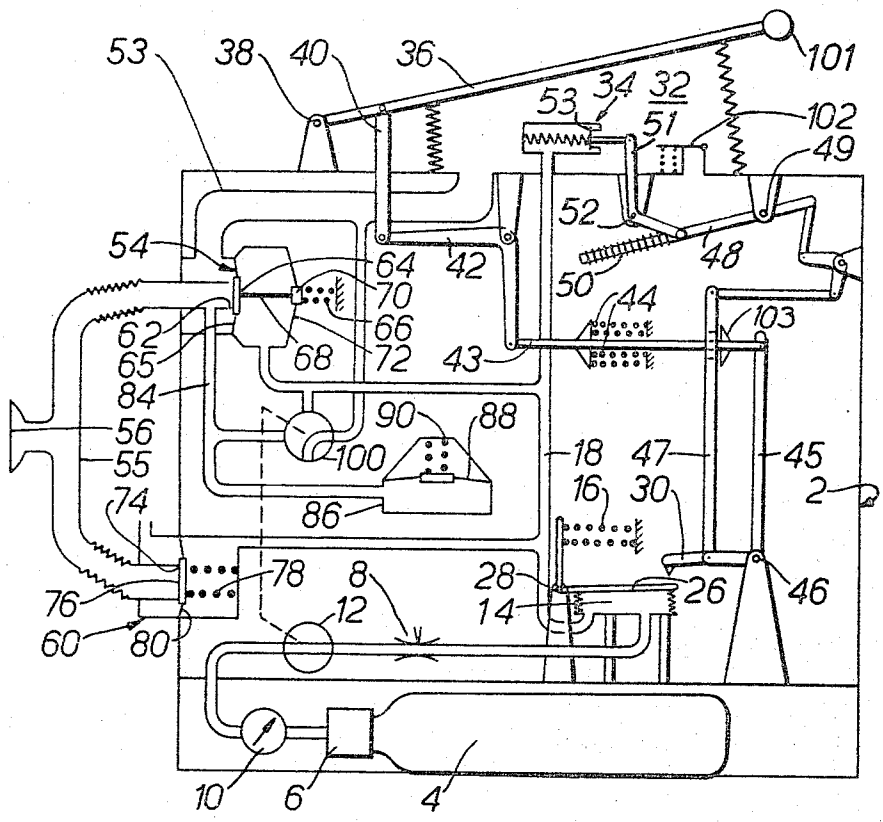
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VENTILATION MACHINES

Filed Nov. 7, 1962

Fig. 1



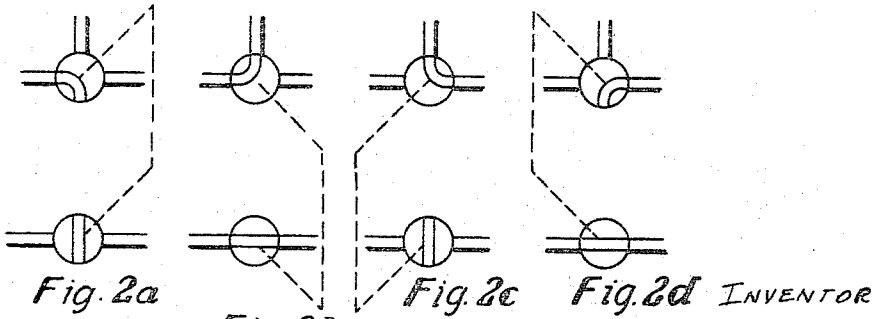


Fig. 2a Fig. 2b Fig. 2c Fig. 2d

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VENTILATION MACHINES

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The present invention relates to ventilation machines, and particularly to machines for supplying anaesthetic or oxygenous gases to patients who are not capable of breathing voluntarily.

Ventilation machines are known which have a plurality of adjustable controls to adjust the output of the machine to the respiratory needs of individual patients. Such machines suffer from the disadvantage that they can only be used safely by skilled persons.

