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ANESTHESIA MACHINES

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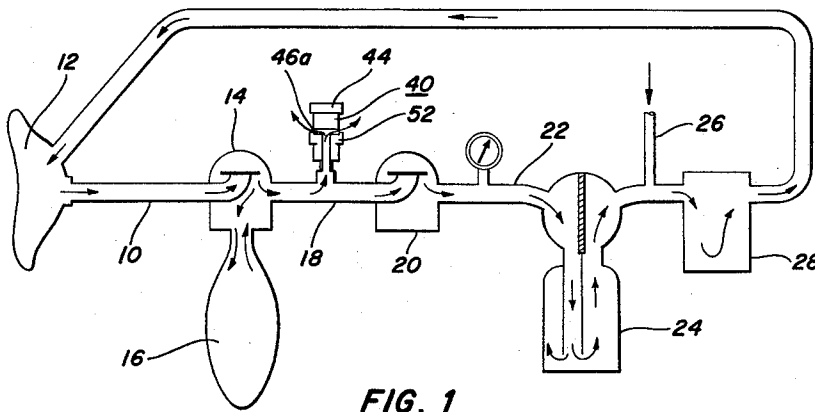


FIG. 1

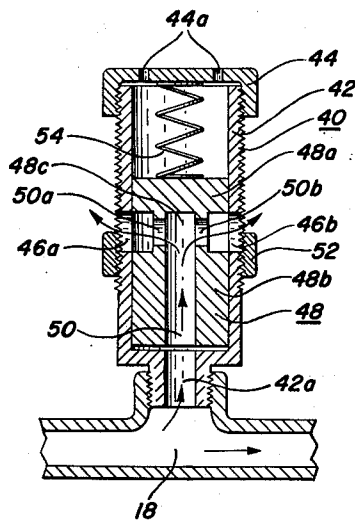


FIG. 2

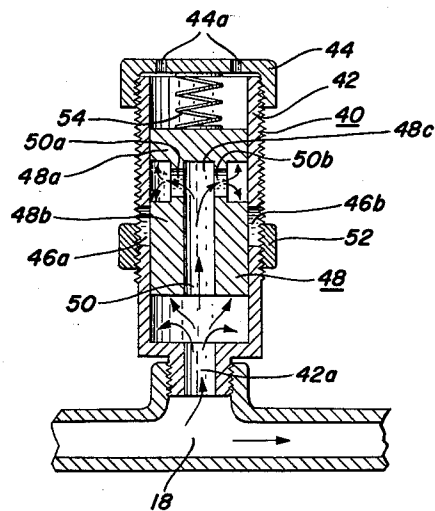


FIG. 3

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This invention relates to improvements in anesthesia machines, and more particularly to an improved anesthesia machine of the semi-closed, partial rebreathing gas-circuit type capable of producing volume ventilation of the patient, as distinguished from pressure ventilation thereof.

In the conventional anesthesia machine operating on the semi-closed principle, wherein at least a part of the expired gases exhaust through an exhalation valve into the air and some rebreathing is understood to be a factor, a reservoir bag provides, upon being squeezed, a means of pumping gases into the patient. In such machine, a pressure-relief valve is usually interposed between the exhalation (exhaust) valve and the inhalation (intake) valve, which can be so set by the operator as to "pop off" when the pressure of gas in the circuit reaches a critical value. The pressure attained may or may not provide the volume of gas necessary to adequately ventilate (move oxygen into and carbon dioxide from) the patient. For example, if in surgery the patient's airway and/or lungs should become obstructed, no gas goes into him; instead, when the reservoir bag is squeezed, it goes to the outside air via the pressure-relief valve upon the critical pressure to which said valve is set being reached. In such circumstances, not only is the patient not adequately ventilated, but it is even possible that the obstruction may go unnoted since, if the anesthetist is meeting a constant maximum resistance in squeezing the bag, he has no way of knowing that the patient is adding resistance or obstruction to gas flow.

Stated broadly, a major object of this invention is the provision of an anesthesia machine incorporating a semi-closed, partial rebreathing type of gas circuit as aforesaid, but which differs from the conventional anesthesia machines employing a similar gas circuit in its ability to produce volume ventilation, rather than pressure ventilation, thus satisfying the requirement of ventilation adequacy based on volume and not pressure of gas being supplied to the patient.

More particularly, it is an object of the present invention to provide an anesthesia machine characterized by a semi-closed, partial rebreathing type of gas circuit as aforesaid, which, in addition to its capacity of meeting the basic requirement of such a machine in producing a continuous flow of gas at anesthetic concentrations, also operates on a normally open-circuit principle according to which the gas circuit is normally open to atmosphere whereby any excess gas flow exhausts to atmosphere but becomes a closed circuit upon the reservoir bag being initially squeezed, with continued squeeze thereon assuring delivery of the full volume of gas contained within the bag to the patient's lungs.

