56 controlling flow in the opposite direction only, and a reservoir 57. In the condition shown, gas is flowing from the reservoir 57 under the control of the throttle 56 into the conduit 51. When the pressure in the reservoir 57 has fallen sufficiently, the valve 53 is thereby operated to cut off the supply of nutrient gas to the inlet 2, whereupon the patient exhales via the outlet 7. Meanwhile, gas commences flowing from the conduit 51 into the reservoir under the control of the throttle 55, until the pressure in the reservoir 57 is sufficient to operate the valve 53 to recommence flow of nutrient gas to the patient.

The basic difference between the version of FIG. 5 and that of FIG. 6 is that, in the version of FIG. 6, the nutrient gas from the reservoir is transmitted to the atmosphere and not to the patient. In FIG. 6, a high-pressure nutrient gas supply point 60 is connected to the inlet 2 via a conduit 61 containing an adjustable throttle 62 and a per se known spring-return relay valve 63. A branch conduit 64 leads from the conduit 61 at a location between the valve 63 and the throttle 62, and via a throttle 65 to the control chamber of a per se known spring-return relay valve 66 and to a reservoir 70. The branch conduit 64 can also be connected, via the valve 66, an adjustable throttle 67, and a reservoir 68, to the control chamber of the valve 63. The throttle 67 controls only flow away from control chamber of the valve 63. In the condition shown, nutrient gas is flowing out of the reservoir 68 to the atmosphere via the valve 66 and under the control of the throttle 67. Moreover, flow of the nutrient gas from the conduit 64 through the valve 66 is blocked at 69. When the pressure in the reservoir 68 has fallen sufficiently, the valve 63 operates to cut off the supply of gas to the inlet 2, whereby exhalation commences. This operation of the valve 63 causes the pressure in the reservoir 70 to increase and operate the valve 66, whereby the conduit 64 is connected to the reservoir 68. Thereupon, nutrient gas flows from the conduit 61 to the reservoir 68 under the control of the throttle 65. When the pressure in the reservoir 68 has risen sufficiently, the valve 63 is thereby operated to connect the supply point 60 to the patient. This causes gas to flow from the throttle 65 and thus causes operation of the valve 66 to re-connect the reservoir 68 to the atmosphere.

The version of FIG. 7 resembles the version of FIG. 5, but is basically different in that, instead of timing control being effected by slight changes in the pressure in the conduit 51 downstream of the throttle 52, it is effected by larger changes between that pressure and atmospheric pressure. In the version of FIG. 7, a high-pressure nutrient gas supply point 80 is connected to the inlet 2 via a conduit 81 containing a per se known spring-return relay valve 83. A branch conduit 84 leads from the conduit 81 at a location between the point 80 and the valve 83 to a per se known spring-return relay valve 85. The conduit 84 can be connected, via the valve 85, two adjustable throttles 86 and 87 and a reservoir 88 to a control chamber of the valve 83. The throttle 86 controls flow in one direction only, whilst the throttle 87 controls flow in the opposite direction only. A branch conduit 89 leading from the conduit 81 at a location downstream of the valve 83 connects the conduit 81 to a control chamber of the valve 85. In the condition shown, nutrient gas is being supplied to the patient via the line 81. Moreover, nutrient gas is flowing out of the reservoir 83 to the atmosphere via the valve 85 and under the control of the throttle 87. When the pressure in the reservoir 88 has fallen sufficiently, the valve 83 operates to cut off the supply of nutrient gas to the inlet 2, whereby exhalation commences and the pressure in the conduit 89 falls sufficiently to permit the valve 85 to operate to connect the conduit 84 to the reservoir 88. The nutrient gas then flows into the reservoir under the control of the throttle 86. When the pressure in the reservoir has increased sufficiently, the valve 83 is operated to re-con-

nect the point 80 to the inlet 2. Thereupon, the pressure in the conduit 89 increases sufficiently to operate the valve 85 to re-connect the reservoir to the atmosphere. Alternatively to the construction shown, either the throttle 87 could be arranged to control flow in both directions, or it could be arranged in the outlet to atmosphere of the valve 85.

