United States Patent [19]

Bird et al.

[54] NON-REBREATHING VALVE ASSEMBLY AND COMPRESSION BULB RESUSCITATOR USING SAME

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- [51]
 Int. Cl.
 A62b 7/00

 [58]
 Field of Search
 128/142.2, 145.5–145.8

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Primary Examiner—Lawrence W. Trapp Attorney—Harold C. Hohbach et al.

[57] ABSTRACT

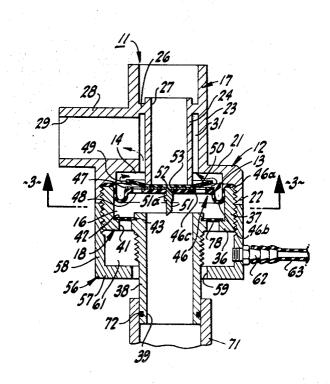
A non-rebreathing valve assembly having a body

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formed of first and second parts with a circular diaphragm assembly disposed between the parts. The diaphragm assembly has a flexible circular diaphragm having its outer margin secured to the first and second parts. The diaphragm is provided with a plurality of holes spaced between the inner portion and the outer margin of the diaphragm which are normally closed by a one-way flapper valve member carried by the diaphragm assembly. The first part is provided with a centrally disposed exhaust opening which is adapted to be closed by the diaphragm assembly. The first part is also provided with a flow passage adapted to be placed in communication with a patient and with said holes in said diaphragm when said flapper valve is in open position. The second part has an inlet opening which is in communication with the other side of the diaphragm assembly. The second part if provided with a plurality of openings which open to ambient. A oneway flapper valve is carried by the second part and normally closes the openings. When utilized as a resuscitator, a compression bulb is secured to the inlet of the second part. For automatic operation, the inlet, in addition, is secured to a source of gas under pressure which is controlled by a controller.

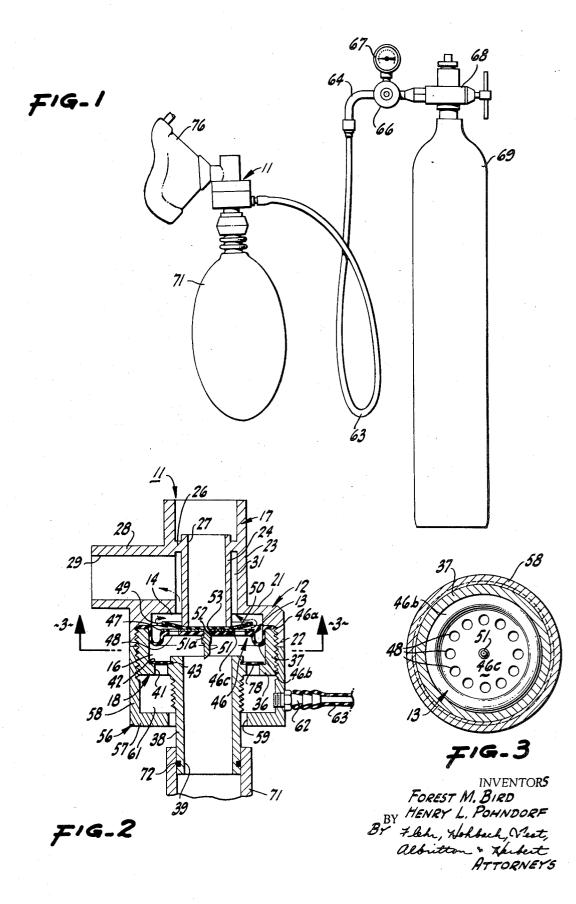
25 Claims, 10 Drawing Figures



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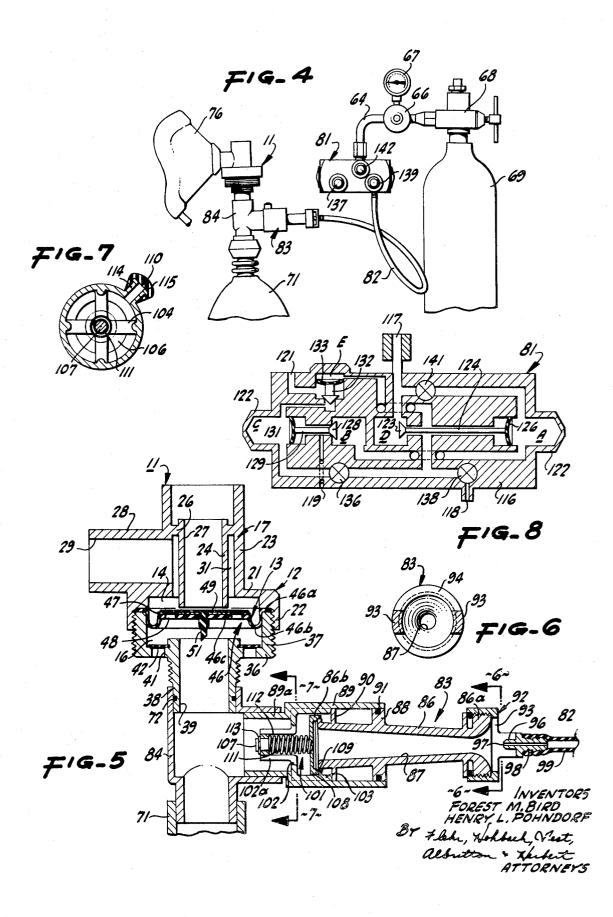
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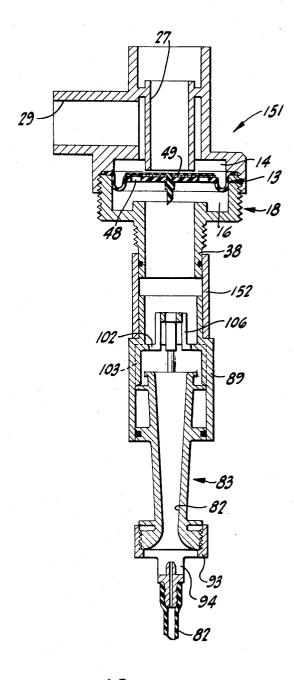
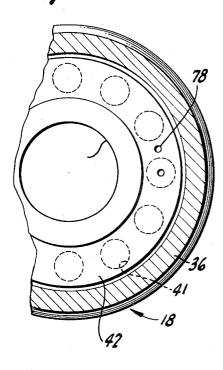


FIG-9



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NON-REBREATHING VALVE ASSEMBLY AND COMPRESSION BULB RESUSCITATOR USING SAME

BACKGROUND OF THE INVENTION

Valves for use with resuscitators have heretofore been provided. However, they have had a number of disadvantages. For example, there has been a tendency to rebreathe some of the exhaled gases. There is, therefore, a need for a new and improved valve assembly which eliminates such rebreathing and one which can be readily used with resuscitators. FIG. 2 is a rebreathing valv shown in FIG. 1. FIG. 3 is a cro 3-3 of FIG. 2.