Yet another object of the invention is the provision of simple means for converting existing and/or known makes of semi-closed anesthesia machine set up to produce pressure ventilation into machines capable of producing volume ventilation.

Still another important object of the invention is the provision of an anesthesia machine combining a reservoir bag normally serving, upon being squeezed, as a means for pumping gases into the patient's lungs and a novel gas-volume control means in such manner as to give instant indication to the anesthetist of an obstruction developing or having developed within the patient's airway

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and/or lungs which needs correction, or that external pressure is being applied to the patient's chest, as by a nurse or other attendant unintentionally leaning on the same, for example.

The above and other objects and features of advantage of an anesthesia machine according to the present invention will appear from the following detailed description thereof, wherein reference is had to the accompanying illustrative drawings, in which:

FIG. 1 is a schematic drawing illustrating the gas circuit of a standard anesthesia machine converted to produce volume ventilation of a patient according to the invention;

FIG. 2 is a vertical section taken through a form of volume-control valve incorporated in said circuit in place of the conventional pressure-relief valve, according to the invention, which has given satisfactory service in actual practice, the valve being shown in its normal or open position; and

FIG. 3 is a view similar to FIG. 2 but illustrating the valve as having been actuated to its closed position.

As conducive to a proper understanding of the present invention, it is explained that the basic gas circuit of the standard anesthesia machine used heretofore to produce so-called pressure ventilation of a patient is employed in an anesthesia machine according to the present invention, with suitable conversion to instead produce volume ventilation of said patient, as will be hereinafter explained in detail. Referring to FIG. 1, illustrative of such a circuit, the exhalation line (hose) 10 extending from the breathing mask 12 connects, through an interposed exhalation check valve (also called the exhaust valve) 14 to a flexible squeeze-type rebreathing or reservoir bag 16 which is usually connected by a short length of pipe 18 to an inhalation check valve (intake valve) 20 to which the inhalation line 22 leading to the breathing mask 12 is connected. Serially connected in the inhalation line is a soda lime canister 24, a fresh gas inlet connection 26, and an ether vaporizer 28.

Heretofore, gas pressure in the circuit was normally maintained below a maximum critical value by a pressure-relief valve interposed in the circuit between the exhaust valve 14 and the intake valve 20, which valve was of the type that "pops off" upon the critical pressure of the gas within the circuit being exceeded. Thus, the gas within the circuit of the prior anesthesia machines was at all times under a positive pressure of value somewhat below the setting of said pressure-relief valve and was relieved upon the critical pressure, which was determined by the setting of the pressure-relief valve, being exceeded.

As explained in the foregoing, the gas pressure obtaining within the circuit utilizing the conventional pressure-relief valve as aforesaid may or may not provide the volume of gas flow necessary to adequately ventilate (force oxygen into and move carbon dioxide out of) the patient. For example, in the event the patient's airway or lungs should become obstructed during surgery, the resistance to gas flow developing within the system when the bag is squeezed results in opening of said pressure-relief valve, and in such circumstance the gas flows to atmosphere rather than to the patient. It will also be appreciated that because of this fact the anesthetist is given no warning of the patient's condition since he has no way of knowing that the increase of pressure which caused the pressure-relief valve to "pop off" resulted from the obstruction in the patient's airway or lungs.

The aforesaid disadvantages and very real objections to the prior semi-closed anesthesia machines are simply overcome by the present invention. More particularly, I have found that by the substitution for the aforesaid

pressure-relief valve conventionally employed in the prior anesthesia machines of a so-called volume-control valve which is normally open but which closes immediately upon any slight pressure developing in the system, as by initial squeeze applied to the reservoir bag, not only is ventilation adequacy to the patient assured, but also the anesthetist is given notice in the event that the patient adds resistance to the gas flow consequent, for example, to his airway or lungs becoming obstructed in surgery, or by reason of external pressure being unintentionally applied to the patient's chest.

The improved or converted gas circuit according to my present invention retains all components of the previously described basic circuit, but differs from such a circuit as previously known in substituting for the aforesaid conventional pressure-relief valve a volume-control valve 40 as the term "volume-control valve" is used herein to designate a valve which is normally open to atmosphere, thus to permit bleeding off of any excess volume of gas within the system, but is pressure-responsive so as to close automatically upon squeeze being imparted to the reservoir bag 16 as causes an increase of pressure within the circuit. Thus, rather than the gas circuit being normally closed to atmosphere and opening thereto upon a critical maximum pressure building up in the circuit as heretofore, the circuit of a machine according to the present invention is normally open to atmosphere and closes only in response to pressure building up in the system by initial squeeze on the reservoir bag, as assures the full gas volume contained in the bag flowing to the patient as the bag is fully squeezed.

