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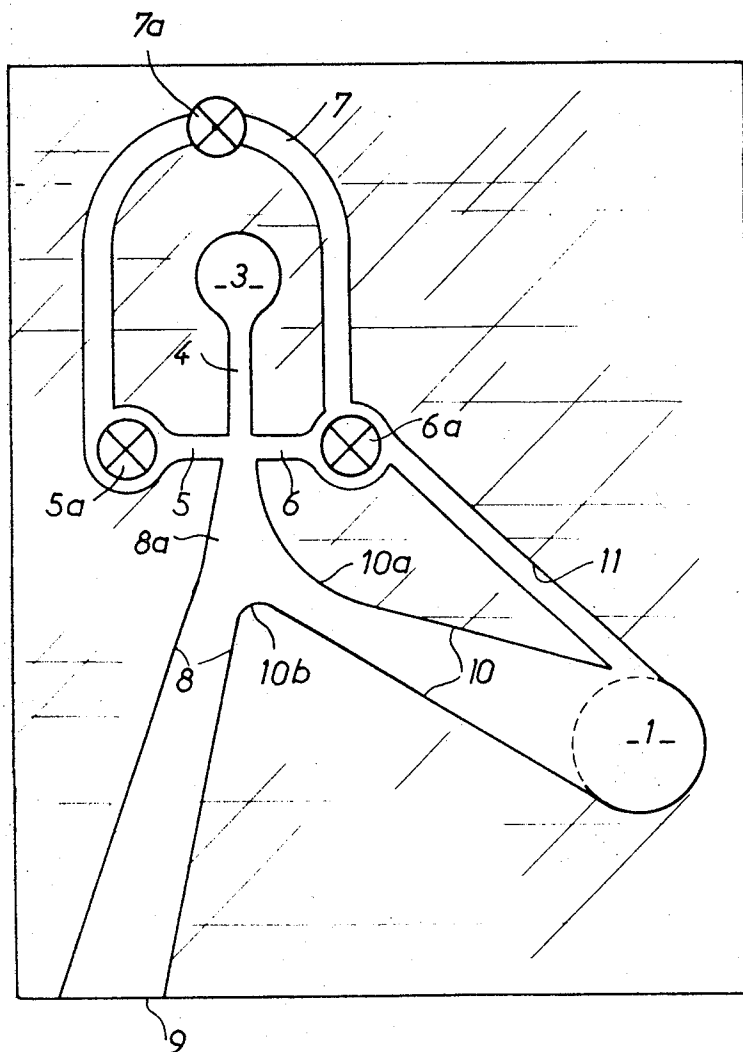
C. F. PAVLIN ETAL
FLUIDIC APPLIANCE FOR ALTERNATELY FILLING
AND EMPTYING AN ENCLOSURE