The present invention aims at providing a ventilation machine which automatically makes allowances for the tidal volume and frequency of breathing of a patient connected to the machine, thereby permitting use of the machine by a relatively unskilled person. Such machines are particularly useful for ventilating people who have been suffocated by drowning or by the inhalation of non-oxygenous gases, or who have had their breathing muscles paralyzed by an electric shock.

Accordingly the present invention provides a ventilation machine of the open-circuit type operated by the pressure of the input gas and including a reservoir of pre-set capacity which is designed to be filled by the input gas during the inspiration period of each breathing cycle of a patient when connected to the machine, and which is exhausted to the atmosphere during the expiration period of each cycle without passing to the patient. The machine is preferably connected through a pressure reduction valve and an on/off valve to a source of gas under high pressure. The volume of the small reservoir and the rate of flow of gas from the source to the machine are pre-set as set out below to give the desired automatic functioning of the machine.

The present invention is based on the fact that there is a mathematical relationship between the body weights, tidal volumes and rates of breathing for people having body weights within a range extending from those of infants to those of adults. This relationship is expressed graphically in Radford's Nomogram as published in the New England Journal of Medicine, volume 251, 1954, p. 877.

It has now been found that if a constant predetermined volume of gas is supplied to the machine during each breathing cycle in addition to the volume of gas required by the patient per cycle, the minute volume needed to be supplied to the machine is substantially constant for patients having a wide range of body weights when the minute volume and the constant predetermined volume have a relationship with each other satisfying the relationship set out in the Nomogram.

This relationship is set out in the following table in which the constant pre-set volume has been chosen to be 170 mls. and the minute volume 8.4 litres.

Body Weight (lbs.)	Expected Tidal Volume (mls.)	Frequency (Radford Nomogram)	(T.V.+170) (mls.)	Frequency (minute vol./ T.V.+170)
6	13	46	183	46
10	24	43	194	43
20	50	38	220	38
35	90	32	260	32
50	130	28	300	28
70	180	24	350	24
100	280	19	450	19
150	450	14	620	14
200	600	11	770	11

It will be seen from the above table that when gases are supplied to a ventilation machine of the present invention at the rate of 8.4 litres per minute, people having a body weight of from 6 lbs. to 200 lbs. will be adequately ventilated.

The present invention is based on the assumption that the patient ventilated by the machine has lungs of normal compliance. However it has been found in practice that if the compliance varies to any extent from normal the patient is either over- or under-ventilated to an extent which is acceptable for greater or lesser periods of time.

The accompanying drawing is a sectional diagram of a ventilation machine of the present invention.

The machine consists of a housing **2** having a cylinder **4** of oxygen, air or other gas secured to its base, gas from the cylinder being supplied through a conventional pressure reduction valve **6**, needle valve **8**, flow meter **10** and tap **12** to the inlet of the machine.

Positioned internally of the housing **2** are small bellows **14** biased by means of a tension spring **16** so that the small bellows expands when the pressure of the gas in the bellows rises to a pressure of 100 cms. of water. Gas issues from the small bellows **14** to a tube **18**. The movable end of the bellows is engaged by a lever **26** pivoted at **28**. Positioned adjacent the free end of the lever **26** is a movable contact **30** of which the purpose is to be described below. The position of contact **30** is such that it is contacted and moved by the free end of the lever **26** as the bellows **14** assumes a volume determined by the position of contact **30**.

Gas issuing from the small bellows **14** passes through the tube **18** into the interior of large bellows **32** through a control valve **34** positioned internally of the bellows. One end of the bellows **32** is fixed to the enclosure **2** and the movable end is contacted by a lever **36** pivoted at **38**. The lever **36** is connected through a link **40** with a pivoted lever **42** connected in turn to a link **43** biased by means of tension springs **44** so that the bellows **32** expands when the internal pressure reaches a pressure greater than 25 cms. of water above atmospheric.

The other end of link **43** is connected to one arm of a double arm lever **45** pivoted at **46**. The other arm of lever **45** is pivotally connected between the ends of a second double lever **47**, of which one arm is provided with the contact **30**.