SUMMARY OF THE INVENTION AND OBJECTS

The non-rebreathing valve assembly consists of a 15 body and a diaphragm assembly mounted in the body with an air-tight seal formed between the outer annular margin of the diaphragm assembly and the body so that chambers are provided on opposite sides of the 20 diaphragm assembly. The portion of the body on one side of the diaphragm is provided with first and second outlet ports. The first port is in communication with the chamber on one side of the body and is adapted to be placed in communication with the patient. The second 25 port is adapted to be occluded by the central portion of the diaphragm assembly. A plurality of openings are provided in the diaphragm between the outer margin and outside the central portion engaging said second port. One-way valve means is provided for closing these 30 openings. The portion of the body on the other side of the diaphragm is provided with an inlet port which is in communication with the chamber on the other side of the diaphragm. The other part of the body is also provided with a plurality of holes in communication with 35 ambient and also with said chamber. One-way valve means is carried by the body and normally occludes said holes or openings in said body. The compression bulb is adapted to be mounted on the inlet port of said other portion of the body. In addition, when automatic 40 operation is desired, a controlled source of gas under pressure is also supplied to the inlet port.

In general, it is an object of the present invention to provide a non-rebreathing valve assembly which can be utilized for ventilating patients without any substantial rebreathing of exhaled gases.

Another object of the invention is to provide a valve assembly of the above character which can be utilized in conjunction with a compression bulb to provide either a manual or automatic resuscitator.

Another object of the invention is to provide a valve assembly of the above character which always allows manual ventilation of the lung of the patient.

Another object of the invention is to provide a valve assembly of the above character which has one-way 55 ambient air entrainment.

Another object of the invention is to provide a valve assembly of the above character in which the valve members in both the inspiratory and expiratory valves are preloaded toward the desired positions to minimize flutter tendencies.

Another object of the invention is to provide a valve assembly of the above character which is particularly adapted for use with resuscitators.

Additional objects and features of the invention will 65 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 side elevational view of a manual compression bulb resuscitator incorporating the present invention and also in particular incorporating a nonrebreathing valve assembly incorporating the present invention.

FIG. 2 is a cross-sectional view of the nonrebreathing valve assembly utilized in the resuscitator shown in FIG. 1.

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

FIG. 4 is a side elevational view of an automatic resuscitator incorporating the present invention.

FIG. 5 is a cross-sectional view of the nonrebreathing valve assembly and the venturi assembly used in the resuscitator shown in FIG. 4.

FIG. 6 is a cross-sectional view taken along the line 6-6 of FIG. 5.

FIG. 7 is a cross-sectional view taken along the line 7-7 of FIG. 5.

FIG. 8 is a schematic illustration showing the manner in which the MARK 2 controller operates.

FIG. 9 is a partial cross-sectional view showing an alternative embodiment of the non-rebreathing valve assembly.

FIG. 10 is a cross sectional view of the nonrebreathing valve assembly utilized in conjunction with a venturi assembly.

DESCRIPTION OF PREFERRED EMBODIMENTS

The non-rebreathing valve assembly 11 which is used as a part of the resuscitator shown in FIG. 1 is shown in detail in FIGS. 2 and 3. As shown therein, it consists of a body 12. A diaphragm assembly 13 is mounted within the body and forms chambers 14 and 16 on opposite sides of the diaphragm assembly within the body. As shown, the body 12 can be formed in two parts which can be identified as first and second parts, or top and bottom parts 17 and 18. Both of the parts are cylindrical and generally cup-shaped. Thus, the first part 17 is provided with a planar circular wall 21 which has formed integral therewith a depending internally threaded side wall 22. A cylinder 23 is formed integral 45 with the wall 21 and extends vertically or outwardly therefrom at right angles. A smaller tube or cylinder 24 is provided within the cylinder 23 and is supported by an annular rib 26 which is formed integral with the cylinder 23 and the cylinder 24. The cylinder or tube 50 24 is provided with a flow passage 27 which opens to atmosphere or ambient and which is in communication with the first chamber 14 to provide an expiratory port as hereinafter described. The lower extremity of tube 24 forms a valve seat adapted to be engaged by the diaphragm assembly 13 to close the expiratory port.

The first part is also provided with a cylindrical extension 28 formed integral with the cylindrical extension 23 and extending at right angles thereto. This cylindrical extension is provided with a flow passage 29 which is adapted to be placed in communication with the airway of the patient as hereinafter described. The passage 29 is in communication with an annular passage 31 which is formed between the outer surface of the inner cylinder 24 and the inner surface of the outer cylinder 23 below the rib 26. This annular passage 31, as can be seen from the drawing, is in communication with the chamber 14 on one side of the diaphragm assembly 13.

The second part 18 is also provided with a circular planar wall 36 and an upstanding externally threaded circular side wall 37 which is formed integral with the 5 wall 36. The second part is formed with a cylindrical extension 38 which extends at right angles or vertically from the planar circular wall 36. The cylindrical extension is provided with a flow passage 39 which can be considered to be an inlet passage that is in communica- 10 tion with the chamber 16 formed on the other side of the diaphragm assembly 13. A plurality of holes or openings 41 are formed in the wall 36 between the side wall 37 and the cylindrical extension 38. The holes or openings 41 are equally spaced in a circle around the cylindrical extension 38 and are in communication with ambient on one side and in communication with the chamber 16 on the other side. One-way valve means is provided for closing the holes or openings 41 and con- 20 sists of an annular resilient member 42 formed of a suitable material such as rubber. The resilient member 42 is carried by the second part and has its inner margin seated in an annular recess 43 provided in the second member 42 is free so that it can act as a one-way flapper valve for normally occluding the holes or openings 41 and so that gases can only pass in one way through the openings 41, that is from ambient into the chamber 16.

