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LUNG VENTILATING EQUIPMENT

Filed June 10, 1963

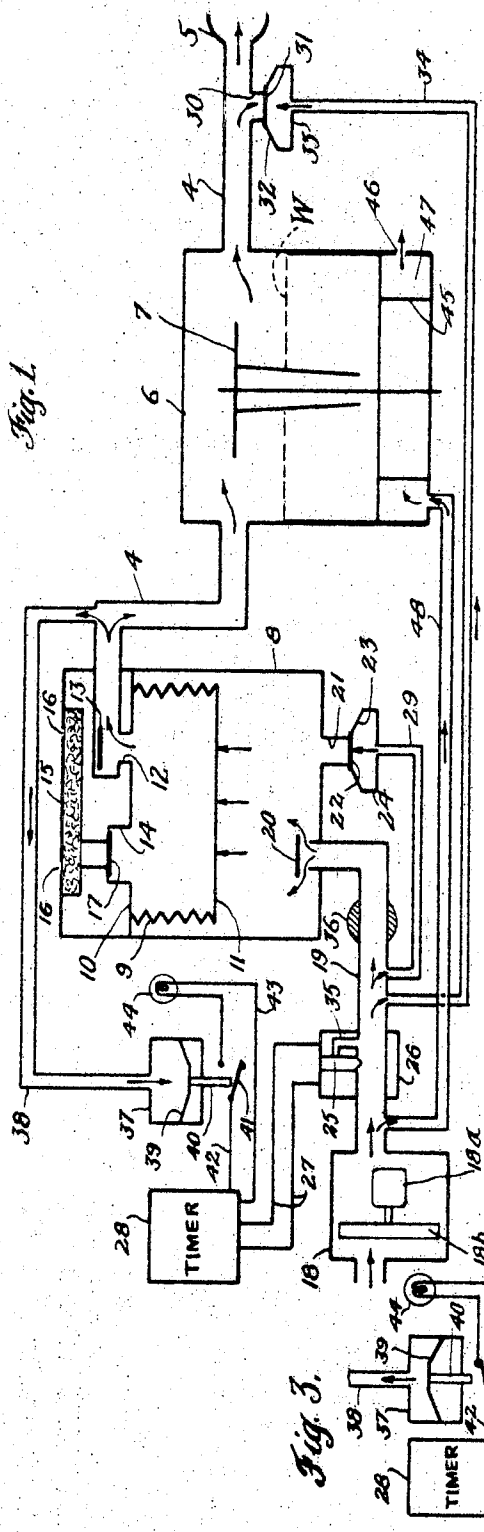



Fig. 1.

