United States Patent

Fumagalli

[15] **3,658,443**

[45] **Apr. 25, 1972**

[54] PRESSURE ALTERNATING DEVICE FOR AUTOMATIC LUNGS VENTILATOR ACTUATION

[72] Inventor: **Giovanni Fumagalli,** 11, Via delle Primule, 20146 Milan, Italy

[22] Filed: **Nov. 20, 1970**

[21] Appl. No.: **91,250**

[30] **Foreign Application Priority Data**

Nov. 21, 1969 Italy 880025

[52] **U.S. Cl.** **417/384,** 417/394

[51] **Int. Cl.** **F04b 9/12,** F04b 35/02, F04b 43/10, F04b 45/00

[58] **Field of Search** 417/384, 385, 388, 394, 395

[56] **References Cited**

UNITED STATES PATENTS

2,478,568 8/1949 Coe 417/385

2,582,210 1/1952 Stanton ..... 417/394 X

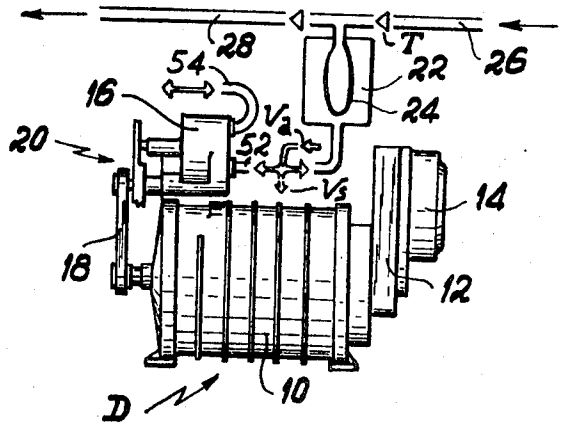
Primary Examiner—Robert M. Walker

Attorney—Michael S. Striker

[57] **ABSTRACT**

The device is designed for alternatingly supplying air at superatmospheric and respectively at subatmospheric pressure into a variable pressure chamber of a lungs ventilator for pulsingly and meteredly supplying fresh gas into a patient's lungs. The device comprises a pump having a rotary piston adapted to unidirectionally and pulsingly feeding air at a rate whose variation in each pulse is substantially defined by the function of "$\sin^2$ alpha" ("alpha" being the amplitude of the rotational motion), and a negative pressure limiting valve including a valve member electromagnetically biased by a biasing force which decreases with the second power of the displacement of said member, to provide a venting passage the cross-sectional area of which varies concurrently with the speed of air through said passage for levelling the variable resistance encountered by said air traversing said passage at different speeds.