The diaphragm assembly 13 consists of a diaphragm 46 formed of a suitable material such as Silastic. The diaphragm is provided with an annular lip portion 46a which is adapted to be clamped between the first and second parts 17 and 18. Cooperative means is provided ³⁵ 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 46 is provided with an annular downwardly extending convolution 46b to impart a memory to the diaphragm so that it will retain itself within a predetermined position within the body 12. The diaphragm 46 is secured by suitable means such as bonding to a rigid circular plate metal.

The inner portion of the diaphragm assembly 13 is adapted to be engaged by the innermost or lowermost extremity of the cylinder 24 provided in the first part. The central portion 46c of the diaphragm 46 underlies 50 sion 28. the passage 27 in the cylinder 24. The convolution 46b is provided in the diaphragm 46 so that it will have a memory to move the diaphragm assembly 13 to a position so that it will normally clear the expiratory port formed by the cylinder 24. A plurality of holes or 55 shown in FIG. 1. Let it also be assumed that an emeropenings 48 in the diaphragm are spaced in a circle around the central portion 46c outside the cylinder 24 and inside the convoluted portion 46b. Holes or openings 50 are provided in the plate 47 in registration with the holes 48 and establish communication 60 between the chambers 14 and 16. One-way valve means is provided for occluding the holes or openings 50 and consists of a circular flapper valve member 49 formed of a suitable material such as Silastic which covers the top of the plate 47. Suitable means is provided for securing the central portion of the flapper valve member 49 to the inner portion of the diaphragm

46 and to the disc 47, and consists of a tit 51 formed integral with the flapper valve member 49 and which extends through holes 52 and 53 provided in the disc 47 and the diaphragm 46. As shown in the drawing, the tit is provided with an enlarged portion 51a so that when the tit 51 is in place, the enlarged portion 51a is on the other side of the diaphragm 46 and will retain the valve member 49. Thus, it can be seen that the flapper valve member 49 only permits gases to flow in one direction through the diaphragm assembly 13, namely in an upward direction as viewed in FIG. 2. The flapper valve 49 in conjunction with the holes or openings 48 and 50 forms a multiorificed directional flapper valve which is used as hereinafter described.

15 In the use of the non-rebreathing valve assembly in the application shown in FIG. 1, a skirt 56 is secured to the body 12 by suitable means such as by threading the same onto the second part 18. The skirt 56 is provided with a planar circular wall 57 and an upwardly extending internally threaded side wall 58 which is integral with the wall 57. A hole 59 which is centrally disposed within the wall 57 is provided to accommodate the cylindrical extension 38. It will be noted that the hole part 18. The outer annular margin of the resilient 25 59 has a size which is slightly greater than the outer circumference of the cylindrical extension 38 so that the chamber 61 within the skirt 56 is open to the atmosphere or ambient. A fitting 62 is threaded into the side wall 58 of the skirt 56 and is connected to a tube 30 63. The tube 63 is connected to a fitting 64 connected to a pressure regulator 66 that has a gauge 67 mounted thereon. The regulator 66 is mounted on a valve assembly 68 of a conventional type mounted on a bottle or tank 69. The bottle or tank 69 contains a supply of a suitable gas such as oxygen which is to be utilized in conjunction with the non-rebreathing valve 11.

A compression bulb 71 of a conventional type is secured to the tubular extension 38 as shown in FIGS. 1 and 2. An O-ring seal 72 is carried by the cylindrical ex-40 tension 38 to form an air-tight seal between the compression bulb 71 and the extension 38. The compression bulb or bag 71 can be formed of a suitable material such as molded rubber or plastic. It is important that or disc 47. The disc 47 is of a suitable material such as 45 the bag or bulb 71 have a good memory, that is, it will recover to its distended position after it has been squeezed or collapsed.

> A patient adapter of a suitable type such as a conventional face mask 76 is secured to the cylindrical exten-

Operation and use of the non-rebreathing valve assembly 11 may now be briefly described. Let it be assumed that the non-rebreathing valve assembly 11 is being utilized in a resuscitator application such as that gency situation has arisen and that it is desired to revive an unconscious patient by the use of an oxygen-enriched atmosphere. The rate of oxygen flow from the cylinder 69 is controlled by the valve assembly 68 to provide oxygen at a suitable pressure as, for example, 2,000 psi to the regulator 66 which would reduce the pressure to a suitable pressure as, for example, 50 psi. This oxygen would be bled continuously into the chamber 61 within the skirt 56. As the oxygen is bled 65 in, a certain amount of it will escape through the hole 59 to ambient during inspiration, but little, if any, during expiration.

The face mask 76 is then placed on the patient. The compression bulb 71 is then squeezed or collapsed with the mask in place to force the gases entrained within the compression bulb to pass through the inlet passage 39 into the chamber 16. The gases then pass through 5the openings 48 to raise the flapper valve member 49 and thence into chamber 14, the annular passage 31 and thence into the passage 29 and the face mask 76 to the airways and lungs of the patient. As soon as the pressure within the chamber 16 is greater than the 10chamber 14, the diaphragm assembly 13 moves upwardly so that the flapper valve member 49 moves into sealing engagement with the lower extremity of the cylinder 24 to occlude the circular expiratory port or 15 the passage 27 and to thereby prevent the gases entering the chamber 14 through the holes 48 from escaping to atmosphere through the passage 27. Contact between the lower extremity of the cylinder 24 and the central area of the flapper valve member 49 increases 20 the closing forces applied by the flapper valve member 49 to the holes 48. This rise in resistance to flow causes a sufficient ratio of pressure differential across the flapper valve member 49 during all expected physiological flow and pressure relationships to isolate inspirato- 25 ry gases. As flapper 49 seats against passage 27, the patient airway inspiratory pressure is removed from the top center of the diaphragm, leaving a greater differential force to firmly hold the expiratory valve closed and maintain integrity of inspiratory gases to be ³⁰ flows. It also serves to provide a closed, competent exdelivered to the patient.