While a volume-control valve 40 as herein contemplated may take numerous physical forms, that illustrated in FIGS. 2 and 3 has proved satisfactory in actual practice and is accordingly a preferred form. Such a valve comprises a cylindrical or shell-form valve body 42 having a reduced-diameter, lower end portion 42a for receiving a fitting by which the valve may be secured to the short-length connecting pipe 18, for example, and being closed at its upper end by a screw-on end cap 44 provided with small, air-release openings 44a. Intermediate its ends, the valve body 42 is provided with diametrical openings 46a, 46b, which establish communication between its interior and the atmosphere. Mounted for reciprocatory travel within the valve body is a piston valve generally designated 48, which is preferably fashioned from a light-weight material such as Teflon, and comprises a head portion 48a, a skirt portion 48b, and an intermediate reduced-diameter neck portion 48c. The piston is axially bored as at 50, the bore extending from the lower end face of the piston through the skirt and neck portions thereof to the line of the under face of the piston head 48a, and said neck portion is provided with lateral ports 50a, 50b through which the bore 50 opens at its upper end laterally into the annular space between the piston head portion 48a and the piston skirt portion 48b. The axial length of the piston valve 48 and the disposition of the reduced neck portion 48c thereof is such that when the valve is disposed in its lowermost (or first) position within the valve body 42, to which it is normally urged by a light spring 54 which is contained within the valve body and is reactive between the end cap 44 and the upper face of the piston valve, the neck ports 50a, 50b are in registry with the side openings 46a, 46b of the valve casing. Accordingly, in the normal position of the piston valve 48, it maintains the gas circuit open to atmosphere. However, analysis will show that upon any sensible pressure developing within the gas-circuit line as occurs upon initial squeeze being applied to the reservoir bag 16, such pressure becomes effective against the under surface of the piston head portion 48a and imparts upward reciprocatory movement of the piston proper against the bias of spring 54, as effects closing of the valve body openings 46a, 46b, thus effectively closing said valve and thereby the circuit to

atmosphere. Upon closing of the valve and assuming continued squeeze being applied to the reservoir bag 16, the full volume of gas contained within said bag is moved through the circuit to the patient's lungs, thus assuring adequacy of ventilation of the patient.

Preferably, the size of the cylinder openings 46a, 46b is made variable, thus to introduce a variable factor in the pressure at which the valve 40 closes the circuit to atmosphere. Such variation may be simply provided, as by threading the outer peripheral surface of the cylindrical valve body 42 as shown and mounting thereon a nut 52 whose axial position along the cylinder determines the degree of covering of said openings 46a, 46b and hence the pressure at which the piston valve 48 will move to its second or circuit closing position. Other appropriate means for achieving this result may of course be substituted.

As forecast previously, an anesthesia machine employing the gas circuit according to the present invention is also of advantage in giving notice to the anesthetist in the event that the patient's airways and/or lungs become unduly obstructed during surgery or because of pressure applied externally to his chest by a person accidentally leaning thereon, for example. Such notice follows from the fact that the skilled anesthetist will immediately sense any appreciable resistance to the reservoir bag being squeezed and thus become immediately aware of a condition requiring correction as above. This type of operation is of course in sharp contrast to that of the prior anesthesia machines employing the pressure-relief valve feature, since the circuit of latter provides no means of enabling the anesthetist to discriminate between normal increase of pressure within the system as results in opening of the pressure-relief valve 18, on the one hand, and abnormal pressure within the system developing as the result of an obstruction in the patient's airway, as also results in the pressure-relief valve opening the circuit to atmosphere.