The version shown in FIG. 8 is based on that of FIG. 7, except that there are two continuous leaks to atmosphere. A high-pressure nutrient-gas supply point 90 is connected to the inlet 2 via a conduit 91 containing a spring-return, single-acting, relay valve 93 known per se. A branch conduit 94 leads from the conduit 91 at a location between the valve 93 and the point 90 to a spring-return, single-acting, relay valve 95 known per se. The conduit 94 can be connected, via the valve 95, a check valve 96, and a reservoir 97, to a control chamber of the valve 93. A branch conduit 98 leading from the conduit 91 at a location between the valve 93 and the inlet 2 extends via a check valve 99 and a reservoir 100 to the control chamber of the valve 95. At a location between the check valve 99 and the reservoir 100, the conduit 98 has a continuous leak to atmosphere via an adjustable throttle 101. Similarly, the conduit 94 has, at a location between the check valve 96 and the reservoir 97, a continuous leak to atmosphere via an adjustable throttle 102. The apparatus is shown in a condition in which the nutrient gas is being supplied to the patient via the conduit 91. Some of the gas is flowing into the branch conduit 98, the resultant pressure in the reservoir 100 maintaining the valve 95 in the position in which the reservoir 97 is disconnected from the nutrient gas supply. Gas from the branch conduit 98 is slowly leaking to atmosphere through the throttle 101, while gas from the reservoir 97 is slowly leaking to atmosphere through the throttle 102. As the gas leaks to atmosphere from the reservoir 97, the pressure therein of course drops. When the pressure in the reservoir 97 has dropped sufficiently, the valve 93 operates to cut off the supply of nutrient gas to the patient, and then the gas in the reservoir 100 begins to leak to atmosphere through the throttle 101. When the pressure in the reservoir 100 has fallen sufficiently, the valve 95 operates to connect the reservoir 97 to the supply point 90. In spite of the leak to atmosphere through the nozzle 102, the pressure builds up in the reservoir 97 until it is high enough to operate the valve 93 to re-connect the patient to the nutrient gas supply. Thereupon, and in spite of the leak to atmosphere via the throttle 101, the pressure in the reservoir 100 builds up until it is high enough to operate the valve 95 to disconnect the reservoir 97 from the supply point 90.

The valve 31 is shown in detail in FIG. 9. The valve has a piston 200 and two control chambers 201 and 202 at the ends of the piston. The control chambers 201 and 202 are connected via connection sockets 203 and 204 to the valves 38 and 36, respectively. The valve ports are connected via connection sockets 205, 206, 207, 208 and 209, to the conduit 32, the valve 41, the atmosphere, the supply point 30, and the atmosphere, respectively.

The valves 36, 38, 53, 63, 83, 93 and 95 can each be as shown in FIG. 10. The valve has a piston 210 with a control chamber 211 at one end thereof, the control chamber being connected via a connection socket 212 to the reservoir 35, the reservoir 40, the reservoir 57, the reservoir 68, the reservoir 88, the branch conduit 89, the reservoir 97, or the reservoir 100, as the case may be. When the pressure in the chamber 211 increases, the piston 210 opens a ball 213 against the action of a return spring 214 for the piston 210 and a return spring 215 for the ball 213. The arrangement is such that a connection socket 216 is connected with two connection sockets 217 and 218, alternately. In the case of the valve 36 or 38, the socket 216 is connected to the control chamber 204 or the control chamber 203, whereas, in the case of the valve 53, 63, 83, or 93, the socket is connected to the patient, and, in the case of the valve 85 or 95, to the throttle 86 or the valve 96. Considering the valve 36, 38, 53, 63, 83 or 93, the socket 217 is connected to atmosphere, and the socket 218 is connected to the

point 37, 39, 50, 60, 80 or 90. However, considering the valve 85 or 95, the socket 217 is connected to the point 80 or 90 and the socket 218 is connected to atmosphere.

