Dec. 23, 1969 F. M. BIRD ET AL 3,485,243

RESPIRATOR WITH IMPROVED EXHALATION VALVE AND CONTROL MEANS

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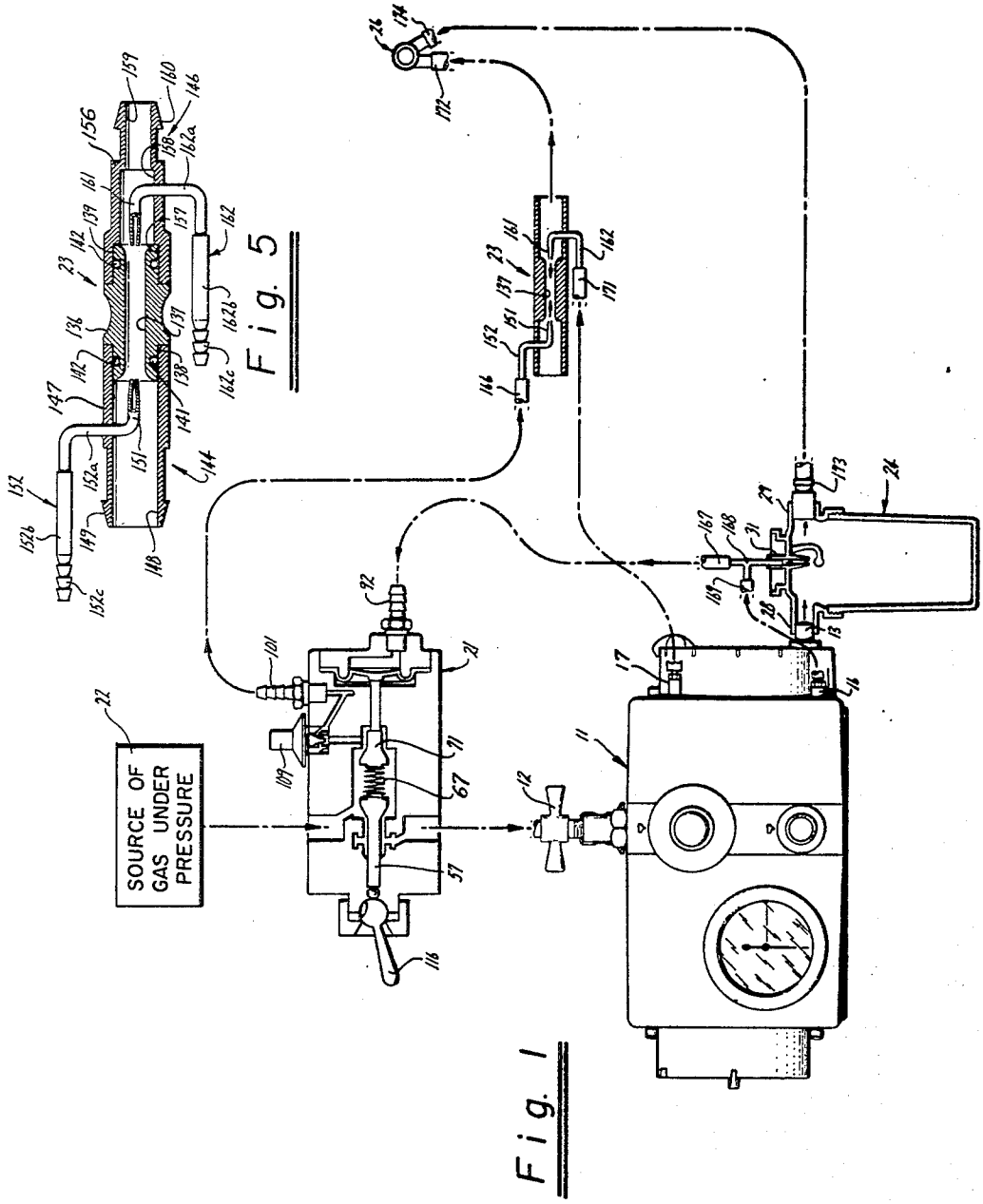