Briefly describing the operation of the modified and improved gas circuit according to the invention, fresh gas (oxygen) is fed at a continuous rate to the circuit from a tank supply through the fresh gas inlet 26 and combines with the vaporized ether (or other suitable gas having anesthetic properties) to make up an anesthetic concentration of gases which, with the part of the expired gases which pass through the exhaust valve (the remaining exhausting to air through said valve), floods the circuit, such assuming the mask by-pass valve (not shown) to be open, with any excess flow of the gas mixture bleeding to atmosphere through the normally open volume-control valve 40. In administering anesthesia, the anesthetist of course applies the mask 12 to the patient's face, meantime closing the aforesaid mask by-pass valve, with the result that the mask and the patient are now connected in the circuit. Thereupon the anesthetist applies squeeze to the flexible reservoir bag 16, with initial squeeze creating a positive gas pressure within the circuit which, although small, is nevertheless sufficient to actuate the piston valve element 48 of the volume-control valve 40 to its circuit closing-off position (FIG. 3) and also to effect closing of the exhaust valve 14 and opening of the intake valve 20, whereupon further or final squeeze on the bag forces the full volume of gas contained therein through the inhalation line 22 to the patient's airway and lungs. Upon squeeze of the bag being relaxed, both the exhaust valve 14 and the volume-control valve 40 return to their open position, the intake valve returns to its closed position, and the reservoir bag distends to its normal position, as results in the gas mixture at anesthetic concentration again flooding the system, with any excess passing to atmosphere through the volume-control valve 40 as before, whereupon the cycle may be repeated as desired.

While to be effective for the purposes of the invention the aforesaid volume-control valve 40 must be interposed

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between the exhaust valve 14 and the intake valve 20, it is to be understood that the position of said valves with respect to other components of the circuit is not so fixed. For example, the position of the reservoir bag and ether vaporizer may be interchanged, and the intake valve 20 may be disposed ahead, i.e. on the breathing mask side, of the soda lime canister and ether vaporizer. Other variations in the position of the system and/or air circuit components are also possible, provided that the volume-control valve 40 is maintained intermediate the exhalation and inhalation check valves as aforesaid.

Thus, as many changes could be made in carrying out the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. In a semi-closed, partial rebreathing-type anesthesia machine, the combination of a patient's breathing mask, means providing a continuous gas-flow circuit extending from and leading to the mask, exhalation and inhalation check valves and a reservoir bag connected in said circuit, said reservoir bag being operative when squeezed to pump gases through the circuit to the patient via the mask, and normally open pressure-responsive valve means connected in the circuit intermediate said valves for normally maintaining said circuit open to atmosphere but being operative automatically to close said circuit to atmosphere responsive to initial squeeze of the bag whereby continued squeeze thereon causes the full volume of gas contained in the bag to move to the patient, said pressure-responsive valve means comprising a valve element, biasing means operative normally to maintain said valve element in a first position in which it opens said gas-flow circuit to atmosphere, and pressure-responsive means for causing said valve element to move to a second position in which it closes said circuit to atmosphere responsive to an increase in pressure in the circuit resulting from initial squeeze on the bag as aforesaid.

2. In a semi-closed, partial rebreathing-type anesthesia machine, the combination of a patient's breathing mask, means providing a continuous gas-flow circuit extending from and leading to the mask, exhalation and inhalation check valves and a reservoir bag connected in said circuit, said reservoir bag being operative when squeezed to pump gases through the circuit to the patient via the mask, and normally open pressure-responsive valve means connected in the circuit intermediate said valves

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for normally maintaining said circuit open to atmosphere but being operative automatically to close said circuit to atmosphere responsive to initial squeeze of the bag whereby continued squeeze thereon causes the full volume of gas contained in the bag to move to the patient, said pressure-responsive valve means comprising a cylindrical valve body, a piston valve mounted to reciprocate therein, the valve body and piston valve having passages adapted in a first position of said piston valve to establish communication between the gas-flow circuit and atmosphere, spring means reactive between said valve body and piston valve for normally maintaining said valve in said first position, and said piston valve having a face portion subject to the pressure within the gas-flow circuit and of sufficient area such that a slight increase of pressure within the gas circuit resulting from initial squeeze on the bag causes said piston valve automatically to move to a second position within the valve body in which is closes off communication between the gas-flow circuit and atmosphere as aforesaid.

3. In a semi-closed, partial rebreathing type anesthesia machine, the combination of a patient's breathing mask, a gas-flow circuit extend from and leading to the mask, exhalation and inhalation valves connected at spaced intervals in said circuit, means for maintaining a continuous flow of gas at anesthetic concentration in the circuit, a squeeze-type flexible reservoir means connected in said circuit and adapted when squeezed to pump gas in the circuit to the patient via the mask, and normally open, pressure-responsive valve means connected in the circuit intermediate said exhalation and inhalation valves for normally bleeding off any excess flow of gas in the circuit to atmosphere but being operative automatically to close off the circuit to atmosphere and thereupon supply a predetermined volume of the gas to the patient via the mask upon initial squeeze applied to said flexible reservoir means, said pressure-responsive valve means comprising a valve element, biasing means normally biasing said valve element to circuit-open position, and pressure-responsive means operative upon a slight increase of pressure within the circuit resulting from initial squeeze on the reservoir means to effect automatic movement of said valve element to circuit-closing position.

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