11 Claims, 5 Drawing Figures



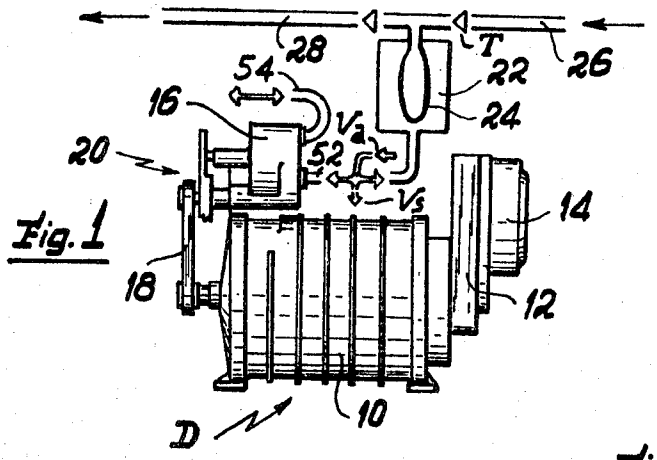


Fig. 1

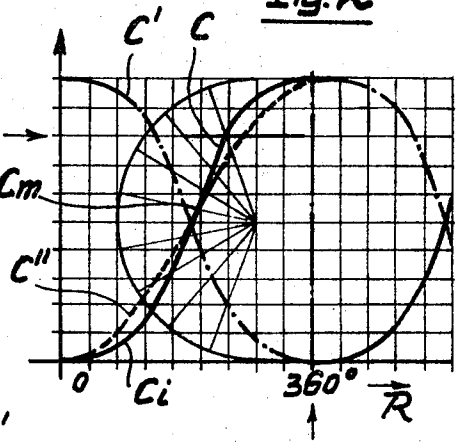


Fig. 2

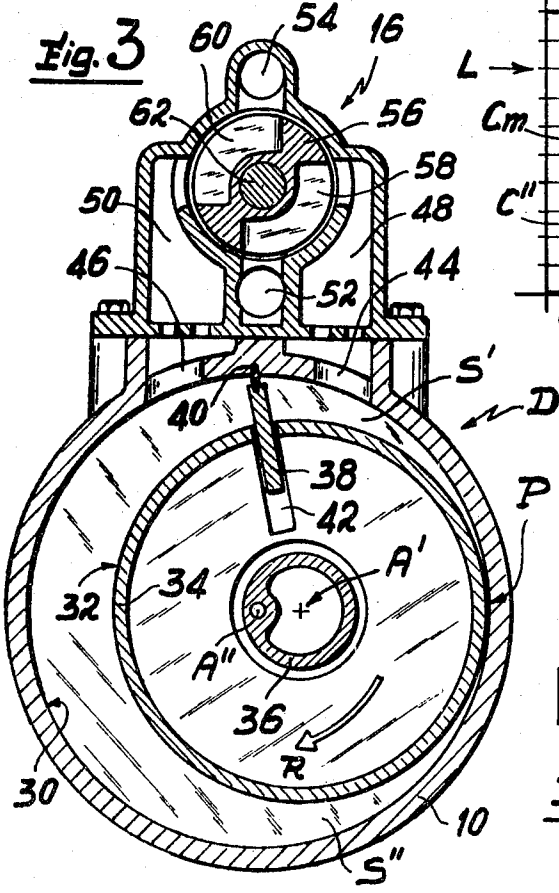


Fig. 3

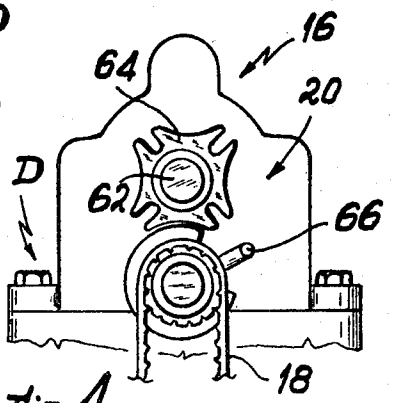


Fig. 4

INVENTOR.
GIOVANNI FUMAGALLI
BY Wilson S. Stickler
Attorney

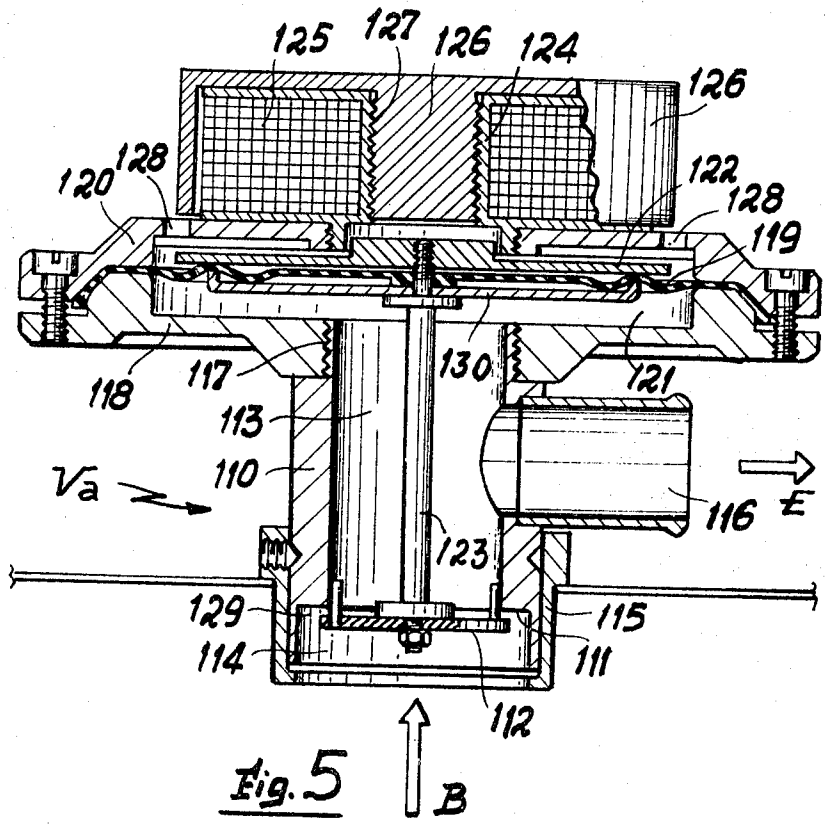


Fig. 5

INVENTOR.
GIOVANNI FUMAGALLI

BY
Milton S. Sale
Attorney

PRESSURE ALTERNATING DEVICE FOR AUTOMATIC LUNGS VENTILATOR ACTUATION

BACKGROUND OF THE INVENTION

This invention is concerned with a device designed for actuating a lungs ventilator apparatus, more particularly for cyclically applying an overatmospheric pressure and a subatmospheric pressure (which will be termed "positive" and respectively "negative" pressure as this description proceeds and in the appended claims) within a chamber and on the outer surface of a collapsible bag or other variable volume reservoir connected in the circuit of an automatic lungs ventilator apparatus for providing the pulsing feed of the gaseous mixture to be cyclically and meteredly supplied into the patient's lungs.

Such automatic ventilators are well known and made use of for improving surgery and anaesthesia standards, for example, and in various occurrences when spontaneous breathing may become seriously depressed and inadequate.

A very wide and exhaustive literature deals with the matter and therefore any further consideration thereabout is superfluous. It is however to be taken into consideration, in view of the scope of this invention, that the precise adjustment of the applied pressures, irrespective of the pulsing cycle, is critical for the most desirable metering of the amount of gas to be supplied into the patient's lungs, and that the mode by which the positive pressure is cyclically increased is of the most importance for proper and effordless filling of the lungs alveolar spaces. Several devices have been heretofore proposed for alternatively applying positive and negative pressure into a variable pressure chamber wherein a breathing bag is located, said devices generally comprising an alternating piston or bellow pump, wherein the piston or the movable end part of the bellow is reciprocated by a crank and connecting rod mechanism, the crank shaft making one complete 360° revolution at each respiratory cycle. Such pumps have a stroke volume in excess than the gas volume to be supplied in the patient's lungs at any respiratory cycle, and ports and limiting valves are provided for venting the variable pressure chamber to the atmosphere and for levelling the pressures at the desired values. A plurality of adjusting means are provided and are to be acted upon for maintaining the desired pressure and/or gas volume, when the frequency of the respiratory cycle is varied.