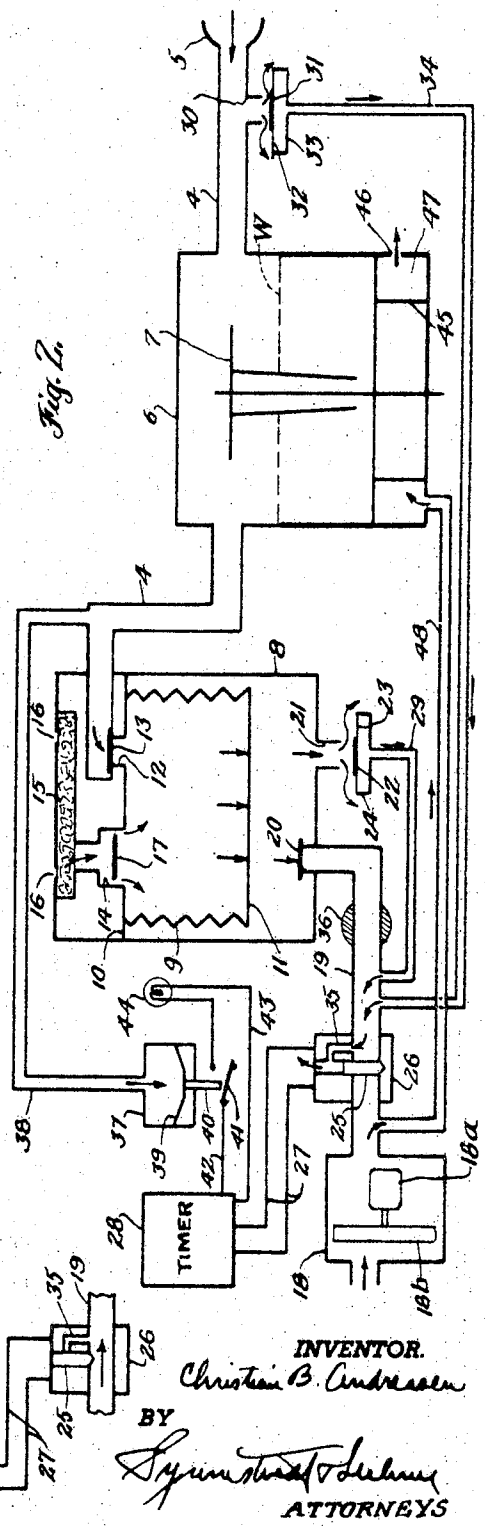



Fig. 2.




Fig. 3.

INVENTOR.
Christian B. Andreasen
BY
Synnestvedt & Lechner
ATTORNEYS

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# LUNG VENTILATING EQUIPMENT

Christian B. Andreasen, New Hope, Pa., assignor to Air-Shields, Inc., Hatboro, Pa., a corporation of Delaware

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This invention relates to lung ventilating equipment and is particularly concerned with apparatus adapted to function so as to induce artificial respiration or so as to assist a patient's respiratory effort.

The invention is especially concerned with the type of equipment or apparatus which comprises a self-contained unit, i.e., incorporates not only the equipment for delivering the breathing gases to the patient but also the power means such as a blower, for developing pressure by means of which the apparatus is operated.

Still further the invention is concerned with the type of ventilating or respiration apparatus incorporating an aerosol or humidification device by which moisture is introduced into the gas delivered to the patient, such humidification device also comprising a part of the self-contained unit.

In apparatus of the kind referred to above, it is a specific object of the invention to provide a number of improvements by which the apparatus is rendered safer, more reliable and more fool-proof than prior equipment, thereby making possible long continued use of the apparatus in the case of patient's experiencing protracted periods of inadequate self-inspirational effort.

It is also an object of the invention to make provision for the important functions of the automatic timing of the patient's breathing, together with an override or trigger device operating by the patient's own inspirational effort, while at the same time simplifying the equipment and making possible the attainment of these functions with a minimum of parts and controls.

In accordance with another aspect of the invention, provision is made for indirectly warming the water in the humidification device by means of a current of warmed air developed by the blower included in the equipment.

In connection with still another aspect of the invention it is mentioned that equipment of this type is frequently associated with the patient either by use of a mask or by connection with the patient's trachea. The arrangement of the invention makes possible substantially unimpeded breathing by a patient either through the mask or connection to the trachea, even in the event of failure of the power or control system for the equipment.

How the foregoing objects and advantages are attained will appear more fully from the following description referring to the accompanying drawing which diagrammatically illustrates a system constructed according to the present invention and in which:

FIGURE 1 is a representation of the apparatus with various valves and parts in the positions occupied during inspiration by the patient as effected by the automatic control provided;

FIGURE 2 is a view similar to FIGURE 1 but illustrating the position of valves and parts during expiration by the patient as effected by the automatic control provided; and

FIGURE 3 is a fragmentary view similar to certain parts of FIGURES 1 and 2 but illustrating the position of those parts assumed in response to a voluntary inspirational effort by the patient.

Turning now to the drawing, the patient's circuit or system includes the conduit means, portions of which are indicated by the numeral **4**. A mask **5** or equivalent is provided at one end of this system for association with the patient, the inspiratory as well as the expiratory gases both passing through this mask. An aerosol or humidification device indicated generally by the numeral **6** is inserted in the conduit means **4** to provide for the introduction of moisture into the air breathed by the patient. This device advantageously contains a reservoir of water, the level of which is indicated at W, together with a rotative atomizing element **7** which may be of the general type disclosed in copending application Serial No. 107,756, filed May 4, 1961, of Christian B. Andreasen, Harold Kenneth Richter and George H. Stoner.



As seen toward the central portion of FIGURES 1 and 2, the equipment includes a chamber **8**, which may advantageously be provided by a transparent cylindrical wall, with end closures. Within the chamber **8** is a bellows **9** supported from the wall of the chamber **8** by the wall **10** which also closes the upper end of the bellows, except for ports to be described. The bottom of the bellows is closed by the wall **11**. The patient's circuit or conduit **4** is connected with the interior of the bellows through the port **12** which is provided with a check valve **13** arranged to prevent flow of gas from the conduit **4** into the bellows but to provide free egress of air from the interior of the bellows into the conduit **4**. The top wall of the bellows **10** is also provided with another port **14** communicating through a filter **15** with the atmosphere as by means of ports indicated at **16**. Port **14** is provided with a check valve **17** which is arranged to prevent exhaust of air from the interior of the bellows to atmosphere but to provide free ingress of atmospheric air through the filter into the interior of the bellows.

