Breathing circuit for use in supplying gas under pressure to the airway of a patient having a control with an inspiratory and expiratory phase for controlling the supply of gas. Means is provided for supplying the gas to the patient to ventilate the patient. An exhalation valve which is controlled by the controller controls the flow of expiratory gases from the patient. Manual means is provided for ventilating the patient in the event of failure of the controller. A first valve assembly having an inspiratory one-way valve and an expiratory one-way valve is provided for maintaining the inspiratory and expiratory gases separate. The first valve assembly is coupled to a second valve assembly which is coupled to the exhalation valve assembly. A resuscitation bulb is coupled to the second valve assembly and is utilized for supplying gas under pressure through the second valve assembly and through the inspiratory one-way check valve to the airway of the patient.

10 Claims, 6 Drawing Figures
FAIL-SAFE BREATHING CIRCUIT AND VALVE ASSEMBLY FOR USE THEREWITH

BACKGROUND OF THE INVENTION

Respirators and ventilators of many types have heretofore been provided which are of the automatic type. In the past in case of failure of such respirators or ventilators, it has been necessary to completely disconnect such a respirator or ventilator from the patient and to utilize other means such as a manual resuscitator on the patient. This has resulted in considerable delay in ventilation of the patient which can cause great danger to the patient particularly if he is under intensive care. There is, therefore, a need for a new and improved respiratory apparatus which overcomes this objection.

SUMMARY OF THE INVENTION AND OBJECTS

The breathing circuit of the present invention is for use in supplying gas under pressure to the airway of a patient. A controller having an inspiratory and expiratory phase in its operative cycle is provided for cyclically applying gas under pressure. A first valve assembly is also provided which has a body having a chamber therein. The body is formed with first, second and third passages therein in communication with said chamber. A one-way expiratory check valve is mounted in said first passage and only permits gas to flow into said chamber. A one-way inspiratory check valve is mounted in the third passage and only permits gas to flow out of said chamber. A second valve assembly is provided which comprises a body. A diaphragm assembly is disposed in the body of the second valve assembly and forms first and second chambers within the body of the second valve assembly on opposite sides of the diaphragm assembly. The body of the second valve assembly is formed with first and second passages in communication with said first chamber and a third passage in communication with said second chamber. The diaphragm assembly is movable to occlude said first passage in said body of said second valve assembly. The diaphragm assembly carries one-way valve means which permits gas to flow only from said second chamber to said first chamber. The body of the second valve assembly carries one-way valve means which permits gas outside the body of the second valve assembly to flow into the second chamber. A compression bulb is coupled to the third passage of the second valve assembly. An exhalation valve assembly is provided and comprises a body having first and second flow passages therein in communication with each other. The second passage is open to ambient. A valve member is mounted in the body of the exhalation valve assembly. Means is provided in the body of the exhalation valve assembly for yieldably urging the valve member into a position to occlude said first passage in said body of the exhalation valve assembly. Means is provided for coupling the first passage of the second valve assembly to the first passage of the exhalation valve assembly. Means is also provided for coupling the second passage of the second valve assembly to the second passage of the first valve assembly. A patient adapter is provided which is adapted to be connected to the airway of a patient. Means is provided for coupling the gas supplied by the controller to the patient adapter and to the third passage of said first valve assembly. Means is also provided for coupling the patient adapter to the first passage of the first valve assembly. When desired, means is provided for supplying a jet of gas during the expiratory phase of the controller in the expiratory flow passage to create a sub-ambient condition in the expiratory flow passage. In general, it is an object of the present invention to provide a breathing circuit which is fail-safe. Another object of the invention is to provide a breathing circuit of the above character which can be manually overridden to continue ventilation of the patient in the event of failure of the automatic controller. Another object of the invention is to provide a breathing circuit of the above character which does not require any switching to transfer from automatic to manual operation. Another object of the invention is to provide a breathing circuit of the above character which permits the operator to monitor the resistance of the patient's lungs. Another object of the invention is to provide a breathing circuit of the above character in which the inspiratory phase can be aided. Another object of the invention is to provide a breathing circuit of the above character which utilizes a particularly novel overriding safety valve. Another object of the invention is to provide a safety valve assembly which can be utilized in conjunction with a breathing circuit to permit manual override in the event of failure of the automatic controller. Another object of the invention is to provide a valve assembly of the above character which does not develop undesirable flutter during operation in a breathing circuit. Additional objects and features of the invention will appear from the following description in which the preferred embodiments are set forth in detail in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a partial plan view disclosing a breathing circuit incorporating the present invention.

FIG. 2 is an enlarged cross-sectional view of the overriding safety valve assembly utilized in the breathing circuit shown in FIG. 1.

FIG. 3 is a cross-sectional view taken along the line 3-3 of FIG. 2.

FIG. 4 is a greatly enlarged portion of one of the one-way check valves of the safety valve assembly shown in FIG. 2.

FIG. 5 is an enlarged cross-sectional view of the non-rebreathing valve assembly utilized in the breathing circuit shown in FIG. 1.

FIG. 6 is an enlarged cross-sectional view of the exhalation valve assembly utilized in the breathing circuit shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A fail-safe breathing circuit incorporating the present invention is shown in FIG. 1. As shown therein, it consists of a conventional stand, only a part of which is shown. Such a stand includes a vertical tube or pipe through which a gas such as oxygen is supplied and which is to be utilized in the fail-safe breathing circuit. The pipe is provided with a gooseneck and is directly connected by a fitting to a controller. If desired, before the gas is supplied to the controller, it can be passed through a blender (not shown) of the
type described in copending application Ser. No. 54,934, filed Mar. 23, 1970.

The controller 14 is of a conventional type supplied under the designation of "MARK 8" by Bird Corporation of Palm Springs, Calif. This controller is also described in U.S. Pat. No. 3,191,596. As described therein, the controller has an inhalation phase and an exhalation phase in its operative cycle. The controller has an inlet which is adapted to be connected to a source of gas under pressure. The controller is provided with an outlet 16 which, as hereinafter described, is adapted to be connected to the airway of a patient. The controller includes a main control valve in the controller which is movable between open and closed positions to control the flow of gas from the inlet to the outlet. The controller also includes means for operating the main control valve so that the main control valve is in an open position during the inhalation phase and in a closed position during the exhalation phase. This means includes means for sensing when a predetermined pressure is reached in the outlet for shifting the main control valve from an open position to a closed position. Thus, it can be seen that the controller 14 supplies gas under pressure at the outlet 16 during the inspiratory phase. The length of the inspiratory phase and the expiratory phase can be readily controlled by adjusting appropriate controls on the controller 14.

The controller 14 is also provided with an outlet 18 which is supplied with gas under positive pressure when the main control valve in the controller is in the open position or, in other words, the controller is in the inspiratory phase. The controller is also provided with an additional outlet 19 which is supplied with gas under positive pressure when the main control valve is in a closed position or, in other words, when the controller is in the expiratory phase.

A fitting 21 is removably mounted in the large outlet 16 and has a large flexible plastic tube 22 connected thereto. The other end of the tube 22 is connected to another fitting 23 mounted on one leg of a tee 24. Another leg of the tee 24 is mounted upon the inlet of a large nebulizer 27 which is utilized for humidifying the gas that is supplied to it. The nebulizer is of the type described in U.S. Pat. No. 3,353,536. The nebulizer 27 is provided with an outlet 28 which has one leg of another tee 29 mounted therein. A fitting 31 is mounted within another leg of the tee 29 and has connected thereto a large flexible plastic tube 32 which has its other end connected to a bifurcated patient wye or adapter 33. The patient wye is adapted to be connected to the airway of the patient in a suitable manner such as by means of a face mask, an endotracheal tube and the like.

In the event that it is desired to supply medication to the air or gas which is being delivered to the patient, an additional nebulizer 36 is mounted on the other leg of the tee 29. The nebulizer 36 is of a type which is described in U.S. Pat. No. 3,172,402.

Gas under positive pressure is supplied to the nebulizer 27 to nebulize the liquid contained therein by connecting a flexible tube 37 to the outlet 18 and to a fitting 38 provided on the nebulizer 27. Alternatively, or in addition, the same tube 37 can be connected to the nebulizer 36 for nebulizing the liquid which is carried by the nebulizer 36.

The gas that is properly humidified and supplied with the desired medicine is supplied to the patient through the wye 33. Expiratory gases from the patient pass into the large tube 41 connected to the wye. The tube 41 is secured to a fitting 42 which is mounted in a check valve assembly 43 of a valve assembly 45. The check valve assembly 43 is mounted on one of the legs of a tee 44 which forms part of the valve assembly 45. The tee 44 forms a body having a chamber 37 therein and first, second and third flow passages 38, 39 and 40 therein, respectively, which are in communication with the chamber 37. The other leg of the tee 44 immediately opposite the leg on which the check valve assembly 43 is mounted has another check valve assembly 46 mounted thereon. The check valve assembly 46 is also connected to one of the legs of the tee 24. The leg of the tee 44 at right angles to the other legs of the tee 44 is mounted in a coupling 48. The coupling 48 is mounted upon a non-rebreathing valve assembly 51. A sleeve 52 is mounted in the valve assembly 51 and is connected to an exhalation valve assembly 55. A compression bulb or bag 56 is also mounted on the non-rebreathing valve assembly 51. A fitting 57 is mounted in the exhalation valve assembly 53 and is connected by a tube 58 to the fitting 38 of the nebulizer 27. A fitting 59 is mounted in the tee 44 and is connected by a tube 61 to the outlet 19 of the controller 14.

The construction of the two check valve assemblies 43 and 46 and the tee 44 is shown in detail in FIG. 2. As shown therein, the tee 44 is provided with a nozzle 66 which is provided equi-distant between the ends of the opposite legs. The nozzle 66 has a port 67 which is in communication with a passage 68 provided in the nozzle and which is adapted to receive the fitting 59 hereinbefore described. The nozzle 66 is in axial alignment with a venturi-like passage 71 provided in the other leg of the tee 44. The passage 71 opens into the passage 40 which is adapted to receive a coupling if so desired.

The check valve assembly 43 is shown in detail in FIGS. 3 and 4. As shown therein, it consists of a pair of rings 76 and 77 formed out of a suitable material such as plastic. The ring 76 is provided with an annular inclined surface 78 which is inclined at a suitable angle such as 45° which is adapted to cooperate with a similar surface 79 provided on the ring 77. It is also inclined at a suitable angle as, for example, 45°. The ring 77 is also provided with an additional annular surface 81 which is adapted to serve as a valve seat. The ring 76 is provided with a circular opening 82 which is substantially larger than the opening 83 provided in the ring 77. A valve member 84 is provided which is yieldably urged into engagement with the valve seat 81. The valve member 84 is formed in a particular manner as hereinafter described to provide a screw which engages the valve member 84 in a closed position. Thus, for the valve member, a fairly low durometer or fairly soft elastomer is chosen. The elastomer is formed into a circular disc 86 having a thickness of approximately one-sixteenth of an inch. The valve member 84 is then formed in the partial shape of a circular disc 86 by cutting an arcuate slit 87 in the disc which extends through an angle greater than 270° and preferably as much as 315° as shown in FIG. 3. This leaves the central portion of the disc 86 as a flapper valve member 84. The disc 86 is then placed between the two rings 76 and 77 so that the outer margin of the disc is engaged by the inclined surfaces 78 and 79. The rings 76 and 77 are pressed together which serves to compress the outer
margin of the disc and in particular to compress the disc at the hinge portion 86a which urges the outer extremity of the valve member 84 downwardly to preload the same against the seat 81. After the desired amount of preload has been obtained, the rings 76 and 77 are cemented in place and are held in place on one end of the tee 44 by adaptor sleeve 91 which is secured to the tee 44. The sleeve 91 is provided with a shoulder 92 that engages the outer ring 77 and serves to hold rings 76 and 77 in place so that they firmly clamp the disc 86 to apply the desired amount of preloading to the valve member 84.

The check valve assembly 46 is constructed in a similar manner although it is yieldably urged towards a closed position in a direction opposite that for the check valve assembly 43. For that reason, it will not be described in detail.

It has been found that by constructing the check valve assembly in this manner, it is possible to preload the valve members so that they will remain closed while opening very easily. The preloading is sufficient to minimize any tendency to flutter during physiological flow of gas through the breathing circuit. Expiratory resistance provided by such a check valve assembly has been minimized. An elastomer force acts upon the hinge of the valve member to provide the desired amount of resistance to opening.

The compression bulb 56 is in the form of a flexible reservoir. It is formed by a balloon type bag formed of a suitable material such as molded rubber or plastic. It is important that the bag have a good memory, that is, that it will recoil to its original shape after it has been squeezed or collapsed.

The non-rebreathing valve assembly 51 which is used as a part of the breathing circuit shown in Fig. 1 is shown in detail in Fig. 5. It is also described in copending application Ser. No. 183,823, filed Sept. 21, 1972. As shown therein, it consists of a body 112. A diaphragm assembly 113 is mounted within the body and forms chambers 114 and 116 on opposite sides of the diaphragm assembly within the body. As shown, the body 112 can be formed in two parts which can be identified as first and second parts or top and bottom parts 117 and 118. Both of the parts are cylindrical and generally cup-shaped. Thus, the first part 117 is provided with a planar circular wall 121 which has formed integral therewith a depending internally threaded side wall 122. A cylinder 123 is formed integral with the wall 121 and extends vertically or outwardly therefrom at right angles. A smaller tube or cylinder 124 is provided within the cylinder 123 and is supported by an annular rib 126 which is formed integral with the cylinder 123 and the cylinder 124. The cylinder or tube 124 is provided with a flow passage 127 which opens to atmosphere or ambient and which is in communication with the first chamber 114 to provide an expiratory port as hereinafter described. The lower extremity of the tube 124 forms a valve seat adapted to be engaged by the diaphragm assembly 113 to close the expiratory port.

The first part is also provided with a cylindrical extension 128 formed integral with the cylindrical extension 123 and extending at right angles thereto. This cylindrical extension is provided with a flow passage 129 which is adapted to be placed in communication with the airway of the patient as hereinafter described. The passage 129 is in communication with an annular passage 131 which is formed between the outer surface of the inner cylinder 124 and the inner surface of the outer cylinder 123 below the rib 126. This annular passage 131, as can be seen from the drawing, is in communication with the chamber 114 on one side of the diaphragm assembly 113.

The second part 118 is also provided with a circular planar wall 136 and an upstanding externally threaded circular side wall 137 which is formed integral with the wall 136. The second part is formed with a cylindrical extension 138 which extends at right angles or vertically from the planar circular wall 136. The cylindrical extension 138 is provided with a flow passage 139 which can be considered to be an inlet passage that is in communication with the chamber 116 formed on the other side of the diaphragm assembly 113. A plurality of holes or openings 141 are formed in the wall 136 between the side wall 137 and the cylindrical extension 138. The holes or openings 141 are equally spaced in a circle around the cylindrical extension 138 in communication with the chamber 116 on the other side. One-way valve means is provided for closing the holes or openings 141 and consists of an annular resilient member 142 formed of a suitable material such as rubber. The resilient member 142 is carried by the second part and has its inner margin seated in an annular recess 143 provided in the second part 118. The outer annular margin of the resilient member 142 is free so that it can act as a one-way flapper valve for normally occluding the holes or openings 141 and so that gases can only pass one way through the openings 141, that is from ambient into the chamber 116.

The diaphragm assembly 113 consists of a diaphragm 146 formed of a suitable material such as Silastic. The diaphragm 146 is provided with an annular lip portion 146a which is adapted to be clamped between the first and second parts 117 and 118. Cooperative means is provided for fastening together the first and second parts to form a unitary assembly and consists of threading the two parts together as shown in Fig. 2. The diaphragm 146 is provided with an annular downwardly extending convolution 146b to impart a memory to the diaphragm so that it will hold itself in a predetermined position within the body 112. The diaphragm 146 is reinforced by suitable means such as by bonding to a rigid circular plate or disc 147. The disc 147 is formed of a suitable material such as metal.

The inner or central portion of the diaphragm assembly 113 is adapted to be engaged by the innermost or lowermost extremity of the cylinder 124 provided in the first part. The central portion 146c of the diaphragm 146 underlies the passage 127 in the cylinder 124. A plurality of holes or openings 148 in the diaphragm are spaced in a circle around the central portion 146c outside the cylinder 124 and inside the convoluted portion 146b. Holes or openings 150 are provided in the plate 147 in registration with the holes 148 and establish communication between the chambers 114 and 116. One-way valve means is provided for occluding the holes or openings 150 and consists of a circular flapper valve member 149 formed of a suitable material such as Silastic which covers the top of the plate 147. Suitable means is provided for securing the central portion of the flapper valve member 149 to the inner portion of the diaphragm 146 and to the disc 147 and consists of a tit 151 formed integral with the flap-
per valve member 149 and which extends through holes 152 and 153 provided in the disc 147 and the diaphragm 146. As shown in the drawing, the tit 151 is provided with an enlarged portion 151a so that when the tit 151 is in place, the enlarged portion 151a is on the other side of the diaphragm 146 and will retain the valve member 149. Thus, it can be seen that the flapper valve member 149 only permits gases to flow in one direction through the diaphragm assembly 113, namely in an upward direction as viewed in FIG. 5. The flapper valve 149 in conjunction with the holes or openings 148 and 150 forms a multi-orificed directional flapper valve which is used as hereinafter described.

The exhalation valve 53 is generally of the type disclosed in copending application Ser. No. 62,343, filed Aug. 10, 1970. It consists of a body 191 (see FIG. 6) which is provided with an inlet passageway 192 that is in communication with an outlet passage 193 at right angles to the inlet passageway 192. A mushroom-shaped valve member 194 is adapted to seat against the valve seat 196 to interrupt the communication between the passages 192 and 193. The valve member 194 is yieldably urged into engagement with the valve seat 196 by a spring 197 mounted concentrically on a sleeve 198 formed integral with the valve member 194. The other end of the spring 197 is mounted in a well 199 formed within a valve guide member 201 disposed within the body 191. The valve member 201 is provided with a cylindrical portion 201a which is provided with spaced ribs 202 extending axially thereof and with an annular skirt-like portion 201b. A guide stem 203 is slidable mounted in the sleeve 198 and is mounted in a diaphragm 204. The outer annular margin of the diaphragm 204 is clamped to the body by a cap 206 which is threaded into the body 191. A chamber 207 is formed between the cap 206 and the diaphragm 204 and is in communication with a passage 208 in the cap 206. The passage 208 has fitting 57 mounted therein. The inlet 192 of the exhalation valve has the sleeve 52 mounted therein. The outlet passage 193 is open to atmosphere or ambient as shown.

Operation of the fail-safe breathing circuit may now be briefly described as follows. Let it be assumed that the bifurcated patient adapter wye 33 has been connected to the patient in a suitable manner and that the controller 14 has been adjusted to provide the desired length of time for the inspiratory phase and the desired length of time for the expiratory phase. The gas to be supplied to the patient flows from the pipe 12 through the controller 14 and out the main outlet 16 through the large tube 22 to the tee 24. This gas is prevented from entering the tee 44 because of the check valve assembly 46. As can be seen from FIG. 2, the check valve member 84 only opens in an opposite direction and, therefore, prevents gas from passing downwardly into the tee 44. Thus, the gas which is supplied by the controller 14 passes into the nebulizer 27 where water is vaporized so that the gas is humidified. The nebulizer operates because of the positive pressure supplied on the tube 37 from the outlet 18. As also explained previously, suitably medicinal preparations may also be supplied to the gas by the nebulizer 36. Thus, the gas, after it has been humidified and the proper medicinal preparation broken up in suspended particles and placed in the gas, is supplied to the large tube 32 to the patient wye 33 and thence to the proximal airway of the patient. The lungs of the patient are inflated during the inspiratory phase.

The application of gas pressure through tube 58 to the exhalation valve assembly 53 keeps the exhalation valve closed during inspiratory phase to prevent venting of inspiratory gases to the atmosphere.

Upon termination of the inspiratory phase by the controller 14, gas under pressure is no longer supplied through the outlets 16 and 18. The expiratory phase begins and the gas in the lungs is expelled by the patient during the expiratory phase through the patient wye 33 and through the large tube 41. The expiratory gases pass upwardly through the check valve assembly 43 opening the one-way flapper valve member 84 and thence passing into the tee 44 through the passage 71 through the sleeve 48 and into the passage 129 of the non-rebreathing valve assembly 51. The expiratory gases then pass into the annular passage 131 into the chamber 114 to move the diaphragm assembly 113 downwradly so that the chamber 114 is vented through the passage 127 to the exhalation valve assembly 53. The valve member 194 of the exhalation valve assembly is moved upwardly against the yieldable force of the spring 197 to thereby vent the passage to atmosphere through the passage 193 in the exhalation valve assembly.

The valve member 194 is permitted to move to the open position because gas pressure is no longer supplied to the tube 58 to apply a pressure to the top of the diaphragm 204 which would keep the valve member 194 in a closed position. The application of gas pressure to the line 58 ceases as soon as the controller 14 terminates the inspiratory phase. Thus, it can be seen that during the inspiratory phase, the positive pressure applied to the tube 37 retains the mechanical exhalation valve 53 in a closed position.

The gas pressure supplied by the outlet 19 by the controller 14 is controlled so that the gas in line 61 is supplied at the very end of the end of the expiratory phase. This introduces a jet of gas under pressure through the port 67 of the nozzle 66 which is directed into the venturi-like passageway 71. This jet serves to entrain gases within the tee 44 and to create a subambient pressure within the tee which serves to hold the upper or inspiratory valve member 84 of the check valve assembly 46 in a more tightly closed position while opening farther the lower or expiratory valve member 84 of the check valve assembly 43. This subambient pressure is thus transferred to the airway of the patient to overcome expiratory resistance in the lungs of the patient. The directional flow introduced by pressurized jet 67 and the added gas therefrom further urges valves 51 and 53 open, effectively reducing resistance of the non-rebreathing assembly 51 and the exhalation valve assembly 53 to the expiratory flow to zero.

Thus, it can be seen that a complete breathing circuit or circuit has been provided in which the one-way check valve assembly 43 acts as an expiratory valve component. It permits expiratory gas to flow up through the same and thence through the non-rebreathing valve assembly 51 and through the exhalation valve assembly 53.

Now let it be assumed that the controller 14 has failed for some reason and that it is desired to continue to supply gases to the patient being treated. This can be accomplished immediately by merely compressing the
The compression bulb supplies gases under pressure to the inlet 139 which moves the diaphragm assembly 113 upwardly to close the expiratory port formed by the passage 124. The gas under pressure enters the holes 148 and 150 and moves the outer margin of the flapper valve 149 upwardly to permit the gases to enter the chamber 114 and thence through the annular passage 131 into the passage 129. These gases then pass through the sleeve 48 and into the tee 44. These gases cannot move downwardly through the check valve assembly 43 because the check valve member 84 can only move in an upward direction. Therefore, the gases move upwardly through the check valve assembly 46 by moving the yieldable check valve member 84 upwardly to permit the gases to flow into the tee 24 and thence through the nebulizer 27. The gases then are supplied to the tube 32 to the patient's wye 33 and to the proximal airway of the patient.

As soon as the lungs of the patient have been filled, the compression bulb 56 is released which creates a sub-ambient pressure below the diaphragm assembly 113 permitting the diaphragm assembly 113 to move downwardly. The expiratory gases from the lungs of the patient again pass through the tube 41 upwardly through the expiratory valve 43 through the sleeve 48 to the non-rebreathing valve assembly 51 through the passage 129, thence through the annular passage 131 into chamber 114 which also helps to push the diaphragm assembly 113 downwardly to permit the expiratory gases to pass into the passage 127 and then through the exhalation valve assembly 53 to the atmosphere. When the compression bulb 56 is released, a sub-ambient pressure is created in the chamber 116 which causes the check valve member 142 to raise to permit air to enter through the openings 141 to pass into the compression bulb 56 until it is filled and the pressure in the chamber 116 reaches ambient.

As soon as the compression bulb 56 is filled, the inspiratory phase can again be commenced by compression of the compression bulb 56 to cause inspiratory gases to flow in the manner hereinbefore described to fill the lungs of the patient.

It can be seen from the foregoing that there has been provided means for providing continuing ventilation to the patient should the controller 14 fail. The controller 14 can be considered to be a mechanical ventilator. Upon failure of the mechanical ventilator, a dynamic airway to the patient is immediately established in the manner hereinbefore described and the inspiratory and expiratory phases can be controlled merely by operation of the compression bulb 56 by the operator.

In the foregoing operation, it should be noted that the check valve assembly 46 serves as an inspiratory valve and is only utilized during manual ventilation of the patient by use of the compression bulb 56. During automatic operation and control of the controller 14, the one-way check valve assembly 46 remains closed. The tee 44 with its check valve assemblies 43 and 46 serves as an overriding safety valve assembly.

The compression bulb 56 also makes it possible to sigh the patient being ventilated. The sigh is equivalent to a deep breath. This is accomplished by the operator merely squeezing the compression bulb during the inspiratory phase of the controller 14 to supply additional gas under pressure to the lungs of the patient through the path hereinbefore described. This is often done by providing three of such deep sighs by squeezing the compression bulb 56 during three successive inspiratory phases of the controller 14 to thereby stretch the lungs of the patient three successive times approximately every 7 minutes. This stretches the lungs of the patient and makes them stay more compliant so that they can be more readily ventilated by the breathing circle which includes the controller 14. An operator such as an anesthetist can by the feel of the compression bulb 56 used for inflating the lungs ascertain the resistance of the patient's lungs to the inflation with a greater tidal volume. This gives certain information to the operator as to the condition of the lungs of the patient.