It is known to those skilled in the art that in a crank driven reciprocating pump the air input and output varies according to a sinusoidal law, which provides a pretty progressive initial increasing of the flow. It has been found that an increasing governed by such law is not as progressive as desirable, while a proper filling of the lungs alveolar spaces would best obtained by supplying in the variable pressure chamber amounts of air whose increase would be defined by an initially flatter and finally steeper curve.

THE INVENTION

The invention provides a new and improved actuator for a lung ventilator apparatus of the type comprising a variable pressure chamber, the new actuator device providing cyclic supplying of air in said chamber at the most desirable rate for obtaining the most favorable curve of positive pressure increasing, and further providing an uniformly levelled negative pressure, irrespective of the frequency of the respiratory cycle. Still further, the invention provides a new and improved mechanism of simple, sturdy and durable construction, not including reciprocating components. Essentially, the new device comprises a rotary pump adapted to provide an unidirectional pulsing flow at each complete revolution and having inlet and outlet parts, and a distributing preferably rotary valve for alternatively connect said inlet and respectively outlet port to the ventilator variable pressure chamber, said pump being such to provide a pulsing flow whose rate of flow is governed by a law of the type "$\sin^2$ alpha", wherein "alpha" is the amplitude of the motion of the rotary components of the pump, and valve means adapted to vent said chamber to the atmosphere, when a given negative pressure is attained, providing an air inlet whose cross-sectional area increases concurrently with the speed of the air sucked-in through the inlet passage. More particularly, said pump comprises a rotary piston consisting of a cylindrical body supported and driven for eccentrically revolving within a cylindrical chamber and cooperating with an oscillatable partition wall. Still more particularly, said valve means comprises a valve body biased towards a valve seat by an electromagnetically actractive means so that a biasing force decreasing as a function of the second power of the spacing between said body and seat is provided, so that a passage whose cross-sectional area increases as the resistance to passage of air increases with its speed is provided, to compensate with the greater resistance which would be encountered by the air, when caused to pass at greater speed through said passage if of constant cross-sectional area.