The lever **47** is connected through a linkage to an over-centre control lever **48** pivoted at **49**. One end of lever **48** is connected by a tension spring **50** to one arm of a double lever **51** pivoted at **52**, of which the other arm is connected to the valve member **53** of control valve **34** so that when the lever **48** is in the illustrated lower position the valve is in its closed position, and as it moves through the over-centre position to an upper position the valve **34** is snapped open.

The movement of the lever **48**, and hence the state of the valve **34**, is controlled directly by movement of the contact **30**. However, because lever **47** is mounted on lever **45**, which is controlled by the position of the large bellows, the movement of valve **34** is controlled by the extents of deflation or inflation of the large and small bellows. The purpose for this will be described more fully below.

When the large bellows **32** is deflated under the action of the bias springs **44** the gas passes through a wide bore passageway **153** to an inspiratory disc valve **54**, from which gas passes to one branch of a conventional two-branched flexible tube **55** to which a breathing mask **56** is connected. The other branch of the tube **55** is connected to the inlet side of an expiration valve **60** forming part of the machine. Gas passing through the expiration valve **60** is exhausted to the atmosphere.

The inspiration valve **54** is of the type in which the mouth **62** of the outlet tube of the valve is closed by a valve member **64** mounted on a diaphragm **65** and biassed into the closed position by means of a compression spring **66** acting on a thrust rod **68**. The thrust rod **68** has one end secured to a stud **70** attached to the centre of a flexible diaphragm **72**. The diaphragm and the walls of the valve **54** form a chamber which is in fluid communication with the tube **18**.

The expiration valve **60** has the mouth **74** of its inlet tube closed by means of a valve member **76** acted upon by a tension spring **78** so that the valve **60** is biassed open. The valve member **76** is mounted on a flexible diaphragm **80** so that the spring **78** is housed in a chamber which is placed in communication with the chamber of the inspiration valve **54** and the tube **18**.

Both the biasing springs **66** and **78** of the inspiration and expiration valves are designed to be adjusted in known manner to permit the operation of the valve to be adjusted. The biasses on the valves are arranged so that the inspiration valve **54** opens at a pressure intermediate the maximum pressure in the large bellows **32** and the maximum pressure in the small bellows **14**, and the expiration valve **60** is arranged to close at a pressure which is lower than the pressure at which the inspiration valve **54** opens and higher than the maximum pressure in the large bellows **32**.

In communication with a tube **84** extending from the inspiration valve is a small collapsible reservoir **86**. The reservoir is in the form of a chamber having a movable end wall so that the difference in volume between the minimum and maximum volumes of the reservoir is a chosen amount, in the present example 170 mls. The movable end wall **88** is biassed by means of a compression spring **90** so that the end wall moves to its distended position when the pressure in the chamber exceeds a pressure of 5 cms. of water.

Ganged to the tap **12** is a four position, three port valve **100**, in which two of the positions are closed. One of the ports is connected to the tube **84**, a second port to the tube **18**, and the third port to the passageway **53**.

The respective positions of the valve **100** and tap **12** are illustrated in FIGS. 2*a* to *d*.

FIG. 2*a* shows the apparatus in the "off" position;

FIG. 2*b* in the "oxygen" position;

FIG. 2*c* in the "manual" position, and

FIG. 2*d* in the "automatic" position.

It will be seen that FIG. 1 shows the apparatus in the "automatic" condition, in which it operates as follows:

Gas passes from the cylinder **4** at a pressure of 300 cms. of water to the inlet of the small bellows **14** from which the gas passes at a low pressure through the control valve **34**, which is assumed to be in the open position, into the interior of the large bellows **32**. The time taken for the bellows **32** to be inflated fully will depend on the tidal volume delivered to the patient during the preceding breathing cycle.