The valve 66 is shown in FIG. 11 and includes a piston 220 having at one end thereof a control chamber 221 communicating via a connection socket 222 with the point 60. A return spring 223 acts on the other end of the piston 220. One of the four ports of the valve is blocked at 69, but the other three ports are in communication with connection sockets 224, 225 and 226 connected respectively to the throttle 67, the reservoir 70 and atmosphere.

Each of the throttle valves 34, 41, 55, 56, 67, 86 and 87 is as shown in FIG. 12. Each includes an annular valve seat 230 which is closed by a valve closure disc 231 under the action of a valve spring 232. The disc 231 allows flow through the seat 230 in the direction from a connection socket 233 to a connection socket 234, but prevents flow through the seat 230 in the opposite direction. However, the seat 230 and the disc 231 are by-passed by a by-pass 235 containing an adjustable throttle 236, so that a throttled flow from the socket 234 to the socket 233 is permitted.

The valve devices of FIGS. 1 and 2 have the following advantages:

a. They will connect an applied pressure wave to a patient on receipt of the pressure wave and will connect the patient to exhalation pressure on removal of the pressure wave.

b. They utilize large operating forces, thus giving reliable operation.

c. They can utilize high-pressure waves transmitted through narrow bore tubes and can be remote from the pressure wave generating equipment.

d. They are compact owing to the utilization of high-pressure gas which occupies relatively little volume.

e. They are of extremely simple, robust, and cheap construction.

f. They can be manufactured from almost any material and, if suitably designed, can be sterilized at much higher temperatures than normally used, e.g. flame sterilization is possible.

g. They fail safe if the applied pressure wave is inadequate or does not arrive.

h. Since they allow the use of small bore tubing for the supply gas, there is avoided the risk of excluding the supply gas from the patient as normally can occur if the supply tubing is kinked or bent.

i. They do not need sharp drops in pressure to change their states.

j. They do not require flow of gas from themselves to the gas sources in order to change their states.

k. They overcome the problem of the inhalation pressure maintaining valves in their inhalation states.

l. They have power in reserve to overcome malfunctioning due to extreme temperatures, corrosion, or distortion.

m. They are capable of being used for the smallest infant or the largest adult.

n. They can be used as a remote driving device with most standard non-return patient valves.

Moreover, the valve devices of FIGS. 1 and 2 can be used as a control device for various anesthetic devices, by connecting the duct 9 to a bag-in-bottle type of arrangement so that the controlled gas flow can alternately inflate and deflate the bag, thus enabling an independent gas supply to be delivered to and drawn from the patient. The valve devices can also have a negative-pressure generating device connected to the outlet 7, which device may be either a constant-pressure generating device, or synchronized with the cycling of the valve by suitable means with a delay prior to its operation if required. Patient triggering can readily be used with the valve devices by using orthodox means to override the control circuitry.

The versions of FIGS. 4 to 8 have the advantages that the supply of relatively high-pressure nutrient gas, for example oxygen, causes flow of gas to the patient to be sharply commenced and sharply ceased. Moreover, their adjustable throttles permit independent adjustment of the durations of the in-

halation and exhalation phases. Since a high-pressure flow is used and the resistance to this is at low pressure and the flow is abruptly commenced and abruptly ceased, the flow rate is relatively constant and varies little with the resistance of the patient under any operating conditions, so that the volume of gas supplied to the patient is proportional to time, i.e., the apparatus is both time-cycled and volume-cycled.

Alternatively, the apparatus can be arranged to be pressure-cycled by having the control circuitry itself controlled by a pressure-sensing device communicating with the duct 9.

We claim:

1. Respiratory apparatus, comprising supply means for supplying gas under high positive pressure, circuit means connected downstream of said supply means and adapted to emit intermittently said gas under high positive pressure, a valve device connected to said circuit means to receive intermittently therefrom said gas under high positive pressure, said valve device being adapted to be operated by said gas from said circuit means and being adapted to reduce the pressure of the intermittent gas pulses received from said circuit means from high positive pressure to low positive pressure, and conduit means connected downstream of said valve device for leading said gas under low positive pressure towards a patient.