These and other features of the invention will be best apparent from the following detailed description of the preferred embodiment shown in the accompanying drawings.

THE DRAWINGS:

FIG. 1 is a small scale and simplified side elevational view of the device, and diagrammatically and fragmentarily illustrates part of the fluid circuit of a known ventilator actuated by said device;

FIG. 2 is a graph illustrating the advantageous mode of operation of the new device;

FIG. 3 is a cross-sectional view of the rotary pump and of the distributing valve;

FIG. 4 is a front elevational view of the drive mechanism actuating said distributing valve; and

FIG. 5 is a cross-sectional detailed illustration of the negative pressure levelling valve.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

As generally shown in FIG. 1, the new device comprises a rotary pump D including a substantially cylindrical pump casing **10**, and driven, through a known variator or stepless speed change drive means **12**, by a motor **14**. Other means can be made use of for driving such pump at adjustable speed, a variable speed motor for example. Such pump cooperates with a distributing valve **16**, phasedly driven by the pump shaft by means of a toothed belt transmission **18** and a mechanism **20** adapted for intermittent drive.

Such pump D and distributing valve **16** are connected to the lungs' ventilator for alternately applying a positive and a negative pressure into a variable pressure chamber **22**, housing a known collapsible bag **24**, the inside of which is connected to the supply circuit **26**, **28** of the ventilator. Either upstream part **26** and downstream part **28** of said circuit comprise check valves for ensuring that the gaseous mixture to be supplied to the patient's lungs will flow in the direction indicated by the arrows only. According to current art, the upstream check valve, indicated at T, is provided or cooperates with a throttle passage, preferably of adjustable cross-sectional area, for metering the rate of flow in said circuit at a given difference of pressure between upstream and downstream of said passage.

A few considerations are to be taken into account with relation to what above. Among the parameters according to which a ventilator for the uses described there are comprised the total average flow rate, defined for example in terms of liters per minute, and the pulsing or respiratory frequency, in terms of cycles per minute, for example. Generally, the flow rate is adjusted for supplying a given amount of gaseous mixture, per minute, irrespectively of the frequency. The ratio "time of application of the negative pressure/total time of each cycle" is a constant. The in-flow rate in a pump is, on the contrary, variable with the speed at which the pump is driven, that is with the frequency. Further, the resistance encountered by a gas flowing through a throttle passage of given constant cross-sec-

tional area, varies with the second power of the speed of such gas in such passage. As a consequence of above, when the air is more speedly sucked off from said chamber **22**, the negative pressure is more speedly built-up in said chamber and the gaseous mixture will be more speedy sucked-in said chamber through the throttle passage at T.

Therefore, the resistance encountered in said passage will vary, thus modifying the rate of flow when the frequency of the pulsing cycle is varied.

As a matter of fact, in the apparatuses of prior art and adjustment of the throttle passage is to be made any time the frequency is varied. Said requirement leads to certain serious problems, in particular when the adjustments, in particular that of frequency, are made in an emergency when is immediate danger for the patient's life. According to one aspect of this invention, said problems have surprisingly been solved by providing a valve V_a (a preferred embodiment of which will be described below) connected to the duct **52**, between the pump, more particularly the distributing valve, and the chamber **22**, so designed to provide a venting port whose cross-sectional area varies, upon opening at a given negative pressure, in such manner to provide a constant resistance to the passage of in-flowing air, irrespective of the speed thereof, so that a given maximum pressure is built-up and maintained in said chamber **22** irrespective of the frequency at which the apparatus is adjusted. Therefore, provided that the total intake time is a constant (generally one/third of the operation time), the amount per minute of fresh gas sucked in bag **24** and then supplied to the patient will remain constant even if the respiratory frequency is drastically modified, by making use of the device of the invention.

