April 23, 1968 H. ZIERMANN 3,379,194

FLUID AMPLIFIER CONTROLLED RESPIRATOR

Filed June 29, 1965 4 Sheets-Sheet 1

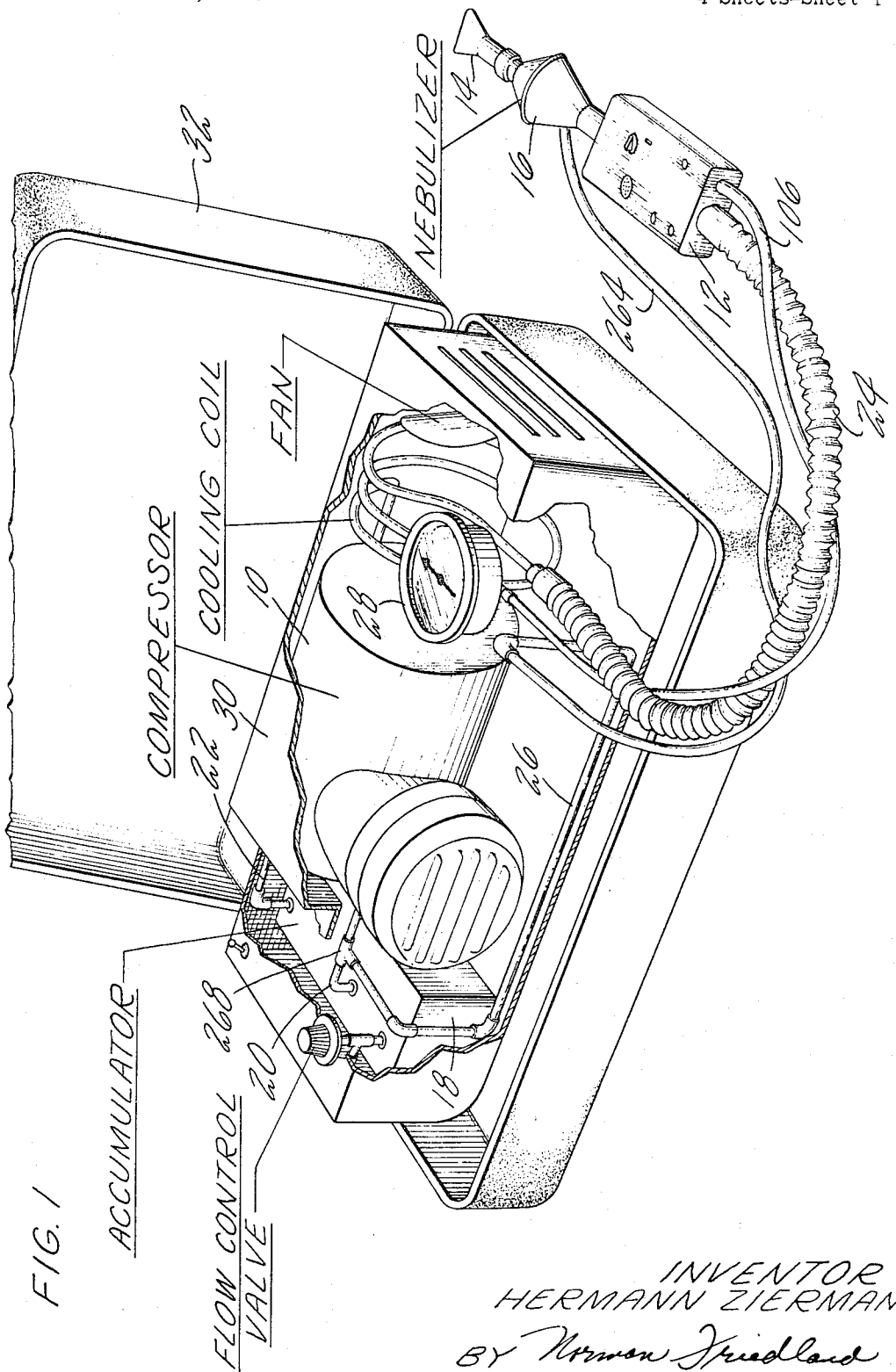


FIG. 1

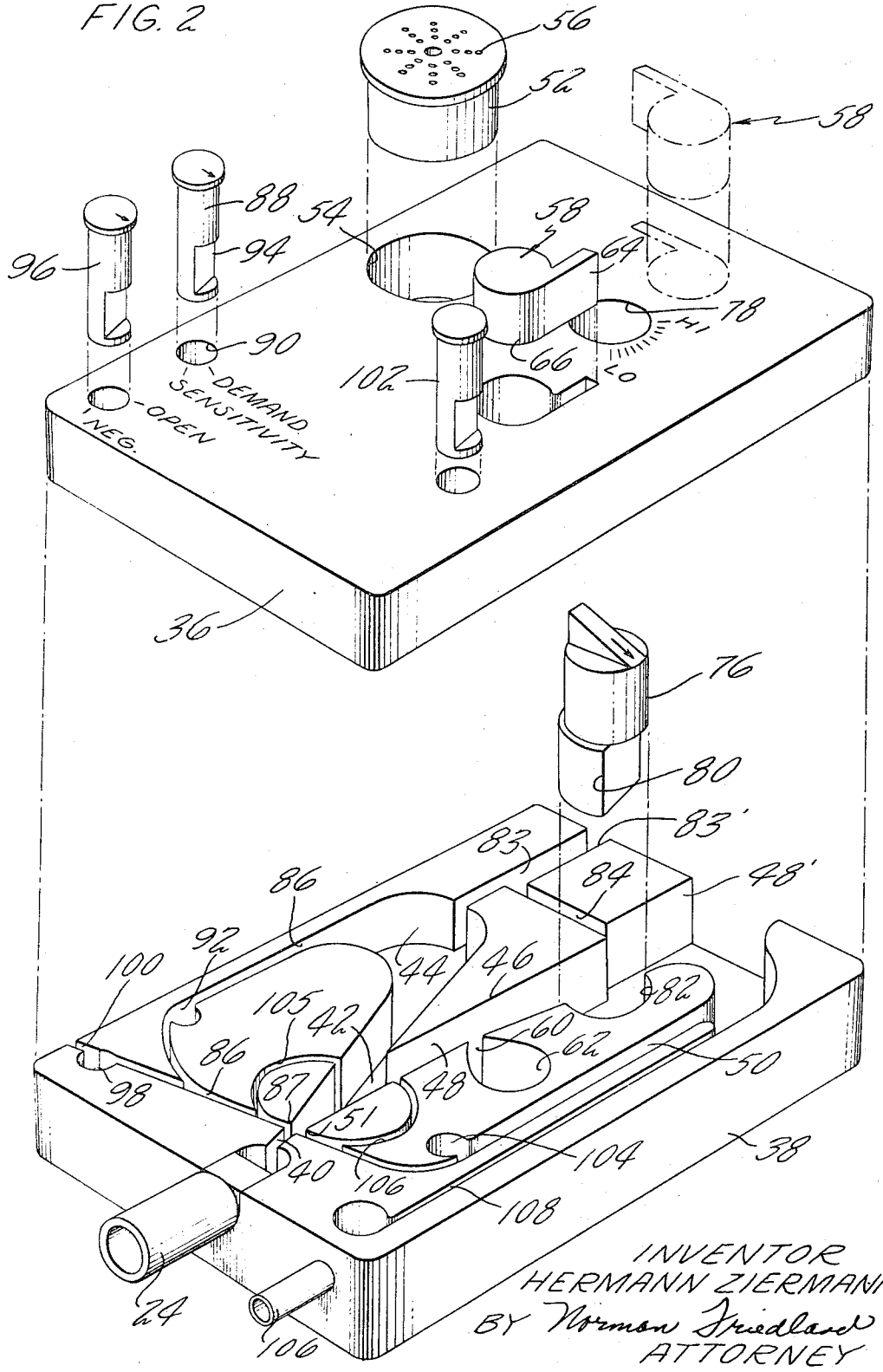
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FLUID AMPLIFIER CONTROLLED RESPIRATOR

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FIG. 2