The large bellows **32** inflates until extension **103** from the link **43** come into contact with and move lever **47** sufficiently for the over-centre mechanism to be operated and the valve **34** to be closed. Immediately when this happens the pressure in the tube **18** starts to rise to the pressure of 100 cms. of water to which the small bellows is set. As this pressure rises first the expiration valve **60** is closed and then the inspiration valve **54** is opened to permit the large bellows **32** to deflate under the action of the biassing spring **44** and force gas into the patient. This deflation of the bellows **32** causes the contact **30** to be moved away from the bellows **14** with the state of valve **34** unaltered.

While gas is passing to the patient the pressure of the gas in the small bellows **14** reaches the pre-set value of 100 cms. of water and the bellows inflates to the position in which the contact member **30** is moved to open the control valve **34**. When this happens the pressure in the

tube **18** decreases causing first the inspiration valve **50** to close and then the expiration valve **60** to open to permit the patient to exhale to the atmosphere through the valve **60**.

During the inspiration part of each breathing cycle while gas is passing from the inspiration valve to the patient, the reservoir **86** is fully inflated to its maximum volume, which means that 170 mls. of the total volume of gas passing through the inspiration valve **54** is stored in the reservoir. When the expiration part of the breathing cycle is reached the inspiration valve is closed and the expiration valve is opened to permit the reservoir **86** to deflate whereby the 170 mls. of gas are exhausted to the atmosphere through the expiration valve **60**. As the patient is exhaling, the gas from the reservoir **86**, which is at a pressure of only 5 cms. of water, does not pass to the patient but by-passes the breathing mask **56**.

The ventilation of the present invention functions so that the volume of gas passed out of the large bellows **32** per breathing cycle is equal to the tidal volume required by the patient plus the volume represented by the reservoir **86**. When the machine is used to ventilate an adult the large bellows **32** deflates almost completely each cycle. This has the effect of pivoting bell crank lever **45** clockwise and thus moving the contact **30** away from the small bellows, so that the small bellows has to inflate almost to the maximum extent before the valve **34** is opened. This thus lengthens the period within which the patient is supplied with gas.

When used to ventilate a child, the large bellows deflates only to a small extent each cycle. Thus the contact **30** is moved not at all, or only by a small amount, way from the small bellows which thereby takes a shorter time to inflate sufficiently to open the valve **34**. This results in a short period of inflation and a consequent rapid ventilation rate.

When the ganged tap **12** and valve **100** are moved to the position shown in FIG. 2*b* the ventilating machine supplies gas, such as oxygen, directly to the patient, with the cycling mechanism inoperative. In this position the tube **18** is in communciation with the outlet of the inspiratory valve and the gas is admitted at a low pressure so that the expiratory valve remains open. The gas is supplied to the patient continuously, any gas not being inhaled being passed directly to the expiratory valve.

In the position shown in FIG. 2*c*, the machine is able to be operated manually to supply air to the patient. This facility is extremely useful, permitting the machine still to be used when the supply of gas in the reservoir **4** has become exhausted. In this position the supply of gas to the machine is stopped by the tap **12**, and the passageway **53** and working chamber of the inspiratory valve **54** are placed in communication by the valve **100**. The lever **36** of large bellows **32** is provided with a knob **101** or other handle, by means of which the bellows can be pumped manually. When the lever **36** is lifted to inflate the bellows atmospheric air passes from the interior of the casing **2**, which is not airtight, through a biassed one-way valve **102**, into the bellows **32**.

During this period the expiratory valve stays open under its bias to permit the patient to exhale.

When the lever **36** is depressed to deflate the bellows the pressure builds up in the passageway **53**, chamber of the valve **72** and tube **18**. First the expiratory valve is closed and then the inspiratory valve is opened by virtue of the difference in areas of the diaphragm **65** and **72**.

The fact that the reservoir **86** is charged and discharged each breathing cycle is of no importance in the light of the manual operation of the machine.

Thus the machine of the present invention adjusts itself automatically to supply small volumes of gas at a high cycling rate, as to an infant, or large volumes of gas at a low rate, as to an adult, the rate and volumes corresponding closely to those of a patient breathing normally.