Fig. 5

Fig. 1

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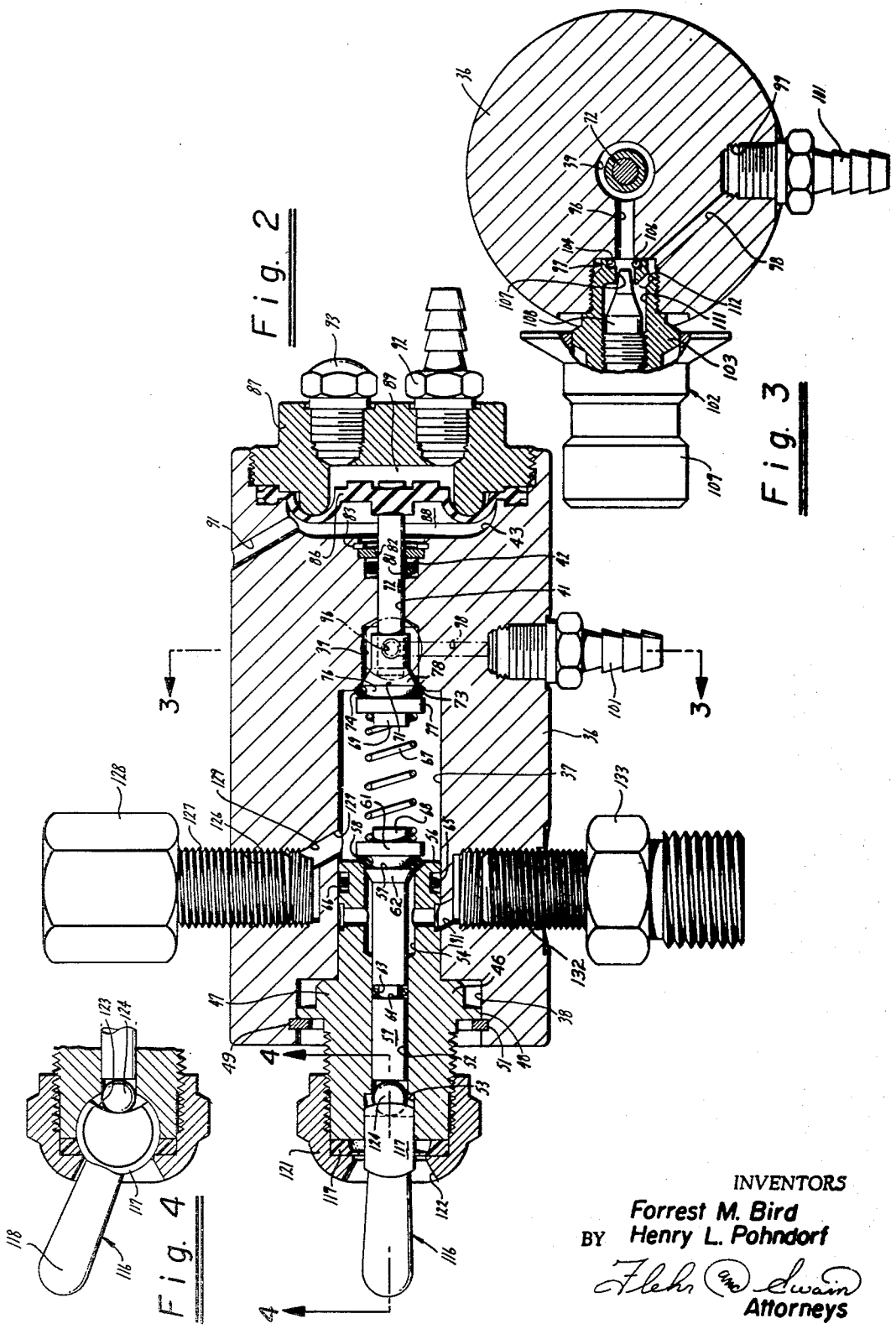

Fig. 2

Fig. 3

Fig. 4

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RESPIRATOR WITH IMPROVED EXHALATION VALVE AND CONTROL MEANS

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U.S. Cl. 128—145.8 13 Claims

ABSTRACT OF THE DISCLOSURE

Respirator having an exhalation valve and two control units and providing inhalation and exhalation phases of operation. The exhalation valve includes a venturi passage, nozzles and tubular members for entraining air flow to and from the airway of a patient.