As soon as the lungs of the patient have received the gases delivered by the compression bulb 71, the compression bulb 71 is released and because of its inherent memory, it recoils to its normal elipsoidal resting 35 geometric configuration. This provides a subambient pressure within the chamber 16 which immediately causes the higher ambient pressure in the center and peak inspiratory positive pressure on the periphery of 40 assembly 13 to move the diaphragm downwardly as viewed in FIG. 2 so that gases from the lungs of the patient in the airway may readily escape through the passage 29 and thence to the inner passage 31 to the chamber 14 and thence out the passage 27 to the at- 45 mosphere.

It can be seen that there is no opportunity for any of the exhaled gases from the lungs of the patient to pass into the chamber 16 or into the compression bulb 71 because the flapper valve member 49, as soon as the in- 50 spiratory phase has been concluded, moves downwardly to its normal position to occlude the openings 48. This is a particularly important feature because it ensures that none of the exhaled gases will be rebreathed by the patient.

During the time that the compression bulb 71 is returning to its normal elipsoidal shape, the creation of the subambient pressure within chamber 16 will cause the atmospheric pressure in the chamber 61 to open the flapper valve member 42 to permit gases in the 60chamber 61 to enter the chamber 16 and thence pass through the inlet passage 39 down into the compression bulb 71. At the same time, air from the atmosphere is being drawn in through the annular opening 59 and is being enriched by oxygen passing from the fitting 62 and then passes through the holes 41 into the compression bulb 71.

Normal phasic release of the compression bulb causes a subambient pressure within the compression bulb. This condition exists until air entrainment through the openings 41 satisfies the demand of the compression bulb and the pressures in the bulb reach ambient. During the maximum subambient phase of refilling of the bag 71, the diaphragm assembly 13 increases its opening with respect to the expiratory port 27 facilitating rapid expiratory flow from the lungs of the patient.

As soon as the compression bulb 71 has been filled with new air and the exhalation phase for the patient has been completed, the compression bulb 71 can again be compressed which again moves the diaphragm valve assembly 13 up into engagement with the lower extremity of the cylinder 24 to occlude the passage 27 and to, therefore, force the fresh gases through the openings 48 into the chamber 14 and thence into the lungs of the patient in the manner hereinbefore described. The compression bulb 71 is operated manually in the desired cyclic or phasic manner to cause inspiratory and expiratory phases to occur to provide the desired breathing pattern for the patient.

The diaphragm assembly 13 functions as a combination diaphragm and flapper valve to provide means whereby differential pressures on components of a single combined diaphragm and flapper valve serve to directionally control inspiratory and expiratory gas halation valve during inspiratory phase. As pointed out above, it prevents rebreathing of exhaled gases. It provides low resistance and permits the patient to breath spontaneously if desired. There is a fail-safe expiratory release of exhaled gases. If the operator does not squeeze bag rapidly enough, the patient can breathe atmospheric air through holes 41 and 48.

As explained previously, the operation of the diaphragm assembly is such that whenever bulb delivery pressures are greater than the patient airway pressures, venting of respiratory gases ceases. During the inspiratory phase as gases are being introduced into the lungs of the patient and as pulmonary resistances rise, the flow gradients across the flapper valve member 49 will decrease and at the same time the forces retaining the diaphragm assembly in a position to occlude the expiratory port 27 decrease to the point where pressures in the breathing circuit to the patient exceed those below the diaphragm assembly. As the patient enters the expiratory phase, the diaphragm assembly 13 moves downwardly to vent the airways of the patient to atmosphere. As the expiratory pressures continue to increase and the compression bulb is released, the 55 diaphragm assembly 13 opens still further. Thus, any build-up in expiratory positive pressure tends to open the diaphragm assembly 13 still further thereby reducing expiratory resistance. The compression bulb pressure is positive during inspiration as it is squeezed, negative or subambient during expiration as it refills, and ambient or zero in the resting state. During the subambient refill period, the negative pressure produced by the bag further results in moving diaphragm assembly 13 downward to assist in releasing expiratory gases.

A small orifice 78 through the one-way check valve 42 prevents static positive pressures from being retained within the chamber 16 which may tend to urge diaphragm assembly 13 upwards. Prolonged inspiration would be minimized by static pressure bleed-down in the event of "bag riding" by inexperienced operators or in the event of failure by an operator to completely 5 release the bag after completing inspiratory compression.

Free spontaneous breathing through the nonrebreathing valve assembly 11 is allowed with a minimum resistance and without rebreathing. The sub- 10 ambient pressure of inspiratory effort by the patient acting on the top side of the diaphragm assembly 13 causes gases from within the compression bulb and from the atmosphere through orifices 41 to move upwardly through the orifices 48. When the demand of 15 the patient during inspiration is satisfied and the patient begins to expire gases, pressure rise in the chamber 14 above the diaphragm assembly 13 causes flapper valve member 49 to close orifices 48 and forces the diaphragm assembly 13 away from the expiratory port 20 27 to vent the airways of the patient to the atmosphere.

The non-rebreathing valve assembly 11 is fail-safe. Static inspiratory forces cannot be locked within the diaphragm assembly 13. Therefore, a rise in expiratory positive pressures acting upon the top side of the diaphragm assembly increases opening forces venting the airways of the patient to ambient. As inspiratory flow produced by the compression bulb commences 30 through the holes 48 past the flapper valve member 49, the gases pass to the patient with minimal resistance.

The construction of the non-rebreathing valve assembly is also advantageous in that it is self-clearing and is very hard to obstruct. Thus, for example, if a pa- 35 tient should vomit into the face mask, it would be rather hard for the vomitus to occlude the annular passage 31 because it extends all the way around the cylinder 24. Any obstruction would have a tendency to increase the expiratory pressure which would move the 40 diaphragm assembly 13 to a greater open position to clear the valve. A screen would probably be obstructed by the particle size allowed to escape to the atmosphere by this design.

