

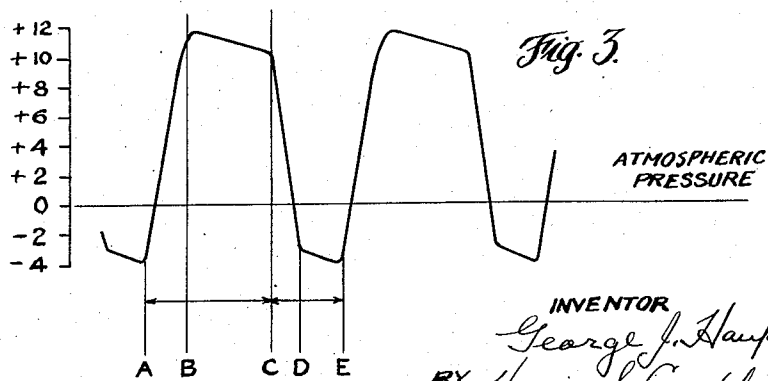
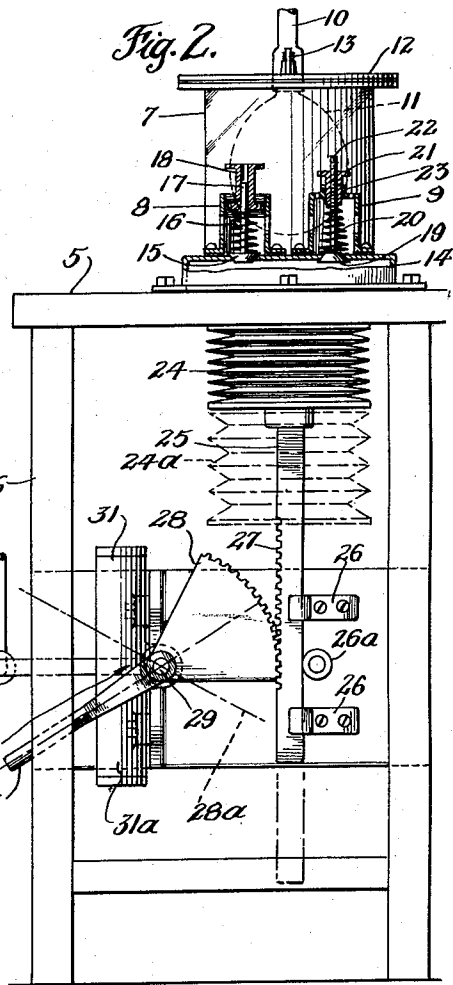
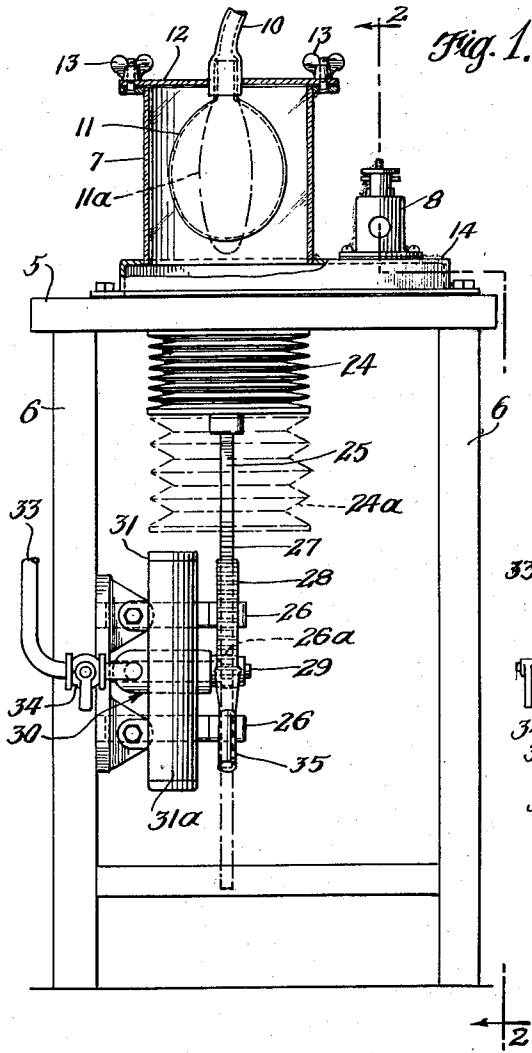
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LUNG VENTILATING APPARATUS

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LUNG VENTILATING APPARATUS

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This invention relates to accessory apparatus for use with anesthesia machines and is more particularly concerned with equipment designed to provide assistance in the breathing or ventilating functions of the patient.