This invention relates to a respirator and more particularly to a respirator particularly useful for infant resuscitation.

With respirators presently available, it has been found to be very difficult to give mechanical assistance to an infant having hyaline membrane disease, obstructive lung disease or other breathing difficulties because the infant lungs are very small and the breathing rates required are very rapid. In addition, occasionally the pressure required to ventilate the small infant lung is much higher than that encountered in adults. There is, therefore, a need for a new and improved respirator which is particularly useful in ventilating infants.

In general, it is an object of the present invention to provide a respirator with which it is possible to ventilate infants.

Another object of the invention is to provide a respirator of the above character which can be recycled very rapidly.

Another object of the invention is to provide a respirator of the above character in which the entire respirator can be turned off with a single control.

Another object of the invention is to provide a respirator of the above character which includes a parallel booster which only operates during the inspiration phase.

Another object of the invention is to provide a respirator of the above character in which a separate independent gas flow can be delivered to the nebulizer.

Another object of the invention is to provide a respirator of the above character which incorporates a particularly unique exhalation valve.

Another object of the invention is to provide a respirator of the above character which includes a particularly unique control cartridge.

Additional objects and features of the invention will appear from the following description in which a preferred embodiment is set forth in detail in conjunction with the accompanying drawings.

Referring to the drawings:

FIGURE 1 is a diagram with certain of the parts schematically illustrated of a respirator incorporating the present invention.

FIGURE 2 is a cross sectional view of the control cartridge utilized as a part of the respirator shown in FIGURE 1.

FIGURE 3 is a cross sectional view taken along the line 3—3 of FIGURE 2.

FIGURE 4 is a cross sectional view taken along the line 4—4 of FIGURE 2.

FIGURE 5 is an enlarged cross sectional view of the exhalation valve utilized in the respirator shown in FIGURE 1.

As shown in the drawings, the respirator consists of a controller **11** of the type shown in United States Letters Patent 3,191,596. As disclosed therein, such a controller includes an inlet **12** adapted to be connected to a source of gas under pressure and an outlet **13** adapted to be connected to the airway of the patient. Such a controller also includes a main control valve (not shown) in the controller movable between open and closed positions to control the flow of inhalant gas from the inlet to the outlet. Means is provided 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 of the respirator. The means for operating the main control valve 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. Such a controller also includes a positive pressure outlet **16** and a negative pressure outlet **17**.

The respirator also includes a control cartridge **21** which is adapted to be connected to the inlet of the controller **11** and which is also adapted to be connected to a source of gas under pressure **22**. The respirator also includes an exhalation valve **23**, a nebulizer **24**, and a patient adapter **26**. The nebulizer can be of the type described in copending application Ser. No. 447,852, filed Apr. 13, 1965, now Patent No. 3,353,536. As described in that application, the nebulizer includes an inlet **28** which, as shown in FIGURE 1, is mounted on the outlet **13** of the controller **11**. It is also provided with an outlet **29** and an additional inlet **31**.

The control cartridge **21** consists of a cylindrical body **36** which is provided with a large, centrally disposed bore extending longitudinally of the body. The bore **37** opens into a large cylindrical recess **38** at one end of the body **36** as shown in FIGURE 2. The large bore **37** also opens into a smaller cylindrical bore **39** at its other end. The bore **39** is in communication with another still smaller bore **41** in the body **36**. The bore **41** is in communication with a larger bore **42** and the bore **42** is in communication with a cup-shaped recess **43** formed on the end of the body **36** opposite the end at which the recess **38** is formed.

A valve member or holder **46** is disposed within the large bore **37** and is provided with an annular shoulder **47** which is seated against the bottom of the recess **38**. The valve member **46** is also provided with a radially extending flange **48** that is of substantially the same diameter as the recess and which is engaged by a snap ring **49** seated within the recess **51** provided in the body **36** to retain the valve member **46** within the body **36**.