3,565,564

Filed March 21, 1968

4 Sheets-Sheet 1

Fig. 1 *PRIOR ART*



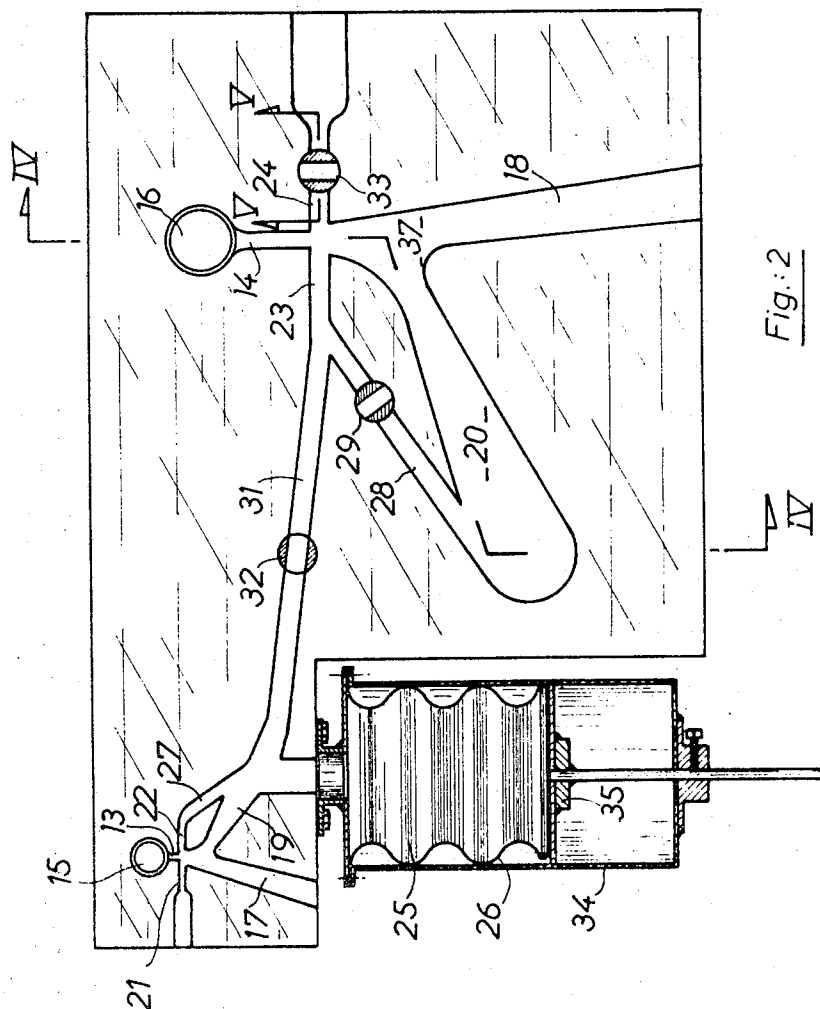
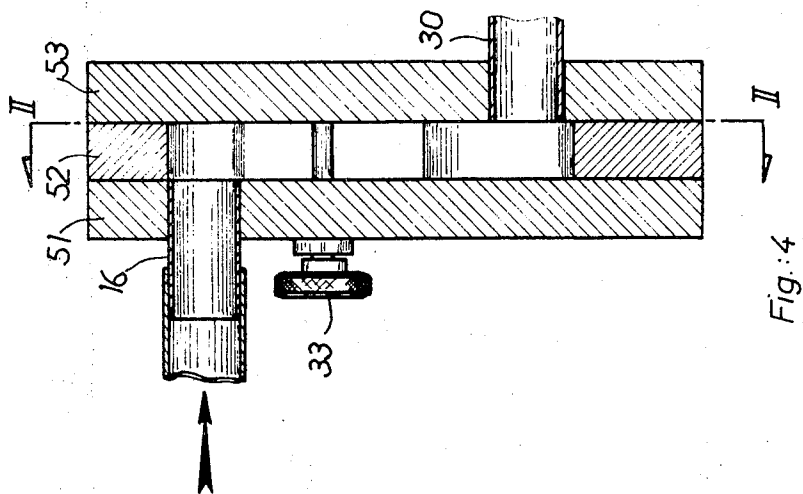
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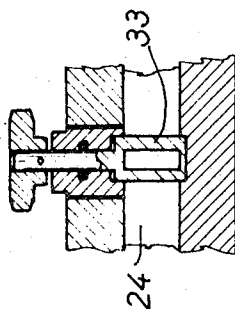