Anesthesia machines normally provide a suitable source of respiratory gas with properly controlled oxygen concentrations as well as proper amounts of anesthetic gases to maintain the patient in the desired state of anesthesia. Controls are provided so that the anesthetist may vary the concentrations of the gas and the amount of anesthetic delivered. There is normally supplied, as part of the anesthesia machine, a flexible bag or bladder by means of which the anesthetist may assist the pulmonary ventilation of the patient. This is accomplished by applying pressure by hand to the bladder to induce or assist the inflation of the lung. Anoxia, which is readily identified by clinical signs such as cyanosis occurs only with extremely poor pulmonary ventilation because the partial pressure of oxygen in the anesthetic gas is very high.

It is an object of the present invention to provide an apparatus which will mechanically assist the ventilation of the patient and thereby relieve the anesthetist of the need for doing so manually. In this way full attention may be given to the proper control and operation of the anesthetic and other vital duties.

A further function of the ventilating action is the removal of carbon dioxide through the lungs. Dangerously high concentrations of carbon dioxide frequently accumulate in the blood, yet give no reliable clinical signs. Periodic testing of blood samples during some operations have shown increases in carbon dioxide content by 50 to 100 percent above normal. This can only be removed by adequate pulmonary ventilation. Manually assisted ventilation has not proven to be consistently reliable in preventing carbon dioxide accumulation. During operations involving an open pneumothorax compression of the rebreathing bag succeeds in distending the lung during the inflation phase of the ventilatory cycle. Deflation is dependent upon the inherent contractility of the lung to overcome the resistance to gas flow in the anesthetic system used. The complete cycle thus takes place at pressures greater than atmospheric.

It is also an object of the invention to provide apparatus which will not only provide pressure to assist the inflation phase but which also provides a reduced or negative pressure to assist in the deflation phase. This alternate pressure change from above to below atmospheric has been found to be highly beneficial. The scavenging action of the negative cycle not only provides more efficient ventilation but serves to maintain the carbon dioxide content of the blood at or below normal by providing adequate alveolar ventilation. When increase in carbon dioxide content occurs the patient normally attempts to increase the respiratory effort resulting in unrest and "bucking" of the respiratory cycle. During operations it is sometimes necessary to increase the amount of anesthesia or administer drugs to induce paralysis of the respiratory muscles in order to

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produce the required stability of the operative field. Neither of these actions are desirable since they do not enhance ventilation but only serve to abolish the patient's unsatisfied respiratory effort. By the use of the positive and negative cycle the improved ventilation results in a quiet state of anesthesia with minimal amounts of ether, thus eliminating the need for paralyzing drugs and providing an improved post operative condition of the patient.

In supplying pressure for breathing assistance it is desirable to bring the pressure quickly up to the desired level and then hold it for the remaining portion of the inflation period. Likewise it is desirable to quickly reduce the pressure at the end of the inflation period to a negative value of a given amount and retain this during the period of deflation. It is an important object of the present invention to provide apparatus which will produce rapid change of pressure and will then retain substantially even pressure under large change of volume. One method of accomplishing this is by the use of a bellows mechanism which can provide a rapid change in volume at low pressures, particularly when driven by suitable mechanism.

It is a further object of the invention to provide a drive mechanism for the bellows system which will permit adjustment of the rate and phase of the ventilatory cycle.

It is also an object of the invention to provide a valve system which will automatically and accurately control the maximum positive pressure desired as well as the maximum negative pressure. Apparatus is included to permit change of the controlled positive and negative pressure values.

How the foregoing and other objects and advantages of the invention are attained will be clear from the following description of the drawings in which:

Figure 1 is a front elevational view of one form of apparatus by means of which the present invention may be applied.

Figure 2 is a side elevational view with a portion shown in section as indicated by the arrows 2—2 in Figure 1.

Figure 3 shows a typical pressure curve for the apparatus covering two cycles of breathing.

Referring to the Figures 1 and 2 it will be seen that the apparatus is supported on a frame work or table, the top of which is indicated at 5 and the vertical structure or legs are shown at 6. Part of the apparatus including closed chamber 7 and valve units 8 and 9 are shown resting on the upper surface of the table. Tube or hose member 10 extends to the delivery system of the anesthesia machine which also connects to the mask applied to the patient so that pressures developed in the hose 10 assist in transferring gas to or from the patient's lungs.