Thus, it can be seen that the breathing circle or circuit which has been provided is fail-safe; that is, if the controller 14 should malfunction, the breathing circuit is such that ventilation for the patient can be immediately continued merely by operation of the compression bulb 56 by the operator. There is no need to make any changes in the breathing circuit and, therefore, a minimum of time is lost.

It should be pointed out that the breathing circuit will operate satisfactorily without the need of establishing a sub-ambient pressure within the tee 44. When this is the case, the tube 61 can be eliminated. The passage 68 in the tee 44 can be plugged.

We claim:

1. In a breathing circuit for use in supplying gas under pressure to the airway of a patient, a first valve assembly comprising a body having a chamber therein, said body being formed to provide first, second and third flow passages in communication with said chamber, a one-way check valve mounted in said first passage and permitting gas to flow only into said chamber, and a one-way check valve mounted in said third passage and permitting gas to flow only out of said chamber, a second valve assembly comprising a body, a diaphragm assembly disposed in the body of said second valve assembly and forming first and second chambers within the body of the second valve assembly on opposite sides of the diaphragm assembly, said body of said second valve assembly being formed with first and second passages in communication with said first chamber and a third passage in communication with said second chamber, said diaphragm assembly being movable to occlude said first passage in said body of said second valve assembly, said diaphragm assembly carrying one-way valve means permitting gas to flow only from said second chamber to said first chamber, said body of said second valve assembly carrying one-way valve means permitting gas outside of the body of the second valve assembly to flow into said second chamber, a compression bulb coupled to said third passage of said second valve assembly, an exhalation valve assembly comprising a body, said body of said exhalation valve assembly having first and second flow passages formed therein in communication with each other, said second passage being open to ambient, a valve member mounted in said body of the exhalation valve assembly, means in the body of the exhalation valve assembly for yieldably urging the valve member into a position to occlude said first passage, means coupling the first passage of the exhalation valve assembly to the first passage of the second valve assembly, means coupling the second passage of the second valve assembly to the second passage of the first valve assembly, a patient adapter
adapted to be connected to the airway of a patient, means coupling said supply of gas under pressure to the patient adapter and to said third passage of said first valve assembly, means coupling the patient adapter to the first passage of said first valve assembly, and an automatically operated controller for controlling the flow of gas from said source and having an inspiratory phase and an expiratory phase in its operative cycle.

2. A circuit as in claim 1 wherein said controller includes means for retaining the valve member of the exhalation valve assembly in a closed position during the inspiratory phase of the controller.

3. A breathing circuit as in claim 2 wherein said means for maintaining said exhalation valve in said exhalation valve assembly in a closed position includes a controller having means for supplying a gas under positive pressure and means for supplying said gas under positive pressure to said valve member of said exhalation valve assembly to maintain said valve member in a closed position during the inspiratory phase of the controller.

4. A circuit as in claim 1 wherein said controller includes means for supplying a gas under positive pressure during the expiratory phase and means for supplying said gas under positive pressure during the expiratory phase into said breathing circuit in a region which is downstream of the one-way valve in the first passage of said first valve assembly to establish a sub-ambient condition in said first flow passage.

5. A breathing circuit as in claim 1 wherein a nozzle is provided in said body of said first valve assembly which is in general axial alignment with the second flow passage in said first valve assembly and means controlled by the controller for supplying gas under pressure to said nozzle during the expiratory phase of the controller.

6. A circuit as in claim 1 together with nebulizing means mounted on the means for coupling the supply of gas under pressure to the patient adapter.

7. A circuit as in claim 1 wherein said body of said first valve assembly is in the form of a tee.

8. A circuit as in claim 1 wherein one-way check valves in said first valve assembly are in the form of yieldable flapper type members.

9. A circuit as in claim 8 wherein said check valves in said first valve assembly are formed so that said flapper valves are yieldably urged towards a closed position.

10. A circuit as in claim 1 wherein each of said one-way check valves comprises first and second rings, a member formed of an elastomer disposed between said first and second rings, an arcuate slot formed in said member and subtending over 270° to provide a hinged flapper type valve member disposed within said rings, one of said rings being provided with a valve seat, said first and second rings being formed with inclined surfaces engaging opposite sides of the member and serving to apply a bias to the flapper valve member so that it is yieldably urged into engagement with the valve seat.