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FIG. 7

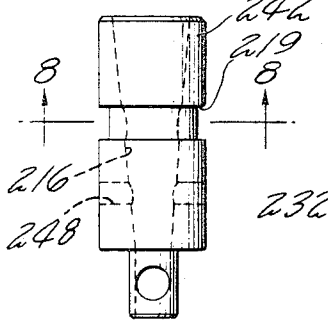


FIG. 5

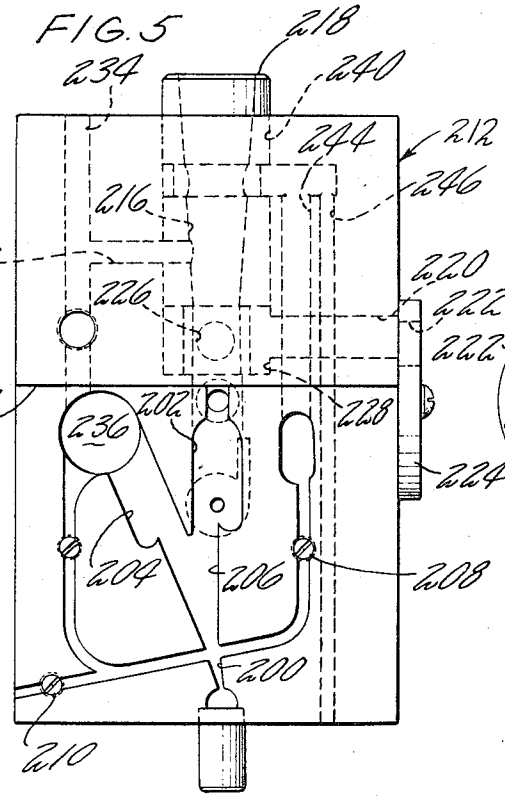


FIG. 6

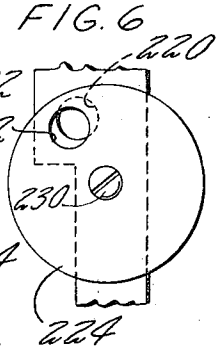


FIG. 8

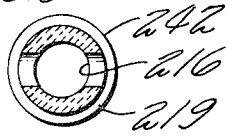


FIG. 3

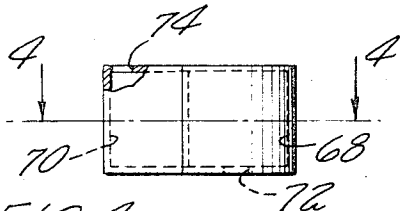


FIG. 4

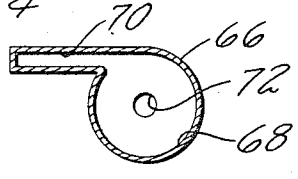
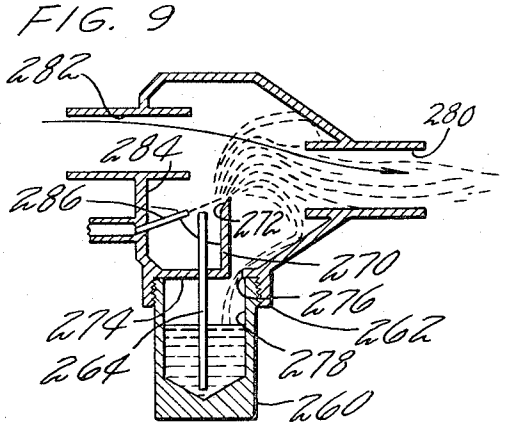