The non-rebreathing valve assembly 11, in addition 45 to being utilized in a simple manual resuscitator as shown in FIG. 1, can also be utilized without a compression bulb or a supply of gas. The simplest use for the non-rebreathing valve assembly 11 would be to take such an assembly without the skirt 56 and the 50supply of oxygen and also without the compression bulb 71. In such use, the operator would place the face mask on the patient and then would place his mouth on the cylindrical extension 38 and would blow in the same to deliver gases under pressure in the same manner as the compression bulb would deliver the same to the patient's airways. As soon as the operator inhales, the diaphragm assembly 13 would move away from the exhalation port 27 to permit the patient's lungs to ve bented to the atmosphere. At the same time, fresh gases would be introduced into the chamber 16 through the openings 41.

By the use of the non-rebreathing valve, it can be seen that there is complete separation between the $_{65}$ physiological airways of the operator and the patient. In other words, it is not necessary for the operator to breathe any of the air expelled by the patient's lungs.

Another embodiment of the non-rebreathing valve assembly and a compression bulb resuscitator utilizing the same is shown in FIGS. 4–8. As shown particularly in FIG. 4, it is very similar to the previous embodiment with the exception that it includes an automatic controller 81 which is mounted on the fitting 64. The automatic controller 81 is connected by a tube 82 to a venturi assembly 83. The venturi assembly is connected to a tee 84 which is mounted between the non-rebreathing valve assembly 11 and the compression bulb 71. The non-rebreathing valve assembly 11 is identical to that shown in FIG. 2 with the exception that the skirt 56 has been removed.

The venturi assembly 83 consists of a body 86 which is provided with a venturi-like passageway 87 extending longitudinally therethrough. The body 86 is provided with a radially extending annular flanges 88 and 90 on which there is mounted a sleeve 89. An O-ring 91 is carried by the outer periphery of the flange 88 and forms an air-tight seal between the sleeve 89 and the flange 88. The sleeve 89 is provided with a portion 89a of reduced diameter which is adapted to fit in the tee 84 as shown in FIG. 5. Thus, it can be seen that the compression bulb to act upon the bottom side of the $_{25}$ sleeve 89 serves as a means for supporting the venturi assembly on the non-rebreathing valve assembly 11.

A nozzle assembly 92 is mounted on the distral end of the body 86 and consists of a cap-like carrier or support member 93 which is removably threaded onto an enlarged portion 86a of the body 86. This carrier 93 is provided with a pair of large openings 94 on opposite sides thereof. A nozzle 96 is formed as an integral part of the carrier 93 and has a discharge port 97 which is axially aligned with the venturi passageway 87 and faces the inlet to the venturi-like passageway 87. A nipple 98 is also formed as an integral part of the carrier 93 and is formed so that a passage 99 extending therethrough opens through the port 97. One end of the tube 82 is mounted on the nipple 98.

Check valve means 101 is mounted within the sleeve 89 at the other end of the venturi-like passageway 87 and contains an end cap, cage or carrier 102. The cage **102** is formed integral with a pair of diametrically spaced ribs 103 formed integral with the sleeve 89. The carrier or cage 102 is provided with a portion 102a of reduced diameter which is carried by four equally spaced, radically extending ribs 104 (see FIG. 7) between which there are provided openings 106. A valve stem 107 is slidably mounted within the cylindrical portion 102a and carries a circular valve member 108 which is adapted to seat against an annular valve seat 109 formed on the end of the body 86. A spring 111 is coaxially mounted on the valve stem 107 and has one end engaging the valve member 108 and has the other end extending into a well 112 provided in the cylindrical portion 102a. A retaining ring 113 is snapped onto the other end of the valve stem 107 and retains the stem 107 during disassembly. It can be seen that the spring 111 serves to yieldably urge the valve 60 member 108 into sealing engagement with the outer end of the body 86 to close off the venturi-like passageway 87. The valve member 108 can be moved to an open postion against the force of the spring 111.

The controller 81 is of a conventional type and is sold under the designation "MARK 2" by Bird Corporation of Palm Springs, California. A similar controller is disclosed in U.S. Pat. No. 3,530,890 in which

the controller is formed as a plurality of separate cartridges rather than as a single body as shown in the drawing in the present invention.

A functional diagram showing the mode of operation for the controller 81 is shown in FIG. 10. As shown 5 therein, it consists of a body 116 which is provided with inlet and outlet passages 117 and 118, respectively. The body is also provided with two orifices 119 and 121 which are open to the atmosphere. The body has five chambers which have been identified with the let- 10 ters A, B, C, D and E. The chambers A and E have been enlarged by the use of end caps 122 provided on the body 116. A valve member or poppet valve 123 is provided in the chamber D and is carried by a valve stem 15 passage 121. or plunger 124 slidably mounted within the body 116. The valve stem or plunger 124 is adapted to be engaged by diaphragm 126 provided in the chamber A. Similarly, a valve member or poppet valve 128 is provided within the chamber B and is carried by valve stem 20 to the closed position. The length of the expiratory or plunger 129 slidably mounted in the body 116. The valve stem or plunger 129 is adapted to be engaged by a diaphragm 131 in chamber C. A plunger 132 is mounted within the chamber E and is adapted to be engaged by a diaphragm 133 within the chamber E. An 25 inspiratory time valve assembly 136 which is provided with a control knob 137 is mounted in the body 116. Similarly, a flow rate control valve assembly 138 with a control knob 139 is also mounted in the body 116. In addition, an expiratory time valve assembly 141 is 30mounted in the body 116 and is provided with a control knob 142.