Still further, the pump D is such (as described below) to provide a steep increase of intake rate up to a given negative pressure level. At differing frequencies, the in-flow speed varies more severely than in current art devices and therefore the provision of said valve V_a is of great importance to compensate, in the intake strokes, the influence of such steep increasing, which is extremely advantageous when the positive pressure is applied for the most proper gradual supplying of fresh gas to patient's lungs. The provision of such valve V_a, therefore further improves the advantageous features of the new device.

The graph of FIG. **2** illustrates the curve C which shows the variation of out-flow rate from the pump D as a function of rotation R of its shaft, during a complete revolution of 360°. The dash-and-dot curve C′ is the inverse thereof and indicates the variation of in-flow. The curve C describes a function of the type "$\sin^2$ alpha", and it is illustrated in comparison with curve C″, which visualizes a function of the type "sin alpha", that is a function typical of the variation of out-flow of a conventional crank driven piston or bellow type pump. From such comparison there is evident that curve C comprise a flatter and more progressive initial part *Ci* and a steeper middle part *Cm* than said conventional curve C″.

The pump D provides a pulsing out-flow (or in-flow) wherein each pulse extends one complete revolution. The pump is connected to the ventilator so that at each respiratory cycle two complete revolutions of its shaft are performed. According to the known fact that any inspiratory time (during which fresh gas is supplied to the patient's lungs) corresponds to one-third of the full cycle time, a distributing valve is provided for supplying the positive pressure to chamber **22** during a rotation of

$$(360 \cdot 2)/3 = 240°$$

that is from 0° to 240° of revolution, the out-flow being discontinued, by venting to atmosphere, at the level L of graph of FIG. **2**. Such features leads to provide, in the chamber **22**, a pressure which initially very gradually increases and then steeply increases, that is varies in the best desirable manner for the patient assisted respiration.

The essential features of pump D and of its associated distributing valve **16** are shown in FIGS. **3** and **4**. The casing **10** defines a chamber having a cylindrical side wall **30** and its axis at A″, common to the axis of the pump shaft. Said shaft comprises, in its parts internal to said chamber, an eccentric **36** having its axis at A′ and about which a piston forming body **34** is rotatably supported. Said body **34** has an outer cylindrical surface **32** dimensioned to contact or pass at a very small clearance adjacent to inner wall **30**. The line of contact P, therefore, travels about the entire surface **30** at any full revolution of eccentric **36**. A partition wall **38** is oscillably connected at **40** to the casing **10** and slidably engages a groove **42** radially provided in body **34**. Two ports **44** and **46** are provided in casing **10**, at either sides of and adjacent to said partition wall **38**. Assuming that the eccentric **36** rotates in the direction indicated by the arrow, said ports **44** and **46** provide the inlet and respectively the outlet of the pump.

Pumps generally constructed as shown in FIG. **3** are known and the operation of such pump will therefore not described. In general, such pumps are not completely desirable either because they comprise eccentrically rotating pretty heavy masses and because a certain difficulty is encountered for ensuring leak-proof contact at the several cylindrical and planar surfaces wherein the eccentrically rotating body engages the casing and the partition wall. Such drawbacks are of null importance in the field of the invention, in view of the very small rotational speed of the pump shaft (the double of an even emergency fast respiratory cycle), of the extremely low positive and negative pressures to be applied, as known to those skilled in the art (well lower than 20 cmH_2O above and below atmospheric), and of the fact the stroke volume of the pump is in a wide excess larger than the one required for operating the bag **24**.

The pump D, therefore, provides a pulsing inlet flow at port **44** and a pulsing outlet flow at port **46**, while in the variable pressure chamber a positive and a negative pressures are to be alternately applied. The distributing valve **16** provides to alternately connect the inlet **44** and the outlet **46** to said chamber **22**. Such valve preferably comprises an essentially cylindrical distributing member **56** rotatively connected to a shaft **62** and supported into a casing having two spaces **48** and **50** communicating with said ports **44** and respectively **46** and two connections for duct **52** leading to chamber **22** (FIG. **1**) and for a venting duct **54**. The pulsing and alternating flow in duct **54** can be made use of, if desired, for actuation of rebreathing means or for other uses, as known in the art of aitomatic ventilation of lungs. The space of said valve casing, housing the member **56**, has four ports evenly arranged thereabout to connect said space, turning clockwise, with duct **54**, with space **48**, with duct **52** and with space **50**. Said member **56** has two shaped recesses **58** and **60**, symmetrically arranged and positioned each to connect to each other two adjacent ports at 90° from each other.