FIG. 9



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FIG. 10

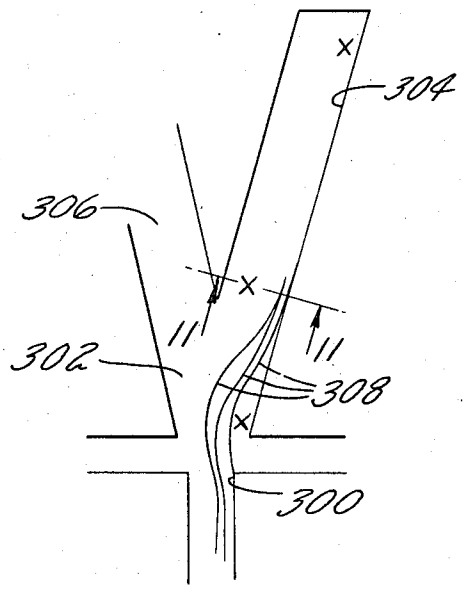
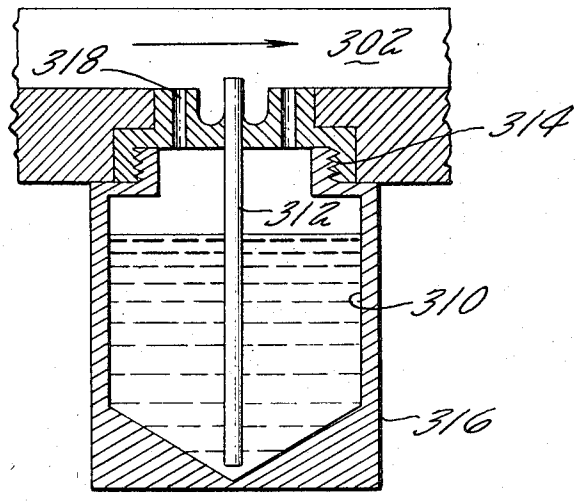


FIG. 11



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United States Patent Office 3,379,194 Patented Apr. 23, 1968

3,379,194

FLUID AMPLIFIER CONTROLLED RESPIRATOR

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Filed June 29, 1965, Ser. No. 467,838
10 Claims. (Cl. 128—145.6)

ABSTRACT OF THE DISCLOSURE

A pure fluid amplifier augments or controls respiration and includes feedback passages and restrictions for controlling the inspiration to expiration ratio, the shape of the pressure curves and the negative pressure. A nebulizer is incorporated in combination with the amplifier in a manner to prevent the loss of medication in the expiration cycle.

This invention relates to respirators of the types that can assist or control respiration utilizing pure fluid amplifiers.

As is generally well known in the art the respirator is a device intended to assist a patient, generally, one afflicted by certain pulmonary diseases, in breathing. In some applications this device may be employed as a respirator which provides an assist to the patient so that relatively little effort on the part of the patient is required to effectuate breathing, and in others it can be employed as a resuscitator to provide positive breathing. While there are presently a number of respiratory devices available, these devices are characterized as being very costly and/or operate by a very high pressure which are occasioned by the fact that they require a number of moving parts such as valves operated by diaphragms and bellows. The complexity of the respirator which obviously materially affects the cost thereof can be reduced by utilizing a pure fluid amplifier which switches without the use of any moving parts the fluid from a source of pressure to supply a certain predetermined volume of fluid during the inhalation cycle and then utilizing the pressure from the source to assist during the exhalation cycle. In such a device the patient's breathing effort is significantly reduced and hence, requires substantially little effort to provide the switching from the inhalation to the exhalation cycles. In this type of respirator it is possible to provide up to 90 liters per minute of air with as little as 2–4 p.s.i. at the power nozzle of the fluid amplifier.

One of the problems attendant the respirator is the application of a nebulizer which is intended to supply to the patient a fine mist of medication which is adapted to be injected into the lungs for breaking down the congestion therein. A nebulizer to be effective must be positive and must be intermittent so that it is only operable during the inhalation cycle and inoperable during the exhalation cycle. If the nebulizer is operated during the expiration cycle, the medication fluid is then rejected out of the system without any benefit to the patient and, hence, is considered a mere loss in the system. Generally, nebulizers, per se, which are well known in the art require a considerable amount of pressure to atomize the medication which pressure is customarily supplied through a separate connection. I have found that I can use a nebulizer with a capillary tube injected into certain locations in the amplifier which will supply positive intermittent nebulization (during the inhalation cycle only) while eliminating a separate extra fluid connection for driving the nebulizer. Again, this affords simplicity in the respirator system while reducing the cost thereof.

As is generally well known in the art a fluid amplifier is basically a device in which an input or power fluid flow is modulated between two or more output channels by the application of a control fluid stream generally disposed at right angles to the power fluid flow at the inter-action section of the fluid amplifier. There are two basic types of fluid amplifiers, namely, proportional and digital. This application is directed to the utilization of the digital type of pure fluid amplifier, i.e., where the power stream adheres to one of the output channels until a control signal causes a switchover. For a general description of pure fluid amplifiers reference should be made to U.S. Patent No. 3,122,165, issued to B. M. Horton.

In the use of fluid amplifiers it is pointed out here that certain dimensions become critical so that the switching from one channel during inhalation to the other channel during exhalation takes place upon reaching a predescribed pressure in the mouthpiece and the transition from the inhalation to exhalation and back to inhalation must be smooth and gradual.