Normally and without assistance, when the patient exhales, a positive pressure is developed at the lungs and air is forced out of the lungs into the system where it is passed through suitable equipment for removing carbon dioxide before it is recirculated. During the inflation phase gas from the anesthesia machine system to which the hose 10 is attached is supplied to the patient.

The bag or bladder member 11 is shown in full line position extended as at the end of the deflationary portion of the ventilatory cycle. This bladder is also shown at 11a in collapsed position corresponding to the position it assumes at the end of the inflationary period after the patient's lungs have been filled with gas from the system. In the regular anesthesia machine this bladder or bag 11 is accessible to the operator and he may squeeze it in rhythm to produce pressure to induce the inflation action of the lungs. Collapsing the bag 11 forces gas from the system into the lungs. After the patient exhales by the contraction forces of the lungs and

respiratory muscles, the system is again filled by the machine and positive pressure develops causing the bag to be extended to its normal position.

According to the present invention bag 11 is supported in the chamber 7 by lid 12 which also seals the upper part of the chamber. Wing nuts 13 serve to allow rapid insertion or removal of the bag. The walls of chamber 7 are preferably made of glass or transparent plastic material so that it is possible to check the action of bladder 11 during its operation. Chamber 7 connects at its lower side to an extension chamber 14 to which valve units 8 and 9 are attached.

Valve unit 8 controls the positive pressure action in the chamber 7 and incorporates valve member 15 which seats against the upper surface of chamber 14 to prevent ingress of air from the outside. Coil spring 16 extends around stem 17 of the valve and urges valve part 15 into closed position. Guide member 18 supports valve stem 17 in position and this guide also serves as the abutment against which spring 16 reacts. Guide 18 is preferably provided with an external threaded connection so that it may be screwed in or out with respect to the housing of valve unit 8 thereby providing for adjustment in spring 16. Thus the pressure at which valve 15 opens to control the maximum pressure in chamber 7 may be varied by means of adjustable guide 18.

Valve unit 9 controls the negative pressure of the chamber and incorporates valve member 19 which is supported on the underside of the upper surface of chamber 14 so that upon opening, air may enter from the outside into the chamber. Positive pressure in the chamber holds the valve in closed position as does conical coiled spring 20 which reacts between the upper surface of the chamber 14 and guide member 21 which is attached to the valve stem 22. Guide 21 is supported for sliding action in the boss 23 which is attached to the housing of valve unit 9. By providing a screw thread connection between guide 21 and valve stem 22, adjustment of spring 20 is provided thereby permitting variation in control of the maximum negative pressure which is developed in chamber 7.

In the form of apparatus shown pressure variation is developed in the chamber 7 through the medium of bellows unit 24. A push rod 25 is attached to the lower end of the bellows 24 to provide for actuation thereof. Guide brackets 26 are supported on the frame structure in position to maintain rod 25 in a fixed vertical position but allowing it to slide through the brackets 26 in its motion to drive the bellows 24. One edge of the rod 26 is provided with teeth 27 which mesh with the sector gear member 28 which in turn is supported on pivot 29 for oscillating movement. Roller 26a carries the gear separating load with minimum friction.

Pivot 29 to which gear member 28 is attached is part of an air-driven mechanism or motor 30 incorporating upper cylinder 31 and lower cylinder 31a. This mechanism is similar to a wind shield wiper motor which is provided with double pistons arranged to transfer their sliding movement into oscillating movement of shaft 29. The air motor is driven by means of compressed air supplied through line 33. Valve 34 controls airflow to the motor and permits throttling the air so that the speed of the motor may be adjusted to the desired speed of operation. Handle 35 is attached to the gear member 28 thereby permitting manual operation of the bellows 24 in the event of failure of the air supply. Selection of an air motor of the proper power provides suitable phase regulation of the system since the time required for motion in the low load direction, that is, the negative pressure phase, is less than for the positive pressure phase. This is inherent in the air motor as it runs faster when under low load than when under normal load as during the pressure phase.

Operation of the machine to assist the patient's ventilation is initiated by opening valve 34 sufficient-

ly to cause the machine to run at a speed which gives the desired ventilating cycle rate. As mentioned above the proper phase relationship is regulated by the variable speed operation of the air motor. If desired, bleed valves may be supplied for the cylinders of the air motor in case it is not properly adjusted to the ventilating cycle load. It has been found that the patient accommodates himself readily to the cycle of the machine inasmuch as it provides ventilation sufficient to abolish the respiratory effort of the patient by providing adequate arterial oxygen saturation and by decreasing the partial pressure of carbon dioxide in arterial blood below normal. This results in physiological apnea.