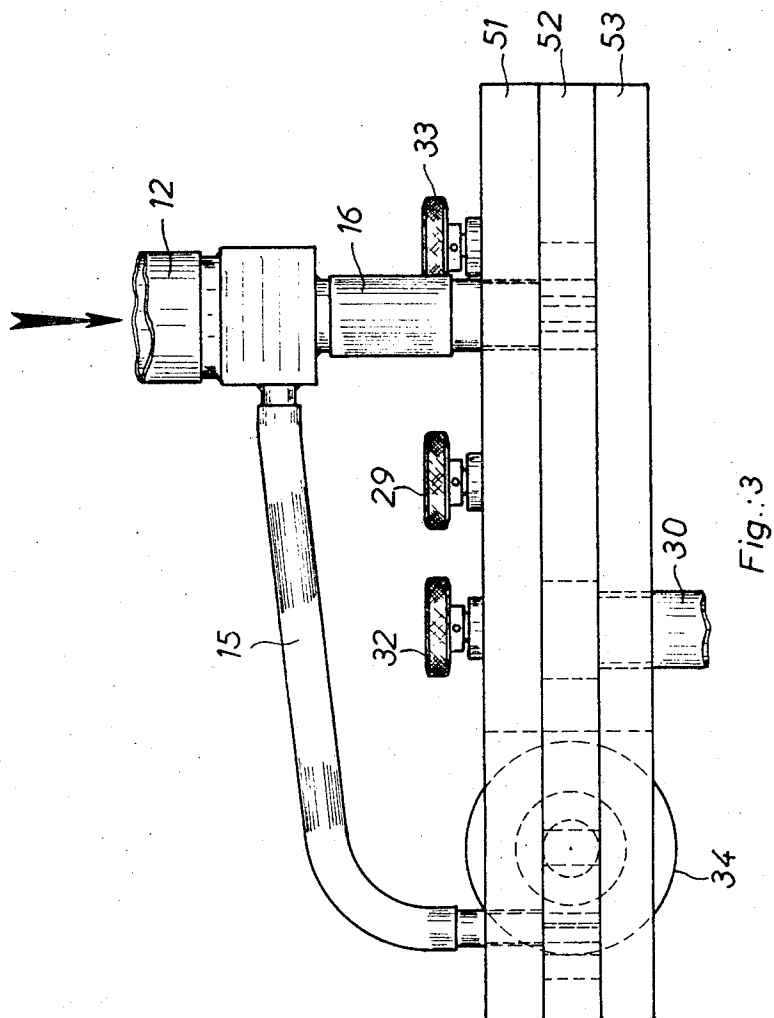
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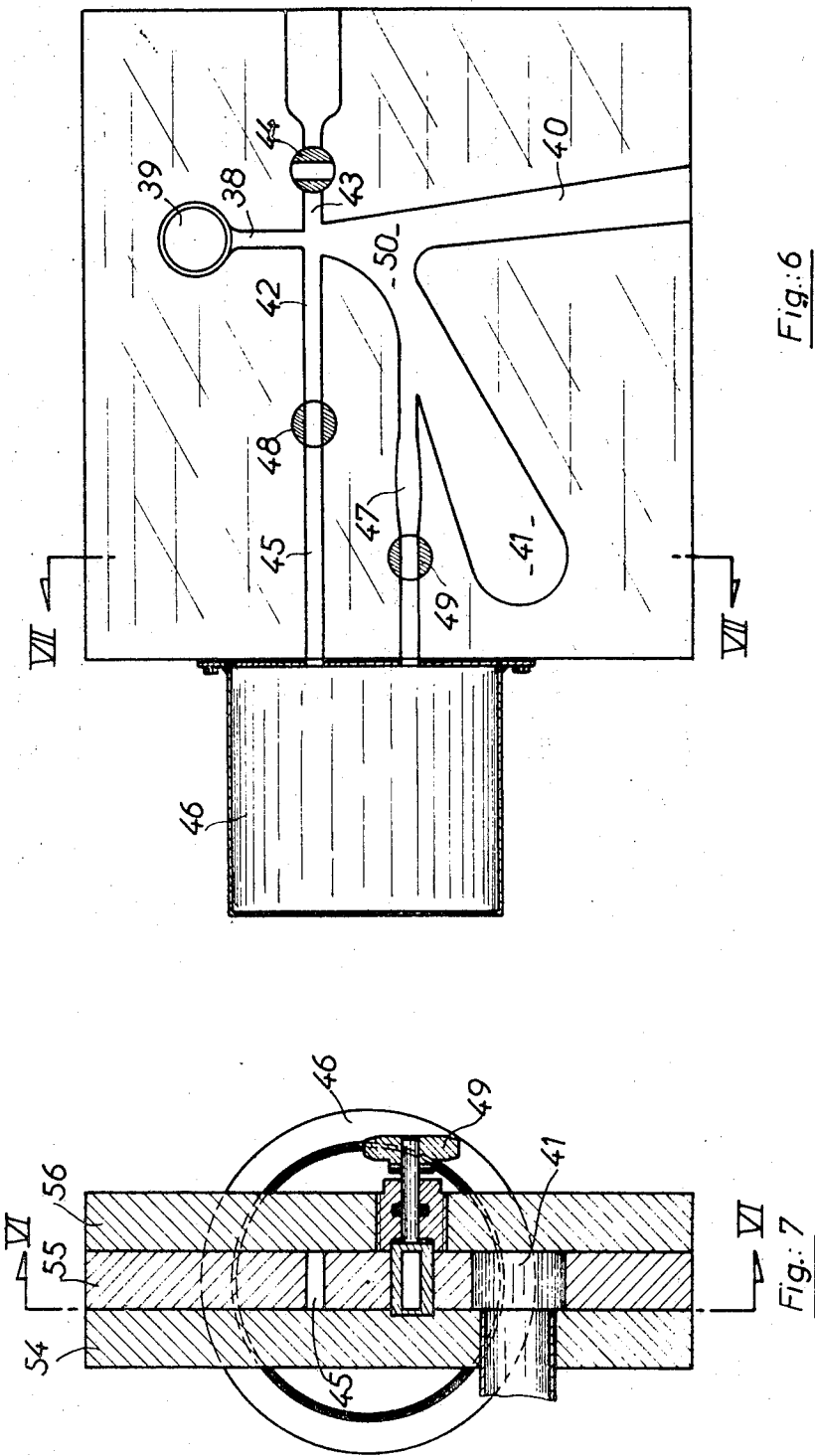
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FLUIDIC APPLIANCE FOR ALTERNATELY FILLING AND EMPTYING AN ENCLOSURE