In addition to the requirements noted above, the respirator must, whether for home or clinical use, be able to supply variable volumes of air inasmuch as lung capacities of different patients vary. As noted above, the type of respirator constituting the present invention operates at a substantially low pressure in comparison to the prior art respirators. There are two ways in which the volume can be altered, one is by supplying more air to the input of the fluid amplifier by increasing the output of the compressor or source of pressurized air and second, to provide additional flow by controlling the output of the amplifier. In either situation care must be taken to assure that the pressure in the mouthpiece or that which enters into the lungs does not exceed an intolerable level which may result in injury to the patient. Two flow controls may be provided such that one of the controls has a varying pressure and the other varies the flow without a pressure change. By the use of one of the flow controls as long as the pressure is sufficient to switch from inhalation to exhalation and vice versa, the patient can vary the flow without a pressure change.

As was mentioned above the respirator must assure that the pressure in the mouthpiece or that which enters into the lungs does not suddenly increase or decrease but rather goes through a smooth transitional change without imposing injury or discomfort to the user. It has been found that this smooth transition can be accomplished by closely controlling the geometry of the inner action region and also by providing in the feedback loop of the fluid amplifier a positive pressure control and in another feedback loop a negative pressure control interconnecting an outlet passage communicating to ambient. These controls are manually adjusted to set an area in these feedback passages and serve to provide a smooth and gradual from inhalation to exhalation and vice versa.

A feedback loop is also provided in the exhalation passage and a manual control is inserted therein which serves to adjust the ratio of inhalation to exhalation cycles. As an assist type of respirator it is noted that the actual control of the inhalation and exhalation cycle is done by the patient by his own impetus in breathing. The respirator is set for a predetermined ratio of exhalation to inhalation. However, the impetus of the switching occurred by the breathing of the patient overrides this ratio but since the fluid amplifier is set for a natural or normal ratio, a little additional effort is required by the patient to overcome this natural setting. However, once the breather becomes accustomed to the respirator with the set inhalation to exhalation ratio he will eventually come into rhythm with this setting.

In the inner region of the fluid amplifier, a double feedback loop may be utilized to bias the control port with the flow in the inlet or outlet output channels for reducing the patient's effort necessary to effectuate switching from the inhalation to exhalation cycles.

The respirator must also assure that during the inhalation cycle the flow can be regulated without a pressure change and the pressure can be regulated without a flow change, and also during the exhalation cycle excessive ambient air must not be induced in the inhalation passage. This is accomplished by the particular flow control and fluid diode valve disclosed in this application. As will be described in more detail hereinbelow, the diode valve is judiciously inserted in the fluid amplifier and serves to decouple the output load (mouthpiece) and the iner action region of the amplifier during the inhalation cycle. In this manner the flow control valve inserted in the fluid amplifier is utilized to adjust the flow to the patient's lungs yet without changing the mouthpiece pressure at which the fluid amplifier switches from inhalation to exhalation. Also a manual positive pressure control in the feedback loop can be utilized to adjust the swiching pressure without affecting the flow.

It is therefore an object of this invention to provide a respirator that is characterized as having no moving parts, highly reliable, can be employed as a clinical or portable home unit, is simple to manufacture and economical to build. Such a respirator is also characterized by the fact that its operation is relatively simple so that the patient can use it without the assistance of a technician or medical doctor. It is also characterized by the fact that it operates at a very substantially low pressure so that in the event of a malfunction the pressure is not sufficient to cause injury to the patient's lungs.

A still further object of this invention is to provide in a respirator as described an intermittent and positive nebulizer uniquely combined with a fluid amplifier so that fluid medication in the nebulizer is not rejected in the exhalation cycle.

A still further object is to provide suitable feedback means for assuring that there is a smooth transition from the exhalation to inhalation and back to the exhalation cycles.

A still further object of this invention is to provide in breathing apparatus means for changing the unit to either an assist or control type of respirator by a mere setting of a valve.

A still further object of this invention is to provide additional feedback means to reduce the patient's efforts in switching from the inhalation to the exhalation cycles.

Other features and advantages will be apparent from the specification and claims and from the accompanying drawings which illustrate an embodiment of the invention.

FIGURE 1 is a perspective view of the entire respirator as packaged as a portable unit.

FIGURE 2 is an exploded perspective view of the amplifier and its varous controls.

FIGURE 3 is an elevated view of the diode valve.

FIGURE 4 is a sectional view taken along lines 4—4 of FIG. 3.

FIGURE 5 is a schematic illustration of the pure fluid amplifier utilizing an ejector.

FIGURE 6 is a partial end view of FIG. 5 illustrating the controllable bleed valve in the ejector.

FIGURE 7 is a view in elevation illustrating the flow inducer section.

FIGURE 8 is a sectional view taken along lines 8—8 of FIG. 7.

FIG. 9 is a sectional view of the nebulizer of the type illustrated in FIG. 1.

FIGURE 10 is a schematic view partly showing the fluid amplifier and particularly illustrating judicious location for placing the neublizer.

FIGURE 11 is a sectional view taken along lines 11—11 of FIG. 10.

Referring now more particularly to the details of this invention as is illustrated in FIG. 1, the respirator comprises basically a compressor generally illustrated by numeral **10**, the fluid amplifier generally illustrated by numeral **12**, the mouthpiece **14** and a nebulizer **16** inserted between the mouthpiece and the amplifier **12**. Compressors that are currently available inherently produce a pressure pulsation in the discharge flow which may be eliminated by incorporating an accumulator which is illustrated by numeral **18**. The accumulator is merely a plenum chamber that is inserted between the fluid amplifier and the discharge end of the compressor. Suitable valving may be utilized to control the flow from the accumulator to the fluid amplifier. Fluid from the compressor is fed to the accumulator through line **20** and is directed to the fluid amplifier through piping **22** which is helically wound so as to reject the heat picked up as a result of compression. A flexible cable **24** may be utilized to interconect line **20** to the fluid amplifier affording freedom of movement of the mouthpiece. A bleed line **26** is tapped into line **20** at the discharge end of the compressor for supplying a pressurized fluid to nebulizer **16**.