The action of the machine on the ventilatory cycle will be more clearly understood by reference to the pressure diagram shown in Figure 3. Just before the inflation cycle the pressure in chamber 7, which corresponds closely to the pressure inside bag 11, is at a negative value which had expanded bag 11 to the full line position indicated. Under this condition bellows 24 is in its extended position indicated at 24a and rod 25 is at the lower end of its stroke as indicated by center line 28a position of the gear sector 28. At the beginning of the upward stroke, that is at the beginning of the inflation period of the cycle the pressure changes from the negative pressure shown at the point A in Figure 3 to the positive pressure at the line B in Figure 3 in a relatively short time as represented by the small time of the upward stroke. The horizontal direction in the diagram represents time rather than the stroke position of the bellows since the nature of the driving motor is such that a variable speed of motion can occur. This is of advantage in creating a rapid transfer from one pressure, that is from the negative pressure at point A, to the high positive pressure at point B. The upstroke of the bellows, that is the collapsing action, continues between lines B and C, Figure 3, the upper pressure limit being controlled by valve 8 which is set to relieve at a pressure approximately 10 to 12 centimeters of water while the bellows continues its movement and causes the bladder 11 to assume the collapsed position 11a. The large volume of the bellows provides the needed volume of air to assure this collapsing action.

The end of the inflation stroke has been reached at the line C in the diagram. At this time it is desired to reverse the pressure and provide a negative pressure in chamber 7 in order to assist bladder 11 in expanding and creating a negative pressure in the tube 10. The negative pressure in the system assists the patient in exhausting the gas from his lungs. The change in the system from positive inflation pressure at C to the negative deflation pressure at D occurs in a relatively short space of time at the beginning of the downward stroke of the bellows 24 from its upper or full line position. The top of the stroke corresponds to position C on the diagram. Thus the first part of the downward stroke quickly changes the pressure in chamber 7 to a negative pressure which is controlled to approximately 2 to 4 centimeters of water negative pressure by valve 9. Continued motion of the bellows downwardly maintains relatively constant negative pressure between the lines D and E thereby providing for the expansion of bladder 11 at a steady rate during the remainder of the deflation period of the cycle. Because of the natural phase adjustment of the motor under load change, less time is required for the downward stroke than for the upward stroke as indicated by the shorter length of time between the lines C and E on the diagram as compared to lines A and C. This time relationship for the deflation period is desirable inasmuch as the time for this should be less than the inflation portion of the cycle.

The use of negative pressure such as provided by the equipment of the present invention is of great benefit to a patient during anesthesia. In addition to assisting the patient in the breathing action this negative portion of the cycle provides for more complete scavenging of the gas from the lungs. This is of direct value inasmuch as

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it provides for removal of carbon dioxide to maintain the partial pressure of carbon dioxide in the arterial blood at or below 40 mm. Hg. Improved alveolar ventilation is directly related to carbon dioxide elimination. The use of equipment which provides for complete mechanical ventilation not only relieves the anesthetist of the arduous repetitive process of squeezing the bag to induce pressure in the system, but provides greatly improved conditions for the patient and the surgeon. The reduction of the endotracheal pressure to a negative value during a part of the cycle produces greater alveolar ventilatory volume than an equal net pressure in the positive range only. Because of the satisfied respiratory requirement of the patient, a quiet operative field is produced with a lighter plane of anesthesia. This is particularly important in operations requiring an open pneumothorax. The burden on the heart is also reduced, and the side effects on the circulatory system eliminated. Cardiac output is enhanced.

By the use of the bellows mechanism with the adjustable control of the valving, rapid change of pressure may be obtained in the system while at the same time constant pressure during the major portion of the stroke is accomplished. The use of an airmotor adjustable for rate and with proper phase, in the drive system assists in this action. This also assists in providing the rapid build up of pressure in the bellows and its sustention in an efficient manner. The use of bellows eliminates the need for seals or sliding surfaces which might require lubrication. The presence of oil in atmospheres having high oxygen concentrations can produce a dangerous explosive condition. With this equipment the negative pressure portion of the cycle may be easily introduced. The system is readily adaptable to any standard anesthesia apparatus. This system further has the advantage that the pneumatic system for applying the pressure is completely independent from the gas system of the anesthesia machine. Thus no part of the ventilation apparatus comes in contact with the anesthesia gases except the bladder which may be readily removed for cleaning and sterilization.