Operation of the embodiment of the invention shown in FIGS. 4-8 may now be briefly described as follows. Let it be assumed that the non-rebreathing valve as- 35 sembly 11 has been connected in the manner shown in FIG. 4 and that it is desired to utilize the automatic controller 81 to apply automatic resuscitation to a patient through the face mask 76. Prior to the application 40 of the face mask, the controller 81 is adjusted to provide the desired flow rate as well as the inspiratory and expiratory times. The desired gas such as oxygen is supplied from the container 69 through the regulator 66 at a desired pressure as, for example, approximately 50 $_{45}$ such as rubber. The cap 115 is provided with a small psi to the controller 81. Let it be assumed that the controller 81 is in the inspiratory phase and that the parts are in the position shown in FIG. 8. When such is the case, gas is metered through the expiratory time valve 141 into the chamber A. The gas also flows from 50 81 provides very simple means for automatically conchamber A into chamber B where the gas is occluded by poppet valve 128 with the poppet valve 123 open as shown in FIG. 8. Gas is also supplied to the chamber D and flows past the poppet valve 123 into the chamber E to begin to pressurize that chamber. Gas also flows 55 through the inspiratory time valve 136 into the chamber C to begin to pressurize that chamber. As the chamber E is pressurized, the plunger valve 132 is moved to a closed position to prevent chamber C from 60 being vented to the atmosphere through the passage 121. The length of the inspiratory phase is determined by the length of time required to pressurize the chamber C sufficiently to move the poppet valve 128 to the right as viewed in FIG. 8 to open the poppet valve 65 128

As soon as the pressure in chamber C has reached a sufficient pressure to apply a force to the diaphragm

131 which is great enough to open the valve 128, the inspiratory phase is terminated. As soon as the valve 128 is open, chamber B will be vented to the atmosphere through the passage 119. As soon as chamber B is vented to the atmosphere, chamber A is also vented to the atmosphere through chamber B. The poppet valve 123 closes and no more gas can flow out through the flow rate valve 138 and through the outlet 118. When this happens, a pressure drop occurs in all the arteries or passages leading to the chamber E so that gas is bled out of chamber E to permit the plunger valve 132 to be raised and to permit chamber C to thereafter be vented to the atmosphere through the

The closing of the poppet valve 123 terminates the inspiratory phase and the expiratory phase commences immediately thereafter. As soon as chamber C is vented to the atmosphere, the poppet valve 128 moves phase is determined by the amount of time that it takes the gas to bleed through the expiratory time valve 141 to pressurize the chamber A and the chamber B which is now occluded by the valve 128 to a sufficient pressure which, through the diaphragm 126, will provide a force that is sufficient to open the poppet valve 123. As soon as the poppet valve 123 is opened, the expiratory phase is terminated and the inspiratory phase commences with gases being supplied through the flow rate valve 138 through the outlet 118. At the same time this begins to occur, chamber E is again pressurized to cause the valve 132 to close which again causes the chamber C to begin filling through the inspiratory time valve 136 in the manner hereinbefore described.

From the foregoing, it can be seen that the length of the inspiratory phase can be readily controlled by the inspiratory time valve 136 and that the length of the expiratory phase can be readily controlled by the expiratory time valve 141. In addition, the rate of flow of gas to the patient can be controlled by the flow rate valve 138

The sleeve 89 can be provided with an outlet 114 which is normally closed by a cap 115 of a suitable type orifice 110 to continuously provide a bleed-down for chamber 16 to prevent inspiratory locking as hereinbefore described.

From the foregoing, it can be seen that the controller trolling the venturi assembly 83 so that with the resuscitator shown in FIG. 4, both automatic and manual resuscitation can be provided. The compression bulb 71 can be utilized for overriding the action of the controller 81 and the venturi assembly 83, if desired. When gas is supplied under pressure from the controller 81 through the tube 82, it is supplied as a jet of gas from the nozzle 96 which is introduced into the venturi-like passageway 87. This jet of gas which may be in the form of oxygen which carries with it atmospheric air that enters through the openings 94. Thus, it can be seen that atmospheric air is mixed with the gas being introduced by the jet from the nozzle 96. This air under pressure opens the check valve to permit the oxygen enriched air to enter the tee 84 and then to pass upwardly into the non-rebreathing valve assembly 11 which operates in the same manner as described in

conjunction with the previous embodiment to supply the gas through the passage 29 to the face mask 76 and thence to the airvays of the patient. The venturi assembly 83 which is utilized limits the pressure which can be delivered to the patient by providing a clutching action which determines the peak positive pressure which is supplied to the patient in a manner well known to those skilled in the art. The peak positive pressure is limited because the inlet to the venturi-like passageway 87 is open to the atmosphere.

As soon as the inspiratory phase is terminated by the controller 81, gas is no longer supplied to the nozzle 96 and the check valve immediately moves to a closed position. The non-rebreathing valve assembly 11 moves 15 to the position shown in FIG. 4 in which the expiratory gases of the patient are vented to the atmosphere through the passage 27.

In the present embodiment of the invention, as soon as the flow of gas through the nozzle 96 is terminated, 20 the check valve will close so that enriched air under pressure is locked within the compression bulb 71. This will have a tendency to hold the diaphragm 46 in a closed position to thereby occlude the patient's airway from venting to the atmosphere. This will have a tendency to hold the lungs of the patient in a fully inflated position or, in other words, in an apneustic plateau. The rate of pressure drop from this apneustic plateau will be determined by the bleeding of gas through the 30 orifice 110 to ambient. The larger the orifice, the faster the bleed-down to ambient at the end of inspiration. This is an important feature because it permits the operator to determine the length of the apneustic plateau. Alternatively, this could be determined by a 35 needle valve connected into the region below the diaphragm 46 to control the rate of bleed-off of the pressure below the diaphragm 46. The rate of bleed-off also could be readily changed merely by using caps 115 having different sized orifices 110 in the same.

As soon as the pressure in the region under the diaphragm **46** decreases and reaches ambient, the diaphragm will move to the open position and the airways of the patient will be open to the atmosphere through the passage **27** to permit the expiratory gases to flow to the atmosphere. This all will occur during the expiratory phase of the controller **81**. As soon as the expiratory phase is commenced to again supply gases to the airways of the patient. Thus, it can be seen that resuscitation of the patient is automatically controlled by the controller **81**.

It also can be seen that at any time, the compression bulb 71 can be utilized especially towards the end of in-55 spiration to augment the venturi and controller 81 by increasing peak inspiratory pressures and tidal volumes, by manually squeezing the same to superimpose higher pressures and additional gas volumes over that provided by the venturi assembly 83 and the controller 81. The compression bulb 71 is always in full communication with the non-rebreathing valve assembly, and may also be used in case of mechanical failure of the automatic equipment, depletion of gas supply in compressed cylinders, or power failure in the event an air compressor is used to create the gas source supplying controller 81.