The unit may also contain a visual pressure gauge of any suitable type generally indicated by numeral **28** which is connected to fluid amplifier **12** in such a way as to allow the patient to visually inspect the pressure of the fluid entering into the mouthpiece **14**.

It will be appreciated that mouthpiece **14** is detachable from the unit so that a suitable face mask may be utilized in its place. The compressor and accumulator and cooling coils are encapsulated in a suitable housing **30** which, in turn, is mounted in a portable suitcase generally indicated by numeral **32**. This, of course, illustrates the simplicity of the unit while also pointing out that such a unit is portable.

Looking now at FIG. 2 the details of the fluid amplifier will next be described. This fluid amplifier may be formed into two plates which may be made from suitable plastic material. The cover plate **35** may be secured by any suitable well-known means to overlie the top surface of plate **38**. Fluid from the compressor **10** is admitted to the power nozzle **40** through line **24**. From there the flow enters the inner chamber **42** of fluid amplifier **12** where it can be directed to either the channel **44** formed on the left of splitter **46** or channel **48** formed on the right side of splitter **46**. The flow passing through channel **48** is eventually directed to the mouthpiece and for the purposes of this description will be hereinafter referred to as the inhalation channel. Looking for the moment at the operation during the inhalation cycle, the flow entering the inner chamber normally will adhere to the right wall to the inner chamber and flow onward through the inhalation channel to the mouthpiece. Channel **50** communicating at the upper end of channel **48** senses the pressure therein which is obviously at the same value as the pressure in the mouthpiece, where it is directed to discharge in the main stream of the inner chamber adjacent the power jet and serves to create a pressure differential thereacross. This is known in the art as the control channel and it may be located so that the flow from the control channel will be 90° relative to the flow in the inner chamber. When the pressure in the feedback channel **50** reaches a predetermined value, the flow in the inner chamber locked-on to the right-hand wall will be caused to switch to the left-hand wall to flow through the left-hand channel **44** hereinafter referred to as the exhalation channel. An enlarged chamber **44** is formed in the upper portion thereof and is adapted to communicate with bleed valve **52** secured in position in a recess **54** formed in the top plate. A plurality of holes **56** formed in the top cover of bleed valve **52** bleed air to ambient at a given back pressure level.

In order to control the flow in the inhalation channel without effecting a pressure change, diode valve **58** judi-

ciously located adjacent the inhalation channel is mounted in the top plate and contains an opening located at the bottom end thereof which is in communication with the opening 60 adjacent the inhalation channel. A portion of the flow in the inhalation channel, therefore, will pass through opening 60 into chamber 62 into the inner cylindrical opening in fluid diode 58, pass through the leg portion 64 of diode 58 and then out to ambient through the opening formed on the top of leg portion 64.

For the moment referring now particularly to FIGS. 3 and 4 which show the details of the fluid diode (like reference numeral reference like parts). The fluid diode is substantially an enclosed cylinder having a leg depending tangential to the outer wall. The diode is enclosed by a suitable wall 66 defining a cylindrical cavity 68 and a rectangular cavity 70. Opening 72 formed on the bottom wall communicates with the inner cylindrical cavity 68 which cavity in turn communicates with cavity 70 from where flow is directed to ambient through opening 74. As will be apparent, fluid in the fluid diode valve flows in both directions, namely, into opening 74 through cavities 70 and 68 and then out through opening 72 and vice versa. Owing to the fact that the flow entering opening 74 is directed tangentially and then swirls to form a vortex in cavity 68 before discharging through aperture 72, a greater resistance will be evidence than when the flow enters 72 and passes through opening 74. Hence, it is apparent from the foregoing that the flow entering through 72 and discharging through 74 under the same pressure conditions will afford less resistance than relative to the flow entering 74 and discharging through 72. The fluid diode, thus, decouples the airstream downstream thereof (inner action region) and the airstream just upstream thereof (mouthpiece) during the inhalation cycle. Fluid is bled to ambient through the fluid diode at a rate dependent on the setting of valve 76. Low settings will provide high leak rates and high settings will provide low leak rates tending to maintain the pressure in the system at a constant value. The fluid diode during the exhalation cycle restricts the admittance of ambient air so that no interference with the switching will occur.

Referring back to FIG. 2 flow valve 76 inserted through opening 78 formed on the top plate contains a portion 80 partially circular in cross section which projects into recess 82 formed adjacent the inhalation channel 48. Rotation of 76 serves to vary the area of the inhalation channel just upstream of the mouthpiece. Flow valve 76 working in conjunction with fluid diode 64 allows the patient to adjust the flow from say 50 liters per minute (l./m.) to 90 l./m. and increments therebetween without changing the pressure necessary to effecuate switching.

Considering next the expiration cycle which occurs when the pressure in the mouthpiece, as will be evidenced in the inhalation channel 48 downstream of recess 82, reaches a predetermined value. This pressure fed back through feedback channel 50 creates an unbalanced force across the main stream and causes it to switch from the inhalation channel to the exhalation channel. The flow, diverted to channel 42 passes into cavity 44 where it is bled to ambient through openings 56 in the bleed valve 52 and through passage 83. As will be observed from FIG. 2, the flow adjacent the edge of the splitter 46 entering channel 42 effectively induces fluid out of channel 48 and the flow in channel 83 likewise induces fluid out of channel 48 through channel 84, having the overall effect of inducing the flow at a quick and fast rate out of the lungs while the patient is exhaling without the necessity of providing a movable type of exhalation valve.

As noted, pressure in chamber 44 is fed to control port 87 via feedback channel 86 and when it reaches a predetermined value, an unbalance of force across the main stream is created causing the stream to switch back to the inhalation channel.