I claim:

1. Apparatus for assisting the ventilation of a patient during anesthesia including a chamber, a flexible breathing bag having a support for mounting inside said chamber, a duct attached to said bag to connect it to the anesthesia machine gas system, equipment for developing a variable pressure cycle in said chamber, said equipment including a bellows device connected to said chamber, pneumatic actuating mechanism connected to said device, control mechanism including a throttle valve for adjusting the cycle frequency, and relief valves for controlling the magnitude of positive and negative pressure.

2. Apparatus for inducing variable pressure in an anesthesia machine system, said apparatus incorporating a variable pressure air chamber, a flexible walled member supported entirely within said chamber and completely segregating the gas on one side of the flexible member from the air in the chamber, the segregated side of said flexible member being connected by a duct into the anesthesia machine circuit, said chamber having a movable wall connected therewith, mechanical means connected to said wall to move it to alternately produce a positive pressure and a negative pressure in said chamber, and adjustable valve devices connected to the air containing portion of said chamber to control the maximum values of the positive and negative pressures to pressure values suitable for application to the anesthesia system.

3. Apparatus for assisting a patient's ventilation during anesthesia including an enclosed chamber, mounting means in said chamber for a flexible wall breathing bag, a duct connecting said mounting means to an anesthesia machine system thereby separating it from the gas in said chamber, a bellows device connected to said cham-

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ber to produce alternate positive and negative pressures therein, a power unit with driving connections to move said bellows device, relief valves between said chamber and the outside atmosphere to limit the maximum values of the positive and negative pressures to amounts suitable for application to the anesthesia machine system.

4. Apparatus for assisting a patient's ventilation during anesthesia including an enclosed chamber, mounting means in said chamber for a flexible wall breathing bag, a duct connecting said mounting means to an anesthesia machine system thereby separating it from the gas in said chamber, a bellows device connected to said chamber to produce alternate positive and negative pressures therein, a power unit with driving connections to move said bellows device, relief valves to limit the maximum values of the positive and negative pressures, the power unit being an air driven motor capable of giving a greater time interval for one phase of the cycle than the other phase.

5. Apparatus for attaching an anesthesia machine system including a variable pressure chamber, mounting means attached to said chamber for supporting the breathing bag of the anesthesia system in said chamber, said mounting means providing a gas tight connection to prevent passage of gas from said chamber to said bag, a movable diaphragm device connected to said chamber to change the pressure therein, a mechanical drive to said diaphragm to alternately move it in a collapsing direction to induce positive pressure in said chamber and in an expanding direction to induce negative pressure in said chamber, two adjustable control valves between said chamber and the outside atmosphere, one of said valves being constructed to limit the maximum positive pressure in said chamber to a value suitable for applying to a patient's lungs through the anesthesia machine system, the other of said valves being constructed to limit the maximum negative pressure to a value suitable for applying to lungs of a patient and a control to change the length of the operating cycle of the movable diaphragm.

6. A construction in accordance with claim 5 in which the mechanical drive includes an air driven device, the control for changing the length of the operating cycle being in the form of a valve to govern the flow of air to said driven device.

7. In anesthesia apparatus of the type in which a compressible and distensible bladder device is interposed in the system supplying gas to the mouthpiece of the anesthesia mask, mechanism for alternately applying compressing and distending pressure to the bladder device, said mechanism including a chamber system filled with atmospheric air having a portion with a movable wall to produce a variable volume in the system, means mounting the bladder device in said chamber, mechanical means for moving said wall to alternately reduce the volume of said chamber system to induce a positive pressure therein and then to increase the volume to induce a negative pressure therein, said mechanical means including an air driven motor with throttle control valve which slows down its speed of motion when under load to provide longer dwell during the positive pressure phase of the cycle than during the negative pressure phase when the load on the motor is reduced.

8. In anesthesia apparatus of the type in which a compressible and distensible bladder device is interposed in the system supplying gas to the mouthpiece of the anesthesia mask, mechanism for alternately applying compressing and distending pressure to the bladder device, said mechanism including a chamber system filled with atmospheric air having a portion with a movable wall to produce a variable volume in the system, means mounting the bladder device in said chamber, mechanical means for moving said wall to alternately reduce the volume of said chamber system to induce a positive pressure therein and then to increase the volume to induce a negative pressure therein, said mechanical means including a gas driven device with driving connections to

said moving wall, said gas driven device incorporating operative characteristics giving greater time of application for the positive pressure phase than for the negative pressure phase.

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