2. Apparatus according to claim 1, wherein said valve device includes a gas inlet connected to said circuit means, valve closure means serving to close said inlet, and biasing means strongly urging said closure means to close said inlet, the minimum throughflow area for gas flowing from said inlet to said conduit means, when said closure means is fully open with respect to said inlet, being small compared to the minimum internal cross-sectional area of said inlet.

3. Apparatus according to claim 1, wherein said circuit means comprises a throttle connected downstream of said supply means, reservoir means connected downstream of said throttle, a single-acting relay valve adapted to alternate between a state in which it prevents and a state in which it allows the flow of said gas under high positive pressure to said valve device, and a control chamber of said relay valve connected downstream of said reservoir means, an increase of the pressure in said chamber beyond a pre-determined value and a decrease of the pressure in said chamber beyond a pre-determined value producing the respective changes of state of said relay valve.

4. Apparatus according to claim 3, and further comprising a throttle via which said control chamber is connected to an exhaust means.

5. Apparatus according to claim 1, wherein said valve device comprises a housing, a high-pressure gas inlet part of said housing of tubular form, a low-pressure gas outlet part of said housing, valve closure means in said housing movable between a first position in which said valve closure means closes the outlet end of said inlet part and the inlet end of said outlet part is open, and a second position in which said valve closure means closes said inlet end and said outlet end is open, a member of said valve closure means co-axial with said inlet part, portions of said member and said inlet part defining radial clearance therebetween, and biasing means urging said valve closure means into said first position, said conduit means communicating with the interior of said housing and thus with said clearance, and with said outlet part when the latter is open.

6. Apparatus according to claim 5, wherein said member is a sleeve encircling said inlet part and closed at one end.

7. Apparatus according to claim 5, wherein said inlet part and said outlet part are disposed at respective opposite sides of said housing and are substantially co-axial.

8. Apparatus according to claim 5 and further comprising a pressure-relief valve in communication with said conduit means.

9. Apparatus according to claim 5, wherein said housing comprises a tubular portion encircling said member, said valve closure means being movable in said tubular portion with clearance and bounding an intermediate-pressure chamber in

said housing which chamber is also bounded by said tubular portion and communicates directly with the clearance between said member and said inlet part.

10. Apparatus according to claim 5, wherein said circuit means comprises throttle means connected downstream of said supply means, and reservoir means connected downstream of said throttle means, said valve device being connected downstream of said reservoir means, the arrangement being such that, when the apparatus is in use, the rate of flow of said gas through said valve device during the time period that said valve device is open is greater than the rate of flow of said gas through said throttle means, and the consequent pressure variations in said reservoir are utilized to operate said valve device.

11. Apparatus according to claim 1, wherein said circuit means comprises first conduit means leading to said valve device, second conduit means, first, second and third supply members of said supply means, a double-acting piston valve interposed between said supply means and said valve device for connecting said first conduit means to the ambient atmosphere and said second conduit means to said first supply member, branch conduit means leading from said first conduit means, portions of said double-acting piston valve defining first and second control chambers thereof for connection to said second and third supply members, respectively, first and second relay valves, portions of said first and second relay valves defining third and fourth control chambers thereof, first and second reservoir means, and first and second throttle means, said second conduit means and said branch conduit means leading via said first and second throttle means, respectively, to said first and second reservoir means and thence to said third and fourth control chambers, said relay valves operatively connecting said first control chamber to its associated supply member and said second control chamber to the ambient atmosphere.

12. Apparatus as claimed in claim 11, wherein said first conduit means is connected to the first supply member and the second conduit means is connected to the ambient atmosphere.

13. Apparatus as claimed in claim 11, wherein the first control chamber is connected to the ambient atmosphere and the second control chamber is connected to its associated supply member.

14. Apparatus as claimed in claim 11, wherein said first conduit means is connected to the first supply member, the second conduit means is connected to the ambient atmosphere, the first control chamber is connected to the ambient atmosphere and the second control chamber is connected to its associated supply member.