From the foregoing it is therefore apparent that the control feedback channels 50 and 86 effectively change the pressure differential across the main stream causing the stream to switch from the inhalation to the exhalation cycle and vice versa. The rate of change of the inhalation to exhalation ratio (*I/E*) is controlled by the proper sizing of openings 56 and the setting of the manual adjustable valve 88 which is rotatably supported in opening 90 formed in the cover plate 36 and the registering recess 92 formed in the bottom plate 38. The slot 94 of valve stem 88 cooperates with feedback channel 86 to meter the flow to control port 87 and the rate of flow therethrough adjusts the *I/E* ratio. Adjustment of valve 88 also controls, the sensitivity from a positive pressure level to a negative pressure level. By virtue of this control the unit can be utilized as an assist or control type of respirator and including the intermittent positive pressure breathing apparatus. That is to say, by changing the setting of valve 88, the pressure in the mouthpiece can be adjusted to a peak pressure and any intermediate pressure for a given *I/E* cycle. Thus, for example, as an intermittent positive pressure type, the pressure in the mouthpiece will range between 10 and 30 centimeters of water. As an assist type of respirator, the pressure in the mouthpiece will normally range between 0 and 30 centimeters of water.

As can be seen from FIG. 2, feedback channel 86 is provided and connected to ambient for the purpose of controlling the sensitivity of the fluid amplifier. A manually adjustable valve 96, similar to valve 88, is inserted into recess 98 adjacent the line 100 for controlling the sensitivity of the fluid amplifier. Valve 96 can be adjusted to create a negative pressure in the face mask if so desired.

Valve 102, similar to valve 88, fits into recess 104 adjacent feedback line 50 for adjusting the flow to control port 51. Proper balancing of the settings of valves 96 and 102 will assure a smooth and gradual transition in the switching from the inhalation to exhalation and exhalation back to inhalation cycles.

It is also possible to reduce the patient's efforts in switching from the inhalation-exhalation cycles by providing an additional pair of feedback channels 105 and 106. Both feedback channels 105 and 106 communicate with the main flow in the inner chamber at a point approximately in line with the edge of splitter 46 so as to bias the control ports 87 and 51.

Channel 108 communicates with the pressure in the inhalation channel and connects with gauge 28 via conduit 106.

In certain applications, when the flow control valve 76 is set for minimum flow, it is possible that the switching will occur prematurely. This premature switching may be prevented by incorporating a fluid diode 58' similar to, but having lower flow characteristics than, fluid diode 58. This fluid diode will serve to decouple the main stream just downstream of valve 76 from the stream upstream of valve 76 during the exhalation cycle.

Still referring to FIG. 2, it will be noted that the width of channels 48 and 83 are wider at the point just downstream of the passage 84. Walls 48' and 83' are stepped inwardly relative to the channels so that when the main stream is flowing through the respective channels 48 and 83 a negative pressure region will be created adjacent the recessed walls. This effectively induces flow from one channel to the other to increase the volume of flow to the lungs in the inhalation cycle and increase the volume of flow discharging out of the lungs in the exhalation cycle. Hence, it will be apparent that during the inhalation cycle, flow passing through channel 48 adjacent wall 48', creates a low pressure region which creates a pressure drop across the ends of channel 84. As a result, flow will be induced from ambient via bleed valve 52 and channel 83.

During the exhalation cycle the main stream being diverted to the left of splitter 46 passes through channel 42 and then through 83. Similarly, adjacent the recessed wall 83' a negative pressure will be created and a pres-

sure drop will be evidenced across channel 84. This will induce flow out of channel 48 when the breather is exhaling.

A respiratory unit as the one described above has proven to be efficacious with the following dimensions of the fluid amplifier. It is to be understood, however, that the example below is included herein for illustration purposes and is not to be construed as limiting the scope of the invention.

Splitter location ---------- So that unit is a memory device.
Aspect ratio ---------- Not smaller than 4 to 1.
Power nozzle width ------- Between .030 and .050 inch.

	Inside Diameter of 68	Diameter 72	Width of 70
Diode 58, in----	.400	.156	.060
Diode 58', in----	.400	.156	.032

While the amplifiers which have already been successfully tested were formed from plastic material, namely, acrylic type polymer and polycarbonate, it is to be understood that it is within the scope of this invention to use any other material whether it be metallic or nonmetallic. However, it should be understood that the material selected must be capable of withstanding autoclaving.

The unit described above has not only been successfully employed to sustain respiration in open-chest surgery of dogs, it has also been successfully used by human patients afflicted with emphysema.

As noted in the description of FIG. 2, additional fluid is induced into the mouthpiece by providing certain passages communicating with ambient and constructing those passages in a particular manner. The description to follow in connection with FIGS. 5–7 are means for inducing the flow by incorporating an ejector pump which pump is suitably controlled by mechanical means for controlling the flow through the mouthpiece. The fluid amplifier portion is similar to the one disclosed and described in connection with FIG. 2 but may include in the various passages divided by a splitter, a bucket for providing smoother flow in the reverse direction. The fluid amplifier similar to the one described in FIG. 2 is comprised of a power nozzle **200** which directs fluid to either inhalation channel **202** and alternately to discharge or exhalation channel **204**. Feedbacks connected to the inner action region **206** are provided and serve the same purpose as was described in connection with FIG. 2. A positive pressure control **208** and negative pressure control **210** are provided and again serve the same purpose. As noted, however, in connection with FIG. 2, the channels were all rectangularly shaped in cross section. However, the shape of the ejector passages are circular in cross section rather than being rectangular. The ejector section **212** may be secured in any suitable means, such as bonding, to the amplification section **214** and contains the main flow passage **216** registering with the inhalation passage **202**. This passage flares out to a wider diameter at the discharge end **218** so that the fluid adjacent the fluid amplifier passes through a restricted area or a throat section of the ejector. Disposed at the throat is a passage **220** which communicates with ambient through the passage **222** formed in the rotatable plate **224**. A plurality of openings **226** are provided to communicate with annular chamber **228** communicating with passage **220**. Thus, the high speed flow passing through the throat section **216** induces the flow through passages **220** and **222** and carries it to the mouthpiece (not shown) through the outlet **218**. Thus, during the inhalation cycle additional flow is induced into the mouthpiece without the need of a larger pump. The amount of additional flow induced through the ejector is controlled by the rotatable

plate **224** which carries opening **222** communicating with the opening **220** and thus defining the area exposed to ambient. Plate **222** is rotatably mounted adjacent the side wall of the combined ejector and fluid amplifier sections and may be retained in position for rotatable movement by any type of rod illustarted by screw arrangement **230**.