In the position shown in FIG. **3**, recess **58** connects the inlet port **44** to the supply duct **52** and recess **60** with the vent duct **54**. Assuming that the eccentric **36** rotates clockwise (as indicated by the arrow), the space S′ at right of the partition wall **38** increases while the volume of other space S″ decreases. In these conditions, the pump D provides a negative pressure into the chamber **22**. Assuming now that the distributing member **56** will be rotated of 90°, the outlet port **46** will be connected to supply duct **52** while the inlet port **44** will be vented, and therefore the pump will provide a positive pressure to chamber **22**.

As a consequence thereof, by steppingly driving said distributing body **56** for 90° at each step, at any second complete revolutions of the pump shaft, the pump will alternate the positive and the negative pressure in said chamber **22**, for properly actuating the ventilator, according to curves C and C′ of the graph of FIG. **2**. The maximum level of positive pressure, in the ventilator circuit, is ensured in conventional manner, by providing a second valve V_s (FIG. **1**) in the supply duct **52**, said valve V_s being conventional pressure limiting one, designed to vent said duct to the atmosphere when the positive pressure attains a given level.

A preferred embodiment of mechanism **20** for steppingly driving the distributing member shaft **62** is shown in FIG. **4**. Such mechanism comprises a well known "Maltese cross" device **64** steppingly engaged by crank pin **66** rotated in phased relationship with the shaft of the pump, such as by means of the above said toothed belt transmission **18**. The duration of the rotation of the Maltese cross **64**, for 90°, that is of shaft **62** and of the distributing member **56**, is timed to provide the desired discontinuance of the flow at the level L of the graph of FIG. **2**.

Assuming that the rotational speed of pump D is a constant and has a given value, the variation of volume of spaces S' and S''(that is of the rate of flow indicated by the curves C and C')might well be read in terms of time, and therefore the steep of said curves will indicate the speed at which the air is supplied to or drawn from chamber **22**, along duct **52**. If such rotational speed will be modified for adjusting the frequency of pulses, such curves will become more or less steep (the abscissae graduation being more or less compressed) meaning that the said air speed will vary. Assuming further that valve V_a will open at a given negative pressure level, the resistance encountered by the air sucked-in through a valve port of given constant area will be modified as a function of the second power of this speed, thus seriously influencing the level of the negative pressure steppingly applied in the chamber **22**.

A valve V_a is now described with reference to FIG. **5**. Said valve comprises a tubular body **110** forming a valve seat **111** on which a disk-shaped valve member **112** abuts for closing the vent passage. The body is secured to a sleeve **115** connected to the structure (not shown) of the apparatus. The inside **113** of the tubular body **110** is connected to a duct **116** adapted for connection with the supply duct **52** of FIG. **1**, and with a chamber **121** formed between a diaphragm **119** and a plate **118** secured at **117** to said body **110**. Said diaphragm **119** has its outer edge portion clamped between the edge portion of said plate **118** and the edge portion of an upper plate **120**. The center portion of same diaphragm **119** is clamped between a ferrous upper disk **122** and a lower counter-disk **130**, and it is connected to said valve member **112** by an axial stem **123**. The part **114** of the tubular body **110** is vented to atmosphere, preferably by means of a silencer.

The spacing **129** between the outer edge of valve member **112** and the valve seat **111** defines the area of passage through the valve, when open (such spacing has been exaggerated in FIG. **5**, for clearer illustration). The space above diaphragm **119** is vented to atmosphere, such as by means of ports **128**, and, therefore, the said diaphragm **119** is downwardly urged by the atmospheric pressure when a subatmospheric pressure axists in said duct **116** (that is in duct **52** and in chamber **22**, see FIG. **1**) and in said chamber **127**, the force tending to open the valve, that to space the valve member **112** from valve seat **111** being a function of the area of the diaphragm **119** facing the chamber **127** and of the subatmospheric pressure, that is of the negative pressure in duct **52** and in chamber **22**, when applied.