The chamber surrounding the bellows **9** is placed in connection with the source of fluid presure such as a motor-blower unit generally indicated at **18**, a duct **19** being provided for connecting this unit with the bellows chamber. A check valve **20** serves to block flow of air from the bellows chamber back into the duct **19** but to permit free ingress of air from the duct into the bellows chamber.

Air may be exhausted from the bellows chamber through a port **21** which is provided with valve **22**, this valve being carried by a flexible diaphragm **23** associated with a pressure chamber **24**. When the valve **22** is open (see FIGURE 2) air may be discharged from the bellows chamber to atmosphere.

The duct **19** may be blocked or closed by means of a valve **25**, this valve being shown in open position in FIGURES 1 and 3 and in closed position in FIGURE 2. The valve is adapted to be operated by a solenoid **26** which is connected through leads **27** with a timer mechanism **28**, for instance an electronic circuit such as a multi-vibrator of well-known type.

When the timer operates to open the valve **25** as shown in FIGURE 1, air under pressure flows from the blower **18** through the duct **19** past valve **20** into the bellows chamber **8**. At the same time, through the control line **29** air under pressure is introduced into the pressure device **24** to thereby retain valve **22** closed. In this condition the air introduced into the bellows chamber acts on the bellows to collapse it and thereby force air out through the port **12** and past valve **13** and through duct **4** to the patient. This pressure developed in the bellows also acts to close the check valve **17**. Moreover, during inspiration by the patient, the exhaust port **30** is closed by means of the exhaust valve **31** which is mounted on flexible diaphragm **32** associated with the pressure device **33** which receives fluid under pressure from the duct **19** by means of the duct **34**. In this way as will be clear from comparison of FIGURES 1 and 2, when the main control valve **25** is open the pressure from the blower not only acts to callapse the bellows **9** and deliver air to the patient, but also operates on the valve **31** to close the exhaust port **30** and thus prevent loss of air through the exhaust port.

At the conclusion of inspiration, the timer **28** operates the solenoid **26** to close valve **25** (see FIGURE 2), whereupon an expiratory phase occurs during which the expiratory gases in the conduit means **4** adjacent the patient will flow therefrom to atmosphere through the port **30** (see FIGURE 2). Upon expiration the pressure in the control line **34** is relieved through the exhaust passage **35** which is also controlled by the valve **25**, this exhaust passage being closed when the main valve is in its upper or open position (see FIGURE 1) and being open when the main valve is in its lower or closed position (see FIGURE 2).

Similarly during the expiratory phase of the breathing cycle pressure is exhausted from the pressure device **24**, so that the valve **22** may readily open by the bleed-off of pressure through the control line **29** into the duct **19** and from there through the exhaust passage **35** which at that time is open to atmosphere as already noted. In view of this the bellows **9** may at that time expand and thereby expell air from the bellows chamber through the port **21** to atmosphere. The expansion of the bellows is desirably effected as a result of its own weight, which may be augmented by weighting of the lower wall **11**. In this way, the bellows expands during the expiration by the patient and then is again ready for the inspiration stroke, i.e., the collapsing stroke effected by introduction of pressure into the chamber **8**.

A valve diagrammatically indicated at **36** may be adjusted to vary the flow of air through the duct **19** into the bellows chamber and thereby regulate the inspiration effect of the apparatus. It is of course also contemplated that the duration of the inspiration and also of the expiratory phase may be regulated by the adjustment of the circuits of the timing mechanism in a manner which is well known with multivibrator or other electronic timing circuits.

The operation described above provides for automatic inspiration by the patient under timer control. The equipmen of the invention further provides for response in accordance with inspirational effort made by the patient at any point during the expiratory phase. This is accomplished by the fluid pressure responsive device **37** having a control connection **38** extended therefrom for communication with the patient's circuit or conduit means **4**. Within the device **37** is a flexible diaphragm **39** carrying a plunger **40** projecting at the bottom in position to operate switch **41** which is connected by lead **42** with the timer mechanism to thereby trigger the mechanism to operate the solenoid **26** in the sense to open valve **25**. The triggered position of these parts is indicated in FIGURE 3 and from this figure it will also be noted that the switch **41** also serves to energize a circuit **43** containing a signal lamp **44** by which a visual indication will be given of the fact that the patient has manifested an inspirational effort.