In the exhalation cycle the flow entering into the opening **218** and discharging from the patient's lungs will discharge overboard to ambient through passages **232** and **234** and will be induced therefrom at the faster rate by virtue of the fact that the flow from the power jet nozzle **200** passes into expiration channel **204** and out of chamber **236** to ambient and then through passage **234**. The high stream flow induces flow out of passage **216**.

Looking at FIG. 7 for the moment, the ejector may be made into a separate part that fits in a cylindrically shaped recess **240** and is comprised of a cylindrical body **242** which contains the diverging passage **216** and the annular groove **218** communicating with the feedback line **244** and the pressure sensing line **246**. Passage **232** communicates with the main stream of the ejector through the passage **248** which registers with passage **232**.

Thus it is apparent from the foregoing that the ejector serves to assist the patient in his breathing both during the inhalation and exhalation cycles.

As was mentioned above, it is necessary in many respirator applications to provide medication to the patient's lungs which may be accomplished by incorporating a suitable nebulizer. FIG. 9 illustrates the nebulizer that uses the aspirator principle for inducing fluid into the main stream during the inhalation cycle and provides means for preventing the medication to be carried over and vented during the exhalation cycle. Looking at the details of FIG. 9 it can be seen that a nebulizer bottle **260** containing suitable medication is threadably secured to the nebulizer section **16** by the internally threaded flange **262** which receives the external thread formed on bottle **260**. A tube **264** projecting into the bottle terminates adjacent tube **286** connected to the discharge end of accumulator **18** by the T connection **268**. The angle of the tube **286** relative to the tube **286** is oriented so that it defines an angle of no less than 72°. A deflector plate **270** having a beveled end **272** is spaced in such a way that the flow discharging from pipe **286** impinges on the beveled face **272** which is spaced approximately .250 inch downstream therefrom. This serves to deflect and break up heavy particles which leave tube **264**. The fine particles which are sheared and deflected in an upward direction owing to the shape of the end of plate **270** discharge into the main stream flowing to the mouthpiece during the inhalation cycle. Plate **270** is supported in position by any suitable means to wall **274**. An opening **276** formed in wall **274** communicates with the reservoir **278** formed in container **260**. This serves to collect the excess particles which are not picked up in the main stream during the inhalation cycle.

It will be noted that the opening **280** which connects to the mouthpiece is lower than the opening **282** which connects to the fluid amplifier. This serves to prevent the medication fluid from being carried back through the fluid amplifier and discharged overboard during the exhalation cycle. Thus, during the exhalation cycle the air flowing back through opening **280** will carry any fluid contained in the stream to impinge on the back wall **284** of the nebulizer and the back face of plate **270**. Additionally, the flow passing over the plate **270** prevents particles from being sheared off and deflected to the main stream and also serves to provide turbulence so as to prevent nebulization.

Nebulization can also be achieved by providing mechanism that may be attached directly to the fluid amplifier. This is illustrated by drawings depicted in FIGS. 10 and 11 wherein FIG. 10 schematically illustrates the fluid amplifier showing the power nozzle **300**, the inner action region **302**, the inhalation channel **304** and exhalation

channel 306. As is understood by those skilled in the art, when the flow discharging from the power jet (illustrated by lines 308) flow adjacent one wall, it creates a low pressure region known as a bubble. By inserting a capillary tube in the bubble, which capillary tube communicates with the medication as can be seen in FIG. 11 during the inhalation cycle, the low pressure region will induce the medication from reservoir 310 and aspirate it into the inner action region of the fluid amplifier where it is picked up and carried to the mouthpiece through channel 304. Since the bubble will be located adjacent the opposite wall of the inner action region during exhalation cycle, there will be no nebulization.

It has also been found that the end of the capillary tube 312 may be located adjacent the end of the inner action region in the center of the inhalation channel 304. Another suitable location for the capillary tube 312 is directly in the channel 304 but in close proximity to its discharge end. With respect to the latter two mentioned locations when the respirator is in the reverse flow, that is during the exhalation cycle, the flow over the capillary tube is so slow that no fluid pickup is possible and therefore intermittent nebulization as assured. The nebulizer bottle may be suitably threaded to recess 314 formed in the wall of the nebulizer. Pressure is bled internally of the container 316 through openings 318 for forcing the medication through the capillary tube 312.

It should be understood that the invention is not limited to the particular embodiments shown and described herein but that various changes and modifications may be made without departing from the spirit or scope of this novel concept as defined by the following claims.

I claim:

1. A respirator of the type that controls or assists in respiration including in a source of fluid under pressure, a pure fluid amplifier, a mouthpiece and conduit means interconnecting said source, said pure fluid amplifier and said mouthpiece, said pure fluid amplifier including a body having a power nozzle, V-shaped passage connected thereto by an inner action region and the apex of said V-shaped passage defining a splitter, the first leg of said V-shaped passage connected to said mouthpiece, first passage means including a first control port angularly disposed relative to the inner action region for leading fluid thereto from one leg of said V-shaped passage for switching the fluid issuing from said power nozzle from one leg to the other leg of said V-shaped passage, second passage means including a second control port angularly disposed relative to said inner action region leading fluid thereto from the other leg for switching the fluid issuing from said power nozzle from said other leg to said one leg of said V-shaped passage, the improvement comprising third passage means in said body interconnecting ambient and said second control port and adjustable valve means disposed in said first, second and third passage means.