The valve member **46** is provided with a bore **52** extending longitudinally thereof intermediate the ends of the same. The bore **52** at one end opens into a flat-sided circular recess **53** and at the other end opens into a larger bore **54**. The innermost end of the valve member **46** is provided with an inclined annular valve seat **56**. A plunger **57** is slidably mounted in the bore **52** and is adapted to be moved between open and closed positions with respect to the valve seat **56**. Suitable sealing means such as an O-ring **58** is carried by the plunger **57** in an annular recess **59** formed between a radially extending collar **61** and a shoulder **62** formed as an integral part of the plunger **57**. Sealing means is disposed between the plunger and the side wall forming the bore **52** and consists of an O-ring **63** disposed in an annular recess **64** provided on the plunger **57**. Sealing means is also disposed between the valve member **46** and the side wall forming the bore **37** and consists of an O-ring **65** mounted in an annular recess **66** in the valve member **46**. Means is provided for yieldably urging the plunger toward a closed position and

consists of a coil spring **67** having one end engaging a cylindrical boss **68** provided as an integral part of the plunger **57**.

The other end of the spring **67** engages a cylindrical boss **69** forming an integral part of a second plunger valve **71**. The plunger valve **71** has a valve stem **72** slidably mounted in the bore **41** and is movable between open and closed positions with respect to an annular inclined valve seat **73** formed in the body **36** adjacent the outer end of the bore **39**. Suitable sealing means is provided for the plunger valve **71** and consists of an O-ring **74** adapted to engage the seat **73** and which is carried in an annular recess **76** formed between a radially extending collar **77** and a shoulder **78** forming an integral part of the plunger valve **71**.

Suitable sealing means is provided for forming a seal about the valve stem **72** and consists of an O-ring **81** mounted within the bore **42** and encircling the valve stem **72**. It also includes a washer **82** which is held in place by snap ring **83**. The outer end of the valve stem **72** is secured to the central portion of a resilient diaphragm **86**. The outer annular margin of the diaphragm **86** is clamped in the recess **43** between the body **36** and a cap **87** which is threaded into the body. It can be seen that separate chambers **88** and **89** are formed on opposite sides of the diaphragm. The chamber **88** is vented to the atmosphere through a small passage **91** provided in the body **36**. A gas under positive pressure is adapted to be supplied to the chamber **89** through a nipple **92** threaded into the cap **87**. A cap screw **93** serves to close another opening provided in the cap **87** and which is not used. The bore **39** is in communication with and opens into a passage **96** in the body **36**. The passage **96** opens into a bore **97** in the body **36**. The bore **97** is also in communication with another passage **98** provided in the body **36** and which opens into another bore **99** provided in the body **36** (see FIGURE 3). A nipple **101** is threaded into the bore **99** whereas a manually controlled flow rate valve **102** is mounted in the bore **97**.

The valve **102** is of a conventional type and, as well known to those skilled in the art, consists of a valve body **103** which is threaded into the bore **97**. The body is provided with an annular recess **104** which carries an O-ring **106** which forms a sealing engagement with the body **36** and which is in registration with the passage **96**. The body is also provided with a passage **107** which is adapted to be opened and closed by a needle valve **108** threaded into the valve body **103**. A knob **109** is mounted on the needle valve **108** and is provided for adjusting the needle valve axially of the valve body **103** to control the size of the opening through which gases can pass into a chamber **111** provided in the valve body. A small passage **112** in the valve body **103** establishes communication between the chamber **111** and the passage **98** provided in the body **36**.

Mean is provided for shifting the plunger valve **57** to an open position and consists of a toggle member **116** having a flat sided cylindrical member **117** with a handle **118** formed thereon. A sealing ring **119** is mounted over the handle **118** and is held in place by a cap **121** threaded onto the outer end of the valve member **46**. The cap **121** is provided with a centrally disposed opening **122** through which the handle **118** extends. The cylindrical member **117** is formed with an arcuate recess **123** and is adapted to accommodate a ball **124** as shown in FIGURES 2 and 4. The ball **124** is of substantially the same diameter as the outer end of the plunger **57** and is adapted to be moved into the bore **52** by movement of the toggle member **116** to shift the plunger to an open position and to retain the same in the open position. The toggle member **116** is shaped in such a manner that the plunger **57** can be held in either an open position or a closed position with respect to the seat **56**.