The present invention is based on the assumption that the patient ventilated by the machine has lungs of normal compliance. However, it has been found in practice that if the compliance varies to any extent from normal the patient is either over- or under-ventilated to an extent which is still acceptable for the short periods of time.

I claim:

1. A ventilation machine of the open-circuit type operated by the pressure of the input gas and including a reservoir of preset capacity which is designed to be filled by the input gas during the inspiration period of each breathing cycle of a patient when connected to the machine, and which is exhausted to the atmosphere during the expiration period of each cycle without passing to the patient, the rate of feed of the input gas to the machine being preset at such a value and the volume of the reservoir being so related thereto that the machine will cycle at frequencies appropriate to individual patients of different normal breathing frequencies.

2. A ventilation machine of the open-circuit type including small bellows intended to be supplied with a constant flow of gas, a large bellows in fluid communication with the small bellows through a control valve, an inspiration valve through which the large bellows are in communication with a patient when connected to the machine, an expiration valve designed to receive gas exhaled by the patient and to exhaust it to the atmosphere, the inspiration and expiration valves being controlled to open and close at the appropriate portions of each breathing cycle of the patient, and a small reservoir designed to receive some of the gas passing through the inspiration valve and to exhaust it to the atmosphere when the expiration valve is open, the rate of feed of the input gas to the machine being preset at such a value and the volume of the reservoir being so related thereto that the machine will cycle at frequencies appropriate to individual patients of different normal breathing frequencies.

3. A ventilation machine as claimed in claim 2, in which the large bellows has means to close the control valve when the large bellows reaches its maximum volume, and in which the small bellows has means to open the control valve when it reaches a preset volume.

4. A ventilation machine as claimed in claim 3, in which the inspiration and expiration valves are controlled by the pressure of the gas in a tube connecting the outlet of the small bellows with the control valve and leading to the large bellows.

5. A ventilation machine as claimed in claim 4, in which the inspiration valve is biassed closed and is opened when the control pressure is intermediate the maximum pressure in the large bellows and the maximum pressure in the small bellows, and in which the expiration valve is biassed open and is closed at a pressure lower than the pressure at which the inspiration valve opens and greater than the maximum pressure in the large bellows.

6. A ventilation machine as claimed in claim 2, in which the small reservoir is of variable capacity and is biassed to assume its minimum volume position when the pressure in the reservoir is less than the minimum pressure in the large bellows.

7. A ventilation machine as claimed in claim 6, in which the reservoir is connected to a passage by-passing the patient and leading to the expiration valve for exhausting of the gas in the small reservoir from the machine via the expiration valve.

8. A ventilation machine as claimed in claim 1, in which the inlet of the machine is connected through an on/off valve and a pressure reduction valve to a source of gas under high pressure.

9. A ventilation machine as claimed in claim 8, in which the gas passes through a rotameter before entering the small bellows.

10. A ventilation machine as claimed in claim 2, in which the machine is designed to receive gas at a minute volume of 8.4 litres and in which the reservoir exhausts 170 mls. each breathing cycle.

11. A ventilating machine of the open-circuit type comprising an inlet adapted for connection to a source of gas under pressure, a small variable volume chamber connected to the said inlet, a larger variable volume chamber connected to the small variable volume chamber by a tube providing fluid communication between the large and small variable volume chambers, a control valve having open and closed conditions disposed in the said tube between said small and large variable volume chambers, an outlet adapted for connection to a face mask for a patient to be ventilated, said outlet being connected to the large variable volume chamber, an actuating mechanism adapted to actuate the control valve between its open and closed conditions and including variable position means associated with the small variable volume chamber for opening the control valve in response to changes in volume of the small variable volume chamber, said actuating mechanism also including means in operative association with said large variable volume chamber for closing the control valve and operational to control the position of said variable position means so that the volume of the small variable volume chamber at which the valve is actuated is dependent on the instant volume of the large variable volume chamber.

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