15. Apparatus according to claim 1, wherein said circuit means comprises another conduit means leading to said valve device, a single-acting relay valve interposed between said supply means and said valve device for connecting said other conduit means periodically to said supply means, portions of said relay valve defining a control chamber thereof, and reservoir means which is connected to an exhaust means, said supply means being connected to said control chamber by way of said reservoir means.

16. Apparatus according to claim 15, wherein said circuit means further comprises throttle means interposed between said supply means and said reservoir means and between said reservoir means and said exhaust means.

17. Apparatus according to claim 16, wherein said reservoir means exhausts to said other conduit means.

18. Apparatus according to claim 17, wherein said circuit means further comprises a conduit connecting said supply means to said relay valve, and a branch conduit leading from said conduit to said reservoir and containing said throttle means.

19. Apparatus according to claim 15, wherein said reservoir means exhausts to atmosphere.

20. Apparatus according to claim 16, wherein said throttle

means comprises a first throttle controlling gas flow from said supply means to said reservoir means and a second throttle controlling gas flow from said reservoir means to said exhaust means.

21. Apparatus according to claim 20, wherein said circuit means further comprises second reservoir means, a second relay valve, and portions of said second relay valve defining a second control chamber thereof, said first throttle being connectable via said second reservoir means, said second relay valve, said second throttle and the first-mentioned reservoir means to said second control chamber, said first-mentioned reservoir means being connectable via said second throttle and said second relay valve to the ambient atmosphere, and said second relay valve being operable to connect said first-mentioned reservoir means to said second reservoir means and the ambient atmosphere, alternately.

22. Apparatus according to claim 20, wherein said circuit means further comprises a second relay valve, a branch conduit, and portions of said second relay valve defining a second control chamber thereof, said supply means being connectable via said second relay valve and said first throttle to said reservoir means, said reservoir means being connectable via said second relay valve and the first and second throttles to the ambient atmosphere, and said second control chamber being connected via said branch conduit to said other conduit means and being operable to connect said reservoir means to said supply means and to ambient atmosphere, alternately.

23. Apparatus according to claim 16, wherein the throttle means is adjustable.

24. Apparatus according to claim 1, wherein said circuit means comprises a conduit connected downstream of said supply means and leading to said valve device, a first single-acting relay valve interposed between said supply means and said conduit and connecting said conduit periodically to said supply means, portions of said valve defining a first control chamber thereof, reservoir means connected to said first control chamber, a second single-acting relay valve interposed between said supply means and said reservoir means and periodically connecting said reservoir means to said supply means, portions of the second relay valve defining a second control chamber thereof, and a branch conduit connecting said second control chamber to the first-mentioned conduit.

25. Apparatus according to claim 24, wherein said circuit means further comprises throttle means interposed between said supply means and said reservoir means, said second relay valve communicating said reservoir means with exhaust, and with said supply means via said throttle means, alternately.

26. Apparatus according to claim 15, wherein said circuit means further comprises continuously open leak means by way of which said reservoir means is continuously connected to atmosphere.

27. Apparatus according to claim 26, wherein said circuit means further comprises a branch conduit containing said reservoir means and leading to said control chamber from a location downstream of said supply means and upstream of said relay valve, another single-acting relay valve connected in the branch conduit between said location, on the one hand, and said reservoir means and said leak means, on the other hand, a check valve connected in the branch conduit between said other single-acting relay valve on the one hand, and said reservoir means and said leak means, on the other hand, and permitting nutrient gas flow towards said reservoir means and said leak means, portions of said other single-acting relay valve defining a control chamber thereof, another branch conduit leading from said other conduit means to the latter control chamber, another reservoir means contained by said other branch conduit, another continuously open leak means by way of which said other reservoir means is continuously connected to atmosphere, and another check valve connected in said other branch conduit between said other conduit means, on the one hand, and said other reservoir means and the other leak means, on the other hand.

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