Means is provided for supplying gas under pressure to the chamber formed within the bore **37** and consists of a threaded bore **126** in which a threaded nipple **127** is mounted. A nut **128** is threaded onto the nipple **127** and is adapted to make a connection with a suitable source of pressure such as the source of pressure **22** indicated in FIGURE 1. The bore **126** is in communication with a passage **129** which opens into the bore **37**. Means is also provided for removing gases from the chamber formed by the bore **37** and consists of a passage **131** which is in communication with a bore **132** provided in the body **36**. A fitting **133** is threaded into the bore and is adapted to be directly connected to the inlet **12** of the controller **11** shown in FIGURE 1.

The exhalation value consists of a central body **136** which has a double throated venturi-like passage **137** extending longitudinally therethrough. In other words, there is a venturi-like passage provided at each end of the body **136**. The body **136** is provided with recessed cylindrical surfaces **138** and **139** on opposite ends. An annular recess **141** is formed in each of the cylindrical surfaces and carries an O-ring **142**. A positive jet subassembly **144** is mounted on one end of the central body **136** and a negative jet subassembly **146** is mounted on the other end of the central body **136**. The positive jet subassembly **144** consists of a tubular member **147** which is provided with a cylindrical bore **148** that is adapted to snugly fit over the cylindrical surface **138** and to be retained thereon by the O-ring **142** as shown. The bore **148** serves as a passage which is axially aligned with the venturi-like passage **137** in the body **136**. The outer end of the tubular member **147** is provided with an inclined raised shoulder **149** which is adapted to grip a tube if one is connected thereto.

A nozzle **151** is mounted in the tubular member **147** and is centrally disposed within the bore **148** so that when the tubular member **147** is mounted on the central body **136**, the nozzle is in axial alignment with one end of the venturi-like passage **137** in the central body **136**. Means is provided for supplying air to the nozzle **151** and consists of a pipe **152** which is provided with a portion **152***a* which extends through the side wall of the tubular member in a radial direction. A portion **152***b* extends at right angles to the portion **152***a* and is provided with a nipple portion **152***c*.

A negative jet subassembly **146** is constructed in a manner similar to the positive jet subassembly **144** and consists of a tubular member **156** which is provided with bores **157**, **158** and **159** communicating with each other and each having different diameters. The bore **157** is of such size that it can readily fit over the surface **139** provided on the other end of the body **136** and be engaged by the O-ring **142** to hold the negative jet subassembly **146** on the central body **136**. The bore **158** serves as a passage which is in alignment with the passage **137** in the body **136**.

A nozzle **161** is disposed within the bore **158** of the tubular member and faces the other throat of the venturi-like passage **137** and is axially aligned therewith as shown in FIGURE 5. Means is provided for supplying gas under pressure to the nozzle **161** and consists of a pipe **162** which is provided with a portion **162***a* which extends radially through the one wall of the tubular member **156** and is secured to the wall of the tubular member. The pipe is also provided with a portion **162***b* which extends at right angles to the portion **162***a* and a nipple portion **162***c* which forms a continuation of the portion **162***b*. The tubular member is provided with an inclined raised shoulder **160** which is adapted to engage any flexible tube which is secured thereto.

As shown in the drawings, the nipple **101** of the control cartridge **21** is connected to one end of a tube **166** and the other end of the tube **166** is connected to the pipe **152**. The nipple **92** of the control cartridge **21** is connected by a tube **167** to a T-shaped fitting **168** which is mounted in inlet **31** of the nebulizer **24**. The T-shaped fitting is also connected by a tube **169** to the positive

pressure outlet 16 of the controller 11. The negative pressure outlet 17 of the controller 11 is connected by a tube 171 to the pipe 162. The tubular member 156 of the exhalation valve 23 is connected to one branch of a bifurcated or Y type patient adapter 26 by tube 172. The outlet 29 of the nebulizer is provided with a fitting 173. The fitting 173 is connected by a tube 174 to the patient adapter 26. The patient adapter 26 can be of any suitable type but, as shown in the drawing, can be a tracheotomy fitting.