The movable members of the valve are biased in direction B by a force determined for causing the valve to open when a given negative pressure is attained. Such force is provided by an electromagnetical device attractively acting on the said ferrous disk **122**. Such device comprises a coil **124** having a winding **125** about a core integral with a bell-sheped pole piece, said core and pole piece being indicated at **126**. The coil is conventionally supplied with D.C. by suitable connections and source of current, not shown. The biasing force in direction B can be adjusted either upon adjustment of the electric supply and by adjusting the spacing between the pole piece and the ferrous disk, said core and pole piece component being screwly engaged at **127** to the coil **124**, which is secured to the upper plate **120**.

The adjusted biasing force, provided by magnetic attraction, defines the level of negative pressure at which the valve V_a opens, that is at which the disk-shaped valve member **112** detaches itself from the valve seat **111**. It is known that a magnetic attractive force decreases with the second power of the space between the magnetically attracted parts. Therefore, as the valve member **112** detaches itself from seat **111**, the biasing force in direction B decreases according to the second function of the spacing **129**, the rate of decreasing being actually adjusted by adjusting the initial spacing between the pole piece **126** and the ferrous disk **122**. By simple experimentation, a variation of the biasing force in direction B, with relation to the actual spacing **129**, can be so provided for attaining a nearly constant resistance to the air, passing through said spacing **129** at differing rates and speeds, said spacing varying essentially according with the second power of the actual speed of the passing air.

I claim:

1. A pressure alternating device for actuating an apparatus for automatic ventilation of lungs, said apparatus including a variable pressure chamber wherein air at superatmospheric and at subatmospheric pressure is to be alternatingly supplied for promoting a pulsing feeding of fresh gas to a patient's lungs in given amounts and positive pressure and at an adjustable respiratory frequency, comprising a pumping assembly adapted to provide alternated pulsing in-flows and out-flows, the negative and respectively positive pressure levels in and the rates of said flows gradually increasing at each pulsing cycle, duct means connecting said pumping assembly to said apparatus chamber, and negative pressure limiting valve means connected to vent said duct means and chamber to atmosphere, said valve means comprising a valve member movable against a biasing force for opening a venting passage when a given negative pressure level is attained, and means to apply to said valve member a biasing force decreasing as the cross-sectional area of said venting passage increases.

2. The device of claim **1**, wherein electromagnetical means are provided to apply a biasing force tending to close said venting passage, said biasing force decreasing as a function of the second power of the amplitude of the motion of said valve member, said amplitude defining the said cross-sectional area of said venting passage.

3. The device of claim **1**, wherein the said pumping assembly comprises a rotary pump adapted for providing an unidirectional pulsing flow at each complete 360° revolution of its rotary components from an inlet and an outlet thereof, and a distributing valve phasedly and timedly connected to said rotary components to alternatingly connect said inlet and respectively said outlet to said duct means and said variable pressure chamber of said apparatus.

4. The device of claim **3**, wherein said rotary pump comprises a rotary piston eccentrically revolved within a chamber formed into a stationary casing, to provide a pulsing in-flow and out-flow, at each 360° revolution of said piston, at a flow rate varying according to a function of the type "$\sin^2$ alpha" (wherein "alpha" is the amplitude of rotary motion), and wherein the said distributing valve is connected to said pump for discontinuing the applying of said flows to said variable pressure chamber of the apparatus after a 240° about revolution of said piston, beginning from the position at which the rate of flow is about null.

5. The device of claim **4**, wherein the said rotary pump comprises a casing having a cylindrical chamber formed thereinto, a shaft rotatively and drivedly supported in said chamber and having an eccentric formed therewith, a cylindrical piston body rotatively sopported about said eccentric and dimensioned for essentially contact the inner wall of said cylindrical chamber sequentially at any point thereof as said eccentric performs a 360° revolution about the axis of said shaft, a partition wall oscillatably connected to said casing at a line parallel to the axis thereof, extending inwardly in said cylindrical chamber and slidably engaged into a radial groove formed in said cylindrical piston body, and inlet and outlet ports formed in said chamber adjacent to and at either sides of said partition wall and each individually communicating with the variable volume spaces formed in said chamber about said piston body and divided by said partition wall and by the line at which said

piston body actually contacts said inner wall of said cylindrical chamber.