Another embodiment of the non-rebreathing valve assembly is shown in FIG. 9 in which the resilient member 42 in which two small orifices 78 are provided rather than one orifice which are spaced apart approximately the same distance as the openings 41 in the second part 18 so that in the event the valve member 42 is mounted within the part 18, it cannot be assembled in such a manner so that neither of the small orifices 78 is in registration with one of the holes 41. This makes possible the random positioning of the annular valve member 42 without danger of having one of the orifices 78 being exposed to one of the openings 41.

Another embodiment of the present invention showing the non-rebreathing valve assembly 11 is shown in FIG. 10 in which a modified non-rebreathing valve assembly 151 is utilized in conjunction with a venturi assembly 83 of the type hereinbefore described with the exception that the check valve means 101 has been omitted. The non-rebreathing valve assembly 151 is very similar to the non-rebreathing valve assembly 11 hereinbefore described with the exception that with respect to the bottom part 18, the bottom part 18 is not provided with holes 41, nor is there provided an annular resilient valve member 42. The venturi assembly 83 25 is mounted on the tubular extension 38 of the nonrebreathing valve assembly 151 by a sleeve or coupling 152 which engages the extension 38 of the nonrebreathing valve assembly 151 and the sleeve 89 of the venturi assembly 83. The venturi assembly 83 is connected by a tube 82 to an automatic controller 81 of the type hereinbefore described.

The assembly shown in FIG. 10 provides a very simple and relatively compact mechanical ventilator which does not require the use of a resuscitation bulb.

In operation, the assembly as shown in FIG. 10 is under the control of the automatic controller. As explained previously, prior to the application of the face mask to the patient, the controller 81 is adjusted to provide the desired flow rate as well as the inspiratory and expiratory times. A desired gas such as oxygen is supplied through the controller and to the tube 82 where it is supplied to the nozzle 97. The jet is introduced into the venturi-like passage 87 and entrains with it air passing through the openings 94 in the carrier 93. This gas under pressure passes through the carrier or cage 102 directly to the chamber 16 on the underside of the diaphragm assembly 13.

As soon as the pressure within the chamber 16 is greater than the chamber 14, the diaphragm assembly 13 moves upwardly so that the flapper valve member 49 moves into sealing engagement with the lower extremity of the passage 27 to thereby prevent the gases entering the chamber 14 through the holes 48 from escaping to the atmosphere through the passage 27. The gases pass into the passage 29 into the mask and into the airways of the patient.

As soon as the lungs of the patient have been filled with gases and the inspiratory phase of the controller has concluded, the expiratory phase commences and the diaphragm assembly 13 moves downwardly as described in the connection with the previous embodiments to vent the airways of the patient to the atmosphere through the passage 27. As soon as the expiratory phase has been completed, the inspiratory phase is again commenced. Thus, it can be seen that the inspiratory and expiratory phases are directly under the control of the automatic controller. It can be seen that the assembly shown in FIG. 10 provides a simple mechanical ventilator.

In all uses of the apparatus, it can be seen that the advantages of the non-rebreathing valve are retained. Substantially none of the expired gases of the patient will be rebreathed by the patient.

From the foregoing, it can be seen that the nonrebreathing valve assembly with the compression bulb always makes possible manual ventilation of the lungs of the patient regardless of any possible malfunction of the automatic controller. By removal of the venturi assembly 83 and the tee 84 and mounting the compression bulb directly on the non-rebreathing valve assembly 11, a simple manual resuscitation device is provided. Supplemental oxygen may be supplied to the compression bulb resuscitator by the installation of a vented reservoir type ring about the base of the nonrebreathing valve assembly. The venting of the ring prevents mechanical lock-up during inspiration.

The modular design of the various parts forming a part of the resuscitator makes possible a combination of automatic and manual resuscitators. By use of the non-rebreathing valve assembly, a constant independent standby manual resuscitator is always available. diaphragm assembly disposed within said body and forming first and second chambers within said body, one portion of said body on one side of said diaphragm assembly being formed with an extension having an expiratory port therein venting said first chamber to am-

We claim:

1. In a non-rebreathing valve assembly adapted to be connected to the airway of a patient, a body, a 30 diaphragm assembly disposed within the body and forming first and second chambers within the body on opposite sides of the diaphragm assembly, one portion of said body on one side of said diaphragm assembly 35 being provided with an exhalation port venting said first chamber to ambient and an additional port in communication with said first chamber and adapted to be placed in communication with the airway of the patient, said diaphragm assembly having valve means 40 movable to a position to occlude said expiratory port, said other portion of the body being formed with an inlet passage on the other side of the diaphragm assembly, said other portion having an opening therein venting said second chamber to ambient, and one-way 45 valve means carried by said body normally occluding said opening in said other portion, said valve means of said diaphragm assembly having at least one opening therein spaced from said expiratory port, and one-way valve means carried by said valve means for normally 50 occluding said opening.

2. A valve assembly as in claim 1 wherein said last named one-way valve means is in the form of a flapper valve.

3. A valve assembly as in claim 1 wherein said ⁵⁵ diaphragm assembly includes a flexible diaphragm, a rigid plate carried by the central portion of said diaphragm and being of a size so as to cover said exhalation port, a plurality of openings formed in said diaphragm and in said plate outside the area used to occlude the exhalation port to establish communication between the first and second chambers and wherein said one-way valve means is carried by the plate.

4. An assembly as in claim 3 wherein said one-way valve means carried by said plate is in the form of a flexible flapper valve member carried by the plate and overlying said holes in the plate and the diaphragm.

5. A valve assembly as in claim 1 wherein said exhalation port is encircled by a valve seat and wherein said one-way valve means is adapted to engage said valve seat.

6. A valve assembly as in claim 1 together with a skirt generally enclosing said second portion, said skirt being adapted to receive a gas to supply the same in the vicinity of the openings venting the second chamber to the atmosphere, said skirt having an opening therein venting the same to the atmosphere.