Operation and use of the respirator may now be briefly described as follows. Let it be assumed that it is desired to place the respirator in operation. This is accomplished by shifting the toggle member 116 into a position so that it urges the ball 124 into the bore 52 to urge the plunger 57 to the right as viewed in FIGURE 2 to move the plunger to an open position with respect to the valve seat 56 against the force of the spring 67. Gas under pressure from the source 22 passes through the fitting 127 through the passage 129 into the bore 37. The gas then passes into the bore 54 through the passage 131 through the fitting 133 to the inlet 12 of the controller 11.

Assuming that the controller 11 is in the inspiration phase, a gas under positive pressure is produced through the main outlet 13 and passes through the nebulizer 24 through the outlet 29 of the nebulizer and to the bifurcated patient adapter 26 to the airway of the patient. At the same time that gases are being supplied under a positive pressure through the outlet 13, gas is also being supplied under a higher positive pressure through the positive pressure outlet 16 to the T-shaped fitting 168. Part of this positive pressure is supplied to the nebulizer 24 to nebulize the bronchial dilator or any other substance carried by the nebulizer so that droplets of the same enter into the main stream of gas passing from the outlet 29 to the patient adapter 26. At this same time, gas under positive pressure is also supplied to the nipple 92 of the control cartridge 21 to supply positive pressure to the chamber 89 and to shift the diaphragm 86 to the left as viewed in FIGURE 2 to also move the plunger 72 to an open position with respect to the seat 73. Gas under pressure, therefore, passes into the bore 39 through the passage 96 and then through the flow rate control valve 102 at a rate determined by the valve 102 through the passage 98 to the nipple 101 and to the nozzle 151 which supplies a jet of air to one end of the venturi-like passage 137. The jet of air passing through the passage 137 causes additional air molecules to be entrained and urged into the passage 137 from the atmosphere and to thus supply additional gas under pressure to the patient adapter 26. The valve 102 is adjusted so that the rate of flow of gas from the nozzle 151 is sufficient to effectively seal the left-hand end of the exhalation valve 23, as viewed in FIGURE 1, to prevent gas being supplied to the patient from being exhausted to the atmosphere. It also has an additional function to aspirate atmospheric air into the right-hand side of the exhalation valve 23 and to deliver additional gas under pressure to the patient adapter during the inspiratory phase of the respirator. Thus, during the inspiratory phase, the jet passing from the nozzle 151 in combination with the venturi-like passage 137 can be considered to create a valve closure to the rear of the nozzle 151 because of the molecular barrier which is set up by this venturi action. This barrier can be stationary or it can move towards the patient at rates depending upon the adjustment of the flow valve 102 and the resistances which may be encountered in the patient due to obstructions in the air ways of the lungs and changes in lung compliance as well as the resistances in the mechanical circuit to the patient adapter.

As soon as the inspiratory phase has been completed and is sensed by the controller 11, the controller switches to the negative or exhalation phase. When this occurs, positive pressure is no longer supplied through the outlet 16 and, therefore, the plunger 72 is returned to its closed position by action of the spring 67. This stops the flow of gas from the nozzle 151. At the same time, a negative pressure flow is developed in the outlet 17 of the controller and is supplied to the nozzle 161 to produce a jet of air passing through the venturi-like passage 137 in an opposite direction to create a negative pressure gradient which aspirates the gases in the airway of the patient and discharges the same to the atmosphere through the tubular member 147. Thus, it can be seen that during the expiratory or exhalation phase, the exhaled gases proceed through the exhalation valve 23 and are discharged to the atmosphere.

As soon as the expiratory phase has been completed, the controller 11 is cycled into the inspiratory phase and the same sequence of operations takes place.