6. The device of claim 4, wherein the said distributing valve comprises an essentially cylindrical distributing member rotatably housed into a casing having diametrally opposed ports connected to inlet and respectively to outlet of the said rotary pump, and other ports at 90° from said former ports, one of said other ports being connected to the said variable pressure chamber of the apparatus, symmetrical recesses formed in said distributing member for connecting pairs of ports at 90° from each other, and comprising drive means for steppingly rotating said member for alternatingly positioning said member so that one of said recesses alternatingly connects said other one port to the port connected to the outlet and respectively to the inlet of the pump, at each second revolution of the rotary components of the pump.

7. The device of claim 2, wherein the said electromagnetical means comprise an energizable coil and a pole piece, the said valve member is connected to a ferrous element magnetically attracted by said pole piece to provide the said biasing force, said pole piece being adjustably secured to said coil for adjustment of its spacing from said ferrous element when the valve is closed.

8. A device for alternatingly supplying a negative and a positive pressure to the variable pressure chamber of a known apparatus for automatic ventilation of a patient's lungs, for pulsingly promoting the supply of fresh gas to the patient at a given pressure and rate and at an adjustable frequency or respiratory cycle, comprising, in combination:

i. a pumping device of rotary type and comprising variable volume chambers whose volumes vary, at each complete revolution of 360° of its rotary components, substantially in accordance with a function of the type "$\sin^2$ alpha", wherein "alpha" is the amplitude of the rotational motion, and comprising inlet and outlet ports wherethrough a pulsing in-flow and respectively out-flow are promoted at said each complete revolution;

ii. a distributing valve phasedly and timedly connected to said pump rotary components, connected to said inlet port, to said outlet port, to a venting port and to the said apparatus variable pressure chamber, and such to alternatingly connecting said inlet port and said outlet port to said chamber at each second complete revolution of the said rotary components of the pumping device; and

iii. a negative pressure level limiting valve connected to said variable pressure chamber, comprising a valve member movable relatively to a valve seat to provide a spacing therebetween for venting said space to atmosphere when the valve opens against a biasing force exerted by an electromagnetic device which provides a biasing force, urging said valve member towards said valve seat, which decreases according to a function of the second power of said spacing, to compensate for the variable resistance encountered by the air passing through the passage provided between the spaced valve member and seat, at different speeds resulting from different durations of the times in which the said negative pressure is increasingly applied into said variable pressure chamber.

9. The device of claim 8, wherein the said rotary pumping device comprises a casing having a cylindrical chamber formed thereinto, a shaft rotatively and drivedly supported in said chamber and having an eccentric formed therewith, a cylindrical piston body rotatively supported about said eccentric and dimensioned for essentially contact the inner wall of said cylindrical chamber sequentially at any point thereof as said eccentric perform a 360° revolution about the axis of said shaft, a partition wall oscillatably connected to said casing at a line parallel to the axis thereof, extending inwardly in said cylindrical chamber and slidably engaged into a radial groove formed in said cylindrical piston body, and inlet and outlet ports formed in said chamber adjacent to and at either sides of said partition wall and each individually communicating with the variable volume spaces formed in said chamber about said piston body and divided by said partition wall and by the line at which said piston body actually contacts said inner wall of said cylindrical chamber.

10. The device of claim 8, wherein the said distributing valve comprises an essentially cylindrical distributing member rotatably housed into a casing having diametrally opposed ports connected to inlet and respectively to outlet of the said rotary pumping device, and other ports at 90° from said former ports, one of said other ports being connected to the said variable pressure chamber of the apparatus, symmetrical recesses formed in said distributing member for connecting pairs of ports at 90° from each other, and comprising drive means for steppingly rotating said member for alternatingly positioning said member so that one of said recesses alternatingly connected said other one port to the port connected to the outlet and respectively to the inlet of the pump, at each second revolution of the rotary components of the pump.

11. The device of claim 8, wherein the said electromagnetical device comprise an energizable coil and a pole piece, the said valve member is connected to a ferrous element magnetically attracted by said pole piece to provide the said biasing force, said pole piece being adjustably secured to said coil for adjustment of its spacing from said ferrous element when the valve is closed.

* * * * *