7. A valve assembly as in claim 1 wherein said exhalation port is formed by a centrally disposed cylindrical extension which extends into the first chamber and wherein the additional port is formed by a coaxial passage surrounding said extension.

8. A valve assembly as in claim 4 wherein said diaphragm is disposed on one side of said plate and said resilient flapper valve member is disposed on the other side of said plate.

9. In a non-rebreathing valve assembly adapted to be connected to the airway of a patient, a body, a diaphragm assembly disposed within said body and forming first and second chambers within said body, assembly being formed with an extension having an expiratory port therein venting said first chamber to ambient, said cylindrical extension being adapted to be engaged by said diaphragm assembly to occlude said expiratory port, a plurality of holes in said diaphragm assembly spaced so that they are out of communication with said expiratory port, one-way valve means included as a part of the diaphragm assembly and normally occluding said openings to prevent communication between said first and second chambers, said one portion also having an additional extension with a port in communication with said first chamber, said port in said additional extension being adapted to be placed in communication with the airway of the patient, the other portion of the body on the other side of the diaphragm assembly being formed with an inlet passage in communication with said second chamber, a plurality of openings in said other part of said body venting said second chamber to ambient and one-way valve means carried by the body for normally occluding said last named openings.

10. A valve as in claim 9 wherein said body is formed in first and second parts and wherein said diaphragm assembly includes a diaphragm having an annular lip clamped between said first and second parts.

11. A valve assembly as in claim 9 wherein said diaphragm assembly includes a flexible diaphragm secured to said body, a rigid plate secured to a central portion of said diaphragm and being of a size that is larger than the expiratory port, a plurality of spaced openings in said diaphragm and in said plate and being arranged so that they are out of communication with said expiratory port, said holes establishing communication between said first and second chambers, and a resilient flapper valve carried by said plate and overlying said openings, said flapper valve being adapted to engage said extension to occlude said expiratory port.

12. A valve assembly as in claim 11 wherein said body is provided with a passage which surrounds said extension for said expiratory port which is in communication with said additional extension.

13. In a compression bulb resuscitator for resuscitating a patient, a non-rebreathing valve assembly, said non-rebreathing valve assembly comprising a body, a diaphragm assembly disposed within the body and portion of said body on one side of said diaphragm assembly being provided with an exhalation port venting said first chamber to ambient and an additional port in communication with said first chamber and adapted to be placed in communication with the airway of the pa-10 tient, said diaphragm assembly having a valve means movable to a position to occlude said expiratory port, said valve means having at least one opening therein out of registration with said exhalation port, and oneway valve means forming a part of said valve means for 15 occluding said opening, said other portion of the body being formed with an inlet passage on the other side of the diaphragm assembly in communication with said second chamber, said other portion having at least one opening therein venting said second chamber to am- 20 bient and one-way valve means carried by said body normally occluding said last named opening, and a compression bulb connected to said non-rebreathing valve assembly for supplying gas under pressure to said 25 valve assembly.

14. A resuscitator as in claim 13 together with a source of gas under pressure, and means connected to the source of gas under pressure for supplying gas in the vicinity of said last named openings in said valve assembly.

15. A resuscitator as in claim 14 wherein said last named means includes a skirt secured to the body, said skirt having an opening therein open to ambient and means for supplying the gas to said skirt so that it is distributed within said skirt.

16. A resuscitator as in claim 13 together with a source of gas under pressure, an automatic controller connected to said source of gas, and means connecting said automatic controller to the inlet passage of said valve assembly.

17. A resuscitator as in claim 16 wherein said controller automatically controls the inspiratory and expiratory phases of the patient.

18. A resuscitator as in claim 17 wherein said compression bulb is always in communication with the inlet 45 of the valve assembly.

19. A resuscitator as in claim 16 together with a venturi assembly connected between said controller and said inlet, said venturi assembly having a venturi-like passageway with its inlet end open to the atmosphere 50 and its outlet end in communication with the inlet of the valve assembly and a nozzle connected to said controller for supplying a jet of gas into the venturi passageway.

20. A resuscitator as in claim 19 wherein said venturi 55 assembly includes a check valve assembly mounted on the outlet end of the venturi-like passageway, said

check valve assembly being yieldably urged into a position to normally close the outlet end of said passageway.

21. A resuscitator as in claim 13 together with means forming first and second chambers within the body, one 5 in communication with the second chamber of the valve assembly for venting the second chamber to am-

bient at a controlled rate. 22. In a valve assembly, a body and a diaphragm assembly disposed in the body and forming first and second chambers within the body on opposite sides of the diaphragm assembly, said body 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, said diaphragm assembly carrying one-way valve means permitting gas to flow only from said second chamber to said first chamber, said body carrying oneway valve means permitting gas outside the body to only flow into said second chamber.

23. A valve assembly as in claim 22 wherein said diaphragm assembly includes a diaphragm having its outer margin secured to said body and wherein said diaphragm is provided with at least one opening forming a part of said one-way valve means carried by said diaphragm assembly.

24. In a resuscitator for resuscitating a patient, a nonrebreathing valve assembly, said non-rebreathing valve assembly comprising a body, a diaphragm assembly disposed within the body and forming first and second 30 chambers within the body, one portion of said body on one side of said diaphragm assembly being provided with an exhalation port venting said first chamber to ambient and an additional port in communication with 35 said first chamber and adapted to be placed in communication with the airway of the patient, said diaphragm assembly having valve means movable to a position to occlude said expiratory port, said valve means having at least one opening therein out of registration with said 40 exhalation port, one-way valve means forming a part of said valve means for occluding said opening, said other portion of said body being formed with an inlet passage on the other side of the diaphragm assembly in communication with said second chamber, said other portion having at least one opening therein, a venturi assembly mounted on said non-rebreathing valve assembly and having an outlet in communication with said opening in said other portion, said venturi assembly having a venturi-like passageway with its inlet end open to the atmosphere, means forming a nozzle mounted on said

venturi assembly and means for supplying a jet of gas through said nozzle to said venturi-like passageway. 25. A resuscitator as in claim 24 together with a

source of gas under pressure, automatic controller connected to said source of gas and means connecting said automatic controller to said nozzle.

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