From the foregoing, it can be seen that the jet of gases passing through the nozzle 151 into the venturi-like passage 137 acts like a pneumatic clutch. If changes in resistance and changes in obstructions are met, the gas flow is automatically converted from pressure into gas flow. In other words, when airway resistance of the patient increases, flow is converted into pressure because of this venturi-like action and when the resistance is diminished, the same venturi-like action converts the pressure into flow of the gases. In other words, the kinetic energy of the gas flow is converted to higher pressures to overcome the resistances and this same kinetic energy is transformed back into flow to increase the gas flow to the patient to improve the ventilation. During the inspiratory phase, the molecular barrier which is created on the left-hand side of the exhalation valve 23, as viewed in FIGURE 1, also can be considered as a type of relief valve which prevents premature peak inspiratory pressure from being developed while obstructions are being overcome.

In view of the fact that the exhalation valve does not contain any moving parts, it can be rapidly shifted from the inhalation phase to the exhalation phase. As hereinbefore described, the exhalation valve merely makes it possible to move a molecular barrier towards or away from the patient to accomplish all the functions of a conventional exhalation valve with moving parts which have inertia.

By utilizing an exhalation valve of this type, rapid cycling between the exhalation and inhalation phases can be accomplished. In view of this fact, the respirator is particularly adapted for giving mechanical assistance to infants where rapid breathing rates are required.

The respirator shown in the drawings has additional advantages in view of the fact that two separate flow passages are provided to the patient adapter 26. One passes through the main controller 11 whereas the other passes through the exhalation valve 23. The control cartridge 21 includes a flow rate control valve 102 for adjusting the rate of flow through the exhalation valve and the controller 11 as described in United States Letters Patent No. 3,191,596 also includes a flow rate control valve for adjusting the rate of flow of gas through the other main outlet passage 13 to the patient adapter 26 through the nebulizer 24. The flow rate to the patient adapter can be increased merely by increasing the amount of gas passing through the nozzle 151. The length of the inspiratory phase can be controlled by the flow rate valve of the controller 11. Thus, by adjusting the rate of flow of gases through the controller 11, the rate of flow of the main stream gases through the nebulizer 24 can be readily controlled and set at a desired value with any additional gases required for the patient being supplied through the exhalation valve 23 by operation of the manually operated flow rate valve 102.

This parallel arterial circuit in the present respirator can also be utilized for operating a spirometer and any other accessory items. Because of the parallel circuit, this can be done without disturbing the flow rate pattern to the patient which is controlled by the controller 11. When increased nebulization is required, additional flow can be

caused to pass through the nebulizer **24** while decreasing the flow through the exhalation valve **23**.

The control cartridge **21** also provides additional features for the respirator. The toggle **116** makes it possible to turn the respirator on and off with a single control. Thus, once a respiratory pattern has been set up for the controller **11**, the entire respirator can be turned on and off with the toggle **116**. The control cartridge **21** also makes possible the parallel booster passage hereinbefore described which is phased with the controller **11** and only works during the inspiratory phase.

It is apparent from the foregoing that there has been provided a new and improved respirator which has many advantageous features which is particularly adapted for use in the infant resuscitation field. The particularly novel pneumatically controlled exhalation valve utilized in the respirator is particularly novel in that it is very simple and does not require any mechanical movements. If desired, the exhalation valve can be utilized with only a positive jet subassembly. The exhalation valve is also advantageous in that it can be made relatively small and light in weight and, therefore, would be particularly advantageous for use on tracheotomized patients. The exhalation valve can also be used in a Q circle.

We claim:

1. In a respirator having an inhalation phase and an exhalation phase in its operative cycle, a controller having an inlet adapted to be connected to a source of gas under pressure, said controller having an outlet adapted to be connected to the airway of the patient, said controller including means permitting gas under pressure to flow from the outlet during the inhalation phase and preventing the flow of gas under pressure from the outlet during the exhalation phase, an exhalation valve, said exhalation valve including a valve body having a venturi-like passage therein, means connected to one end of the body and adapted for directly connecting one end of the passage to the airway of the patient, a tubular member mounted on the other end of the body having a passage extending therethrough in axial alignment with the passage in the body, a nozzle mounted within said tubular member and facing the passage in said body, the other end of said passage being open directly to the atmosphere through the passage in said tubular member, and means including a control cartridge connected to said nozzle and adapted for connection to a source of gas under pressure for supplying gas under pressure to the nozzle during the inhalation phase to cause a jet of gas to travel from the nozzle down the passage in a direction toward said one end of the passage to cause molecules of gas from the atmosphere to be entrained and to pass through said passage.

2. A respirator as in claim **1** together with means for adjusting the rate of flow through the nozzle.

3. A respirator as in claim **1** together with means connecting the control cartridge to the controller so that the control cartridge operates in phase with the controller.

4. A respirator as in claim **1** wherein said exhalation valve includes a second nozzle mounted on the body and facing oppositely of said first named nozzle and means for supplying gas under pressure to said second named nozzle during the exhalation phase of the respirator.

5. In a respirator having an inhalation phase and an exhalation phase in its operative cycle, a controller having an inlet adapted to be connected to a source of gas under pressure and an outlet adapted to be connected to the airway of the patient, said controller including means for controlling the flow of gas through the controller so that gas is only supplied to the outlet during the inhalation phase of the controller, said controller also having a positive pressure outlet, a control cartridge, said control cartridge having an inlet adapted to be connected to the source of gas under pressure, an outlet, and diaphragm operated valve means movable between open and closed positions for controlling the flow of gas from the inlet to the outlet of the control cartridge, means for supplying gas from the positive pressure outlet of the controller to said diaphragm operated means to move said diaphragm operated valve means to an open position to permit gas to flow from the inlet to the outlet of the control cartridge, an exhalation valve comprising a valve body having a venturi-like passage therein, means adapted for connecting one end of the passage to the airway of the patient, a nozzle mounted on the body adjacent to the other end of the passage and facing said one end, said other end of the venturi-like passage being open to the atmosphere, and means connecting the outlet of the control cartridge to the nozzle to supply gas under pressure to the nozzle to produce a jet of gas entering the venturi-like passage and entraining atmospheric air for delivery to the airway of the patient.

6. A respirator as in claim **5** together with means mounted on the cartridge for controlling the rate of flow of gas from the inlet to the outlet of the control cartridge.

7. A respirator as in claim **5** wherein said controller includes a negative pressure outlet, and wherein said exhalation valve includes an additional nozzle mounted on the valve body and facing oppositely of said first named nozzle and means connecting the negative pressure outlet of the controller to the additional nozzle to supply air under pressure to the nozzle during the exhalation phase of the respirator.

8. In a respirator having an inhalation phase and an exhalation phase in its operative cycle, a controller having an inlet and an outlet, a control cartridge having an inlet adapted to be connected to a source of gas under pressure, said control cartridge also having an outlet, means connecting the outlet of the control cartridge to the inlet of the controller, said control cartridge including manually operated valve means for controlling the flow of gas under pressure from the inlet to the outlet, means for connecting the outlet of the controller to the airway of the patient, said controller having a positive pressure outlet, the control cartridge having an additional outlet in communication with the inlet of the control cartridge, diaphragm operated valve means for controlling the flow of gas from the inlet to the additional outlet of the control cartridge, means connecting the positive pressure outlet of the controller to the diaphragm operated valve means, said controller including means for supplying gas under pressure to the positive pressure outlet of the controller only during the inhalation phase, whereby said diaphragm operated valve means is moved to an open position during the inhalation phase and permits gas under pressure to flow through the additional outlet of the control cartridge, an exhalation valve comprising a valve body having a venturi-like passage therein, a nozzle mounted on the body and facing one end of the venturi-like passage, the other end of the venturi-like passage being open to the atmosphere, means adapted to connect the one end of the venturi-like passage to the airway of the patient, and means connecting the additional outlet of the control cartridge to the nozzle of the exhalation valve for supplying a jet of gas to the venturi-like passage to cause additional air to be entrained for delivery to the airway of the patient.

9. A respirator as in claim **8** wherein said control cartridge includes a flow rate valve for adjusting the rate of flow from the inlet to the additional outlet.

10. A respirator as in claim **8** wherein said controller includes a negative pressure outlet in which air under pressure is supplied during the exhalation phase of the respirator, an additional nozzle mounted on said valve body and facing said other end of said passage and means connecting the negative pressure outlet to said additional