According to the foregoing the equipment of the invention provides not only for the automatic cycling of the patient's breathing but also provides for operation in the manner of a breathing assistor, according to which inspirational effort by the patient will trigger the mechanism to bring about the feed of air through the conduit means **4** to the patient.

By arranging the control pressure supply passages **29** and **34** and the exhaust passage **35** in the manner described and illustrated, it will be noted that the main control valve **25** controls not only the flow of air into the bellows chamber **8** but also the supply of air to the control device **24** and **33** for valves **22** and **31**, and still further provides for bleed-off of pressure from the control devices **24** and **33** through the exhaust passage **35**.

It may further be noted that the arrangement of the check valves **13** and **17** which are associated with the interior of the bellows and with the conduit means **4** are arranged so that in the event of failure of the apparatus, even of the action of the bellows **9**, the patient's breathing still would not be substantially impeded, it being noted that



inspiration by the patient may occur through the filter **15** and the interior of the bellows. In such a case the patient's inspiration will act to open both of the check valves **13** and **17** and thus provide a channel of fresh air through the bellows space.

In the lower portion of the humidification unit, below the water bath is a chamber **47** having baffles or the like therein such as represented by the numeral **45**, this chamber also being open to atmosphere at **46**. The chamber is supplied with air through the connection **48** which extends for communication with the duct **19**. It will be noted that the blower motor **18***a* and the blower fan **18***b* are positioned within the blower unit **18** in such manner that the air handled by the fan passes over the motor for cooling purposes. Thus it is warmed air which is delivered to the chamber **47** at the bottom of the humidifier and this tends to warm the water in the humidifier and thereby enhances the humidifying action.

This use of the warm air from the blower enhances the humidification without delivery of air which has passed over the blower motor into the patient's circuit. Moreover the arrangement as described just above also has the advantage that the warming effect of the water in the humidifier continues regardless of whether the main shut-off valve in the duct **19** is opened or closed.

I claim:

**1.** Lung ventilating equipment comprising a patient's circuit including means adapted to be associated with a patient for supply of breathing gas and further including a bellows collapsible to develop pressure in the patient's circuit to effect inspiration by the patient, a chamber surrounding the bellows, power means for introducing pressure into said chamber to effect collapse of the bellows and inspiration by the patient, an expiration valve associated with the patient's circuit for discharge of expiratory gas, valve means for blocking or passing the pressure supplied by the power means into said chamber, an exhaust valve for relieving pressure in said chamber when the bellows expands, said expiration valve and said exhaust valve having pressure responsive devices associated therewith for holding those valves closed during the introduction of pressure thereto, pressure supply passages controlled by said valve means for the introduction of pressure to said pressure responsive devices when said valve means passes pressure into said chamber; portage for venting said pressure supply passages and means controlled by said valve means to open said portage when the valve means is operated to block delivery of pressure into said chamber and thereby provide for opening of both the expiration valve and the exhaust valve during expansion of the bellows and to close said portage when the valve means passes passage into the chamber.

**2.** A construction according to claim **1** and further including a fluid pressure device responsive to voluntary inspirational effort by the patient to operate the valve means to close said venting means and to pass pressure into said chamber to effect inspiration by the patient.

**3.** Lung ventilating equipment comprising a patient's circuit including means adapted to be associated with a patient for supply of breathing gas and further including a bellows collapsible to develop pressure in the patient's circuit to effect inspiration by the patient, a chamber surrounding the bellows, power means for developing air pressure, a conduit for delivering air under pressure from the power means to said chamber to effect collapse of the bellows and inspiration by the patient, an expiration valve associated with the patient's circuit for discharge of expiratory gas, valve means for blocking or passing the air under pressure in said conduit, a check valve for blocking flow from said chamber into said conduit when the bellows expands, an exhaust valve for relieving pressure in said chamber when the bellows expands, said expiration valve and said exhaust valve having pressure responsive devices associated therewith for holding those valves closed during the introduction of pressure thereto, pressure sup-

ply passages controlled by said valve means for the introduction of pressure to said pressure responsive devices when said valve means passes pressure into said chamber, portage for venting said pressure supply passages to atmosphere and means connected to said valve means to open said portage when the valve means blocks delivery of pressure into said chamber and thereby provide for opening of both the expiration valve and the exhaust valve during expansion of the bellows and to close said portage when the valve means passes pressure to said chamber, a solenoid for actuating the valve means, timer circuit means connected to the solenoid to provide for timed operation of the solenoid to actuate the valve means to provide a period of inspiration and also an expiratory pause, a fluid pressure device in said patient's circuit operable in response to voluntary inspirational effort by the patient, and means circuit controlled by said pressure device to operate said valve means to pass air into said chamber at any time during said expiratory pause.