2. A respirator as claimed in claim 1 including restriction means disposed in said second passage means communicating with ambient.

3. A respirator as claimed in claim 2 wherein said restriction means includes a hollow cylindrical member mounted in a complementary opening formed in said body and a top plate having a plurality of openings formed therein.

4. A respirator as claimed in claim 1 including nebulizing means, said nebulizing means including a container for holding liquid medication mounted adjacent to but external of said body, a capillary tube extending internally in said container and projecting in the inner action region adjacent the wall of said first leg where the bubble forms, and openings in said body interconnecting said inner action region and said container.

5. A respirator as claimed in claim 1 including nebulizing means, said nebuilizing means including a container for holding liquid medication mounted adjacent to but external of said body, a capillary tube extending internally in said container and projecting in said first leg adjacent said splitter, and openings in said body interconnecting said first leg and said container.

6. A respirator as claimed in claim 1 including nebulizing means, said nebulizing means including a nebulizing section in said conduit means intermediate said mouthpiece and said pure fluid amplifier, a container housing liquid medication mounted adjacent said nebulizing section, inlet and outlet ports in said nebulizing section being axially disposed relative to each other but having the outlet port being lower than the inlet port, a first tube extending from said container into said nebulizing section adjacent to but below the inlet port, a second tube also extending into said nebulizing section having its end terminating adjacent the end of said first tube and disposed at an angle of no less than 72° relative to said first tube, a flat plate having a beveled face extending into said neubulizing section, and passage means interconnecting said second tube and said source, such that the fluid issuing from said second tube impinges on said beveled face.

7. A respirator adapted to control or assist in respiration of the type that includes, a source of fluid under pressure, a pure fluid amplifier, said pure fluid amplifier including a body having a power nozzle, and V-shaped passage connected thereto by an inner action region, a mouthpiece and conduit means interconnecting said source, one leg of said V-shaped passage of said pure fluid amplifier and said mouthpiece, first feedback means for switching the fluid issuing from said power nozzle to one leg or the other leg of said V-shaped passages, said feedback means including a first control port angularly disposed relative to the inner action region for leading fluid downstream of said inner action region thereto from one leg of said V-shaped passage, and a second control port angularly disposed relative to said inner action region leading fluid downstream of said inner action region thereto from the other leg, the improvement comprising second feedback means including passages formed in said body for leading fluid from said inner action region to said first and second control ports.

8. A respirator adapted to control or assist in respiration comprising, in combination, a source of fluid under pressure, a pure fluid amplifier, a mouthpiece and conduit means interconnecting said source, said pure fluid amplifier and said mouthpiece, said pure fluid amplifier including a body having a power nozzle, V-shaped passage connected thereto by an inner action region, the first leg of said V-shaped passage connected to said mouthpiece, first passage means including a first control port angularly disposed relative to the inner action region for leading fluid thereto from one leg of said V-shaped passage for switching the fluid issuing from said power nozzle from one leg to the other leg of said V-shaped passage, second passage means including a second control port angularly disposed relative to said inner action region leading fluid thereto from the other leg for switching the fluid issuing from said power nozzle from said other leg to said one leg of said V-shaped passage, the improvement including third passage means in said body interconnecting ambient and said second control port, adjustable valve means disposed in said first, second and third passage means, restriction means disposed in said second passage means communicating with ambient, a fourth passage means interconnecting said restriction means and ambient and a fifth passage means interconnecting said fourth passage means and first leg.

9. A respirator as claimed in claim 8 wherein said first leg and said fourth passage means are defined by parallelly spaced wall means, the distance between opposing parallel walls being increased for a predetermined length extending from said fifth passage means to the edge of said body.

10. A respirator adapted to control or assist in respiration comprising, in combination, a source of fluid under

pressure, a pure fluid amplifier, a mouthpiece and conduit means interconecting said source, said pure fluid amplifier and said mouthpiece, said pure fluid amplifier including a body having a power nozzle, V-shaped passage connected thereto by an inner action region, the first leg of said V-shaped passage connected to said mouthpiece, first passage means including a first control port angularly disposed relative to the inner action region for leading fluid thereto from one leg of said V-shaped passage for switching the fluid issuing from said power nozzle from one leg to the other leg of said V-shaped passage, second passage means including a second control port angularly disposed relative to said inner action region leading fluid thereto from the other leg for switching the fluid issuing from said power nozzle from said other leg to said one leg of said V-shaped passage, third passage means in said body interconnecting ambient and said second control port, adjustable valve means disposed in said first, second and third passage means, and ejector pumping means for inducing additional flow to the mouthpiece and increasing the rate of discharge from the mouthpiece, said ejector pump means including a casing member mounted adjacent the end of said body and having a bore registering with said first leg, said bore flaring into a wider diameter discharge end, ports at the narrow diameter communicating with ambient, valve means for metering ambient air to said port, and passage means interconnecting said bore, ambient and the other leg of said V-shaped passage.

References Cited

UNITED STATES PATENTS

3,030,979	4/1962	Reilly	137—81.5
3,068,856	12/1962	Bird et al.	128—145.5
3,198,214	8/1965	Lorenz	137—81.5
3,244,189	4/1966	Bailey	137—81.5
3,280,832	10/1966	Burns	137—81.5
3,292,623	12/1966	Warren	137—81.5

FOREIGN PATENTS

709,848	6/1954	Great Britain.

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