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Continuation-in-part of application Ser. No. 475,696,
July 29, 1965. This application Mar. 21, 1968, Ser.
No. 714,861

The portion of the term of the patent subsequent to
June 25, 1985, has been disclaimed
Int. Cl. A62b 7/02

U.S. Cl. 128—145.5

9 Claims

ABSTRACT OF THE DISCLOSURE

An appliance, chiefly a respirator adapted to exert an alternating pressure and suction, for instance in a patient's lungs, of the type including a nozzle projecting a jet which is periodically deflected between an exhaust pipe and an utilisation chamber leading to the patient's lungs or any other suitable capacity. The rhythm of said deflection is caused to suit a predetermined rhythm such as that of the patient's lungs. To this end, an auxiliary deformable capacity is connected with a duct opening into the output of the nozzle in registry with another duct leading to the atmosphere. It is possible to control the appliance by a similar pilot appliance connected with the auxiliary deformable chamber.

This is a continuation-in-part of our application Ser. No. 475,696 filed July 29, 1965, now patent specification No. 3,389,698.

In this specification, we have described a device operable with a source of motive fluid for alternately filling and emptying an enclosure, comprising a motive fluid supply duct leading from an intake to a stream switching zone at opposite sides of which open two control ports acting respectively to deflect the stream of motive fluid away from the axis of said duct in either one of two directions, said motive fluid supply duct being extended beyond said zone by two branched ducts at different angular inclinations with respect to said axis, one of said branched ducts being an exhaust duct inclined at a relatively small angle and adapted to collect said motive fluid stream when the same is deflected in one of said directions and the other of said branched ducts being a load duct inclined at a relatively large angle to said axis and adapted to collect said motive fluid stream when the same is deflected in the other of said directions, said load duct leading into said enclosure and being connected to said supply duct along a curved convex wall and being further connected permanently with one of said control ports through a feedback passage.

This arrangement has been tested in a very complete manner and this has shown the detail of its operation and the possibility of providing various modifications for predetermined applications.

We have also disclosed embodiments forming artificial breathing appliances which are extremely light and sturdy so that they may be readily used in a first aid station or in a conveyance for injured persons.

Our present invention has for its object improvements in such artificial breathing appliances or respirators.

It is preferable for such respirators to constrain the patient to breathe at a predetermined frequency that is the periods of emptying and filling the enclosure constituted by the patient's lungs should not be modified by a counter-pressure directed from the downstream side of the appliance during the breathing out stage of the lungs.

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The present invention has for its object an improvement for this purpose.

In the accompanying drawings:

FIG. 1 is an exact reproduction of FIG. 1 of our above-mentioned specification.

FIGS. 2 and 3 are a cross-sectional view through line II—II of FIG. 4 and a side view of the chief components of a respirator according to first embodiment of our invention.

FIGS. 4 and 5 are cross-sections of said first embodiment through lines IV—IV and V—V of FIG. 2.

FIG. 6 is a sectional view through line VI—VI of FIG. 7 showing the chief components of the second embodiment of our respirator.

FIG. 7 is a sectional view through line VII—VII of FIG. 6.

Turning to the first embodiment, FIG. 1 shows as already mentioned the following components of our prior invention:

- a supply duct 4 producing a drive jet and fed from a fluid intake 3
- control nozzles 5 and 6 extending in opposite directions which are substantially perpendicular to the general direction of said duct 4, said nozzles being adapted to be interconnected by the connecting channel 7 provided with a gate 7a. Said nozzles may be connected with the outer atmosphere through the gates 5a and 6a
- an exhaust duct 8 forming an extension in substantial alignment with the motive jet
- a load duct 10 connected through an incurved section with the supply duct 4 and the general direction of which forms with said duct 4 an angle which is larger than that formed between said nozzle and the exhaust duct 8, said load duct 10 leading to the enclosure 1, the pressure and the mass of fluid in which are to be controlled
- a feedback passage 11 connecting the load duct with the control nozzle 6.

We will now again disclose the operation of such an arrangement so as to further the understanding of the operation of the novel appliances to be described hereinafter.

Assuming first that the gate 6a is open and the gates 5a and 7a are closed, the admission of compressed driving gas from the intake 3 and its projection out of the supply 4 result in the production by a suction effect of a relative reduction in pressure in the control nozzle 5 and the section of the channel 7 connected with the latter. No similar reduction in pressure can appear in the nozzle 6 which is connected with the atmosphere through the open gate 6a and the same is the case for the load duct 10 connected with the atmosphere through the passage 11. Therefore, the jet of driving gas adheres to the wall 8a of the exhaust duct 8 where it is compressed again at least partly before it is exhausted at 9.

If now the gate 5a is open while the gate 6a is closed and the gate 7a remains closed, the suction effect arises in the nozzle 6 and in the load duct 10 and feedback 11. If the curvature of the wall 10a of the duct 10 has a radius larger than four times the breadth of the supply 4, as disclosed in our prior specification, the jet passing out of the supply 4 adheres to said wall 10a and it follows thus at least transiently the load duct 10 in which it is compressed again. The driving gas provides thus for an expansion of the enclosure 1 in which the pressure rises.

Said increase in pressure is however transmitted by the feedback passage 11 to the control nozzle 6 and even if this does not constitute strictly a control jet, yet the transverse pressure gradient at the output of the supply 4 is

reversed and has a tendency to deflect the jet of the driving fluid towards the wall 8a and the exhaust duct 8.

The pressure in the enclosure 1 decreases therefore finally underneath atmospheric pressure by reason of the suction effect furthered by the rounded wall 10b where the exhaust 8 merges into the load duct 10 and by the divergent cross-section of the exhaust duct 8. This being obtained, the operative cycle is repeated.

In other words, the conditions of operation are defined in all cases by the flow of driving jet in the exhaust duct 8. As a matter of fact, when the supply 4 is fed with compressed fluid, while the nozzles 5 and 6 are subjected to the pressure of the circumambient medium such as the atmosphere, the jet projected by said supply adheres according to the initial shape given to it either to the wall 10a or to the wall 8a.

If the jet adheres to the wall 10a and continues consequently progressing through the load duct 10, it is in all cases rejected after a certain time of operation into the exhaust 8 as provided by the overpressure obtained in the enclosure 1 which it has just filled, which overpressure is transmitted chiefly by the feedback 11 into the control nozzle 6.

If in contradistinction the jet adheres to the wall 8a it remains indefinitely in the exhaust duct 8 or else it passes alternately through said duct 8 and through the load duct 10 according to the connections provided between the different channels of the appliance and between said channels and the atmosphere, that is according to the adjustment of the gates 5a, 6a, 7a.

FIGS. 2 to 5 inclusively include a two stage respirator according to our present invention. The two stages are fed by a common motive fluid source 12 and they include each a supply duct 13, 14 and its intake 15, 16, an exhaust duct 17, 18, a load duct channel 19, 20 and control nozzles 21-22, 23-24 which elements are formed within the thickness of the three juxtaposed plates 51, 52, 53.

The first stage is a pilot stage constituted by a respirator similar to that described in our prior above-mentioned specification, but preferably of a smaller size such as a reproduction on a scale of 1/5 of a normal respirator. Its exhaust duct 17 is connected with the outer atmosphere while its load duct channel 19 opens into a deformable capacity 25 constituted advantageously by a small rubber gas-bag 26. Its control nozzle 21 is connected with the outer atmosphere, while its other control nozzle 22 is connected with the load duct channel 19 through a feedback 27.

The second stage forms a respirator of a standard size wherein the feedback 28 may be closed by a gate 29. The exhaust duct 18 is connected with the outer atmosphere while the load duct 20 is to be connected through a pipe 30 (FIG. 4) with the lungs of a patient.

The two stages are connected by means of a channel 31 provided with a gate 32. The channel 31 connects the auxiliary capacity 25 of the first stage with the control nozzle 23 of the second stage. The other control nozzle 24 is connected with the outer atmosphere under the control of the gate 33.

The operation of said appliance is as follows:

The common supply source 12 for the two stages is fed by means of a mixture of oxygen and nitrogen for instance through a gate which is not illustrated, the feed provided for the first stage being substantially lower as a result for instance of the insertion of a throughput-limiting device or merely of the relative size of the supply ducts 13 and 14 constricting the jet in both transverse directions. It is assumed that the gates 32 and 33 are open and the gate 29 closed. At the start, the jet produced by the supply 13 of the first stage passes indifferently into the exhaust duct 17 or into the load duct 19.

If the jet enters the exhaust duct 17, it produces a suction effect in registry with the branching off load duct 19. The capacity 25 is therefore emptied during a period which varies according to its volume. In the example illustrated, said volume is adjustable, as provided by enclosing the

air-bag 26 in a cylinder 34 and by limiting the volume of said airbag by a piston 35 slidably engaging the cylinder 34. A locking screw 36 engaging the rod of the piston 35 provides for a modification of the volume of the capacity 25.

When the capacity 25 is emptied, the pressure in the feedback 27 and control nozzle 22 drops substantially underneath the pressure in the control nozzle 21. The jet produced by the supply 13 rocks and its inclination is reverse, so as to enter the load duct 19.

When the jet enters the load duct 19, it feeds preferably the capacity 25, since the diameter of the channel feeding it is selected so as to be much larger than that of the coupling channel 31. The capacity 25 is thus filled and after its filling, the jet is shifted through the channel 31 into the nozzle 23 of the second stage. At the same time, the level of the pressure in the control nozzle 22 of the first stage rises above the level of the pressure in the other control nozzle 21 connected with the outer atmosphere, so that the jet rocks back so as to enter the exhaust duct 17 and a further cycle begins which is similar to that which has just been described.

The control jet passing out of the first stage into the coupling channel 31 causes the jet produced by the supply 14 in the second stage to enter the exhaust duct 18, whereby a suction effect arises at 37, where said exhaust duct branches off the load duct 20 and this reduces the pressure in the latter. The respirator being applied to the patient by means of a mask, said reduction in pressure has for its result to constrain the patient to breathe out, the breathing out being more or less marked according to the position given to the gate 33 in the nozzle 24 opening into the atmosphere.

When the jet in the first stage is shifted towards the exhaust duct 17, the capacity 25 empties and at the same time the pressure sinks in the coupling channel 31. Said reduction in pressure is transmitted by the control nozzle 23 so that the jet produced by the supply 14 in the second stage rocks and enters the load duct 20, which leads to a breathing in of the patient. The jet continues passing into the load duct 20 until the pressure in the capacity 25 has sunk by a sufficient amount and no counterpressure produced by the patient can lead to any shifting of the jet, during said time.

The pressure in the downstream section of the branching off duct 20 connected with the patient's lungs is limited to the possible compression of the jet in the divergent section of said channel. As soon as said maximum pressure is reached, the air is urged towards the other path 18 without however the jet issuing from 14 being swung and so the maximum pressure is retained until the signal rocking the jet is obtained. The appliance operates thus after the manner of a check valve preventing overpressure.

The respirator described constrains thus the patient to breathe in the air sent to him at a predetermined frequency, said frequency being adjusted as mentioned hereinabove by modifying the volume of the capacity 25 since the cycle controlling the jet of the second stage is controlled by the first stage.

The apparatus described hereinabove may also operate without the first stage. In such a case, the gate 32 is closed and the gate 29 is opened. There is no longer any coupling between the two stages and the respirator operates after the manner described for the respirator disclosed in our prior abovementioned specification, the rocking of the jet being obtained when a predetermined pressure is reached inside the load duct 20 which produces the desired alternation.

In the second embodiment of our invention illustrated in FIGS. 6 and 7, the respirator includes a supply 38 producing the driving jet and fed from intake 39, while the exhaust duct is shown at 40, the load duct at 41 and two control nozzles at 42 and 43. The control nozzle 43 is connected with the outer atmosphere through a gate 44,

while the nozzle 42 is connected through a feedback passage 45 with an inflatable capacity 46 connected in its turn through a channel 47 with the load duct 41. The channels 45 and 47 are each provided with a gate shown respectively at 48 and 49. These different components are formed within the thickness of three juxtaposed plates 54, 55, 56.

The operation of such an arrangement is as follows:

The gates 44, 48 and 49 being open and the intake 39 being suitably fed with the driving fluid, the load duct 41 is connected with the patient's lungs. The jet produced by the supply 38 may enter selectively the load duct or the exhaust pipe.

If the jet enters the load duct 41, it feeds the patient's lungs at the same time as the capacity 46.

When the pressure in said capacity reaches a predetermined level, it causes the jet produced by the supply 38 to rock under the action of a stream of air blown into the nozzle 42, so that said jet is deflected into the exhaust duct 40.

When the jet enters thus the exhaust duct 40, a suction effect is obtained at a point in registry with the branching off point 50 for the duct 41, whereby the patient's lungs are emptied simultaneously with the capacity 46. The difference in pressure in the two nozzles 42 and 43 causes finally for a predetermined reduction in pressure in the capacity 46 a deflection of the jet which enters now the load duct 41.

Said respirator cannot be controlled by a counterpressure produced by the patient and the shifting of the jet at the breathing in and breathing out moments depends solely on the duration of filling and of emptying of the capacity 46.

By causing the losses of head to vary through operation of the gates 48 and 49 at the input and at the output of the capacity 46, the duration of filling and emptying of the capacity is modified, which leads to a modification in duration of the breathing in and breathing out periods.

It is possible by adjusting said durations or throughputs in a manner such that they may show similar values to obtain either for a predetermined volume of the capacity 46 an increase in the time constant or else for a predetermined time constant and predetermined volume of the capacity an increase in the cross-section afforded for the passage of fluid, which limits the risk of a closing of the shunt circuit.

Furthermore, the gate 44 has for its object to modify the pressure levels for the positive and negative inclination of the direction of the jet in accordance with the extent of opening of said gate 44.

The air passing through the feed back loop including the capacity 46 is recycled by the control means and leads therefore to no extra consumption of air.

The pressure in the load duct and patient's lungs depends on the loss of head in the circuit and on the leaks if any. It remains limited to a maximum defined by the original compression to which the fluid is capable of rising in the downstream section of the reversing means. If said maximum pressure is reached before the reversing or deflecting signal has been entered, the fluid is delivered outwardly by the other section of the reversing means which act as a check valve discharging into the atmosphere without any deflection of the jet and therefore without any action reducing the pressure in the duct 41.

Furthermore, the input of the channel 47 is located in the area of the load duct 41 in which a substantial fluid speed still prevails and said channel 47 becomes divergent ahead of the gate 49 so as to allow setting the capacity 46 under normal pressure even if a leak in the pipe leading to the patient's lungs were to limit the pressure in the duct 41.

What we claim is:

1. A fluid amplifier appliance operable with a source of motive fluid (12) for alternately filling and emptying

an enclosure, of the kind comprising a motive fluid intake (15, 39) to be connected to said source, a motive fluid supply duct (13, 38) leading from said intake and having two opposite sides, two control nozzles (21-22, 42-43) opening into said supply duct at said opposite sides thereof and adapted to deflect the motive fluid supplied by the said duct away from the axis thereof in either one of two opposite directions, two branched ducts (17-19, 40-41) extending said motive fluid supply duct beyond said control nozzles respectively in said opposite directions and at different angular inclinations with respect to said axis, one of said branched ducts being an exhaust duct (17, 40) forming a branch of said supply duct extending the same beyond said control nozzles at a relatively small angle of inclination with respect to the axis of said supply duct, said exhaust duct being adapted to collect said motive fluid when the same is deflected in one of said two opposite directions and to lead said fluid exhaust, the other of said branched ducts being a load duct (19, 41) having an outlet leading into said enclosure and forming a further branch of said supply duct extending the same beyond said control nozzles at a relatively large angle of inclination with respect to the axis of said supply duct, said load duct having a boundary surface being connected to the adjacent one of said sides of said supply duct along a curved convex wall smoothly merging with said surface and adjacent side and being adapted to collect said motive fluid when deflected in the other one of said two opposite directions and to lead said fluid through said outlet into said enclosure, and a feedback passage (27, 45) permanently interconnecting said load duct with one (22, 42) of said control nozzles, wherein the improvement comprises:

an auxiliary selectively and gradually adjustable capacity (25, 46) connected both with said feedback passage (27, 45) and with said load duct (19, 41) at an intermediate point thereof way upstream of said outlet thereof and fluidly distinct therefrom, whereby to fluidly differentiate said auxiliary adjustable capacity and said enclosure.

2. An appliance as claimed in claim 1, wherein the auxiliary adjustable capacity is a yielding air-bag, said appliance comprising furthermore a cylinder enclosing said yielding air-bag and a piston closing said cylinder to an adjustable extent to define the operative volume of said air-bag.

3. An appliance as claimed in claim 1, comprising a gate in series with the auxiliary adjustable capacity.

4. An appliance as claimed in claim 1, wherein said auxiliary adjustable capacity (46) is fitted in series in said feedback passage (45).

5. An appliance as claimed in claim 1, wherein said load duct (19, 41) comprises a divergent section downstream of said intermediate point thereof.

6. An appliance as claimed in claim 1, wherein said auxiliary adjustable capacity (25) is fitted in parallel with said feedback passage (27).

7. An appliance as claimed in claim 1, further comprising a further motive fluid intake (16) to be connected to said source, a further motive fluid supply duct (14) leading from said further intake and having two further opposite sides, two further control nozzles (23, 24) opening into said further supply duct at said further opposite sides thereof and adapted to deflect the motive fluid supplied by said further duct away from the axis thereof in either one of two further opposite directions, one (23) of said further control nozzles being connected with said load duct (19), and two further branched ducts (18-20) extending said further supply duct beyond said further control nozzles in said further opposite directions and at different angular inclinations with respect to said axis, one of said further branched ducts being a further exhaust duct (18) forming a branch of said further supply duct extending the same beyond said further control nozzles at a relatively small angle of inclination with respect

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to the axis of said further supply duct, said further exhaust duct being adapted to collect said further motive fluid when the same is deflected in one of said two further opposite directions and to lead said further fluid to exhaust, the other of said further branched ducts being a further load duct (20) having an outlet (30) leading into said enclosure and forming a further branch of said further supply duct extending the same beyond said further control nozzles at a relatively large angle of inclination with respect to the axis of said further supply duct, said further load duct having a further boundary surface, being connected to the adjacent one of said further sides of said further supply duct along a further curved convex wall smoothly merging with said further surface and adjacent side and being adapted to collect said further motive fluid when deflected in the other of said two further opposite directions and to lead said further fluid through said outlet into said enclosure.

8. An appliance as claimed in claim 7, further comprising a further feedback passage (28) interconnecting said further load duct (20) with said one (23) of said further control nozzles (23, 24).

9. An appliance as claimed in claim 8, further com-

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prising controllable valve means (29-32) associated with said one (23) of said further control nozzles (23, 24) selectively to open the connection thereof with said former-mentioned load duct (19) while closing the connection thereof with said further feedback passage (28) or to close the connection thereof with said former-mentioned load duct while opening the connection thereof with said further feedback passage.

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U.S. Cl. X.R.

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