4. Lung ventilating equipment comprising conduit means adapted to be associated with a patient for supply of breathing gas, a gas blower including a blower motor and a blower fan for developing pressure to effect delivery of breathing gas from the circuit means to the patient, the blower having a gas delivery duct with valve means therein for blocking delivery of gas from the blower, control means for opening and closing said valve means to provide for inspiration by the patient and for an expiratory pause, a humidifier associated with said conduit means for humidifying gas delivered to the patient and including a reservoir for the humidifying water, the humidifier further having an air chamber below the reservoir, and an air supply connection for said chamber connected with the gas delivery duct of the blower in advance of the valve means therein said blower motor and said blower fan being relatively arranged to provide for flow of air over the motor and into the duct, and to thereby continually supply warm air to the chamber below the water reservoir in the humidifier regardless of whether said valve means is open or closed.

5. Lung ventilating equipment comprising conduit means adapted to be associated with a patient for supply of breathing gas, a gas blower for developing pressure to effect delivery of breathing gas from the conduit means to the patient, an expiration valve associated with the conduit means for discharge of expiratory gas and having a pressure responsive device for effecting closure of the expiration valve, a pressure supply passage for said device, an air supply valve means for blocking delivery of gas from the blower, timer mechanism connected with said valve means and providing for timed operation of the valve means to establish a period of inspiration and also an expiratory phase, said pressure supply passage being pneumatically connected to said gas blower and controlled by said valve means to provide for timed delivery of pressure through said pressure supply passage to said pressure responsive device when said valve means is open, thereby providing for closure of the expiration valve during delivery of breathing gas to the patient, a port for venting said pressure supply passage, means associated with said valve means and controlled thereby to open the port to vent said pressure supply passage when the valve means is conditioned to block delivery



of gas from the blower, and thereby provide for timed opening of the expiration valve during the expiratory phase and to close the port when the valve means is opened, and a fluid pressure device responsive to voluntary inspiration effort by the patient and including means for opening the air supply valve means at all times during said expiratory phase thereby overriding the timer mechanism and to provide for development of pressure to effect delivery of breathing gas to the patient.

6. Lung ventilating equipment comprising conduit means adapted to be associated with a patient for supply of breathing gas, a gas blower for developing pressure to effect delivery of breathing gas from the conduit means to the patient, an expiration valve associated with the conduit means for discharge of expiratory gas and having a pressure responsive device for effecting closure of the expiration valve, a pressure supply passage for said device, valve means for blocking delivery of gas from the blower, a solenoid for actuating the valve means, timer circuit means connected to the solenoid to provide for timed operation of the solenoid to actuate the valve means to provide a period of inspiration and also an expiratory phase, said pressure supply passage being pneumatically connected to said gas blower and controlled by said valve means to provide for delivering of pressure to said pressure responsive device when said valve means is open, thereby providing for closure of the expiration valve during delivery of breathing gas to the patient, a port for venting said pressure supply passage, means associated with said valve means and controlled thereby to open the port to vent said pressure supply passage when the valve means is operated to block delivery of gas from the blower and to close the port when the valve means is opened, and thereby provide for opening of the expiration valve during the expiratory phase, a fluid pressure responsive device, an air supply passage interconnecting said fluid pressure responsive device with said conduit means, said fluid pressure responsive device being responsive to a voluntary inspirational effort by the patient, and means controlled by said pressure responsive device to open the air supply valve means at all times during said expiratory phase thereby overriding the timer mechanism and to provide for development of pressure to effect delivery of breathing gas to the patient.


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RICHARD A. GAUDET, *Primary Examiner.*

C. F. ROSENBAUM, *Assistant Examiner.*

# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,266,488 August 16, 1966

Christian B. Andreasen

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 52, for "passage" read -- pressure --.

Signed and sealed this 8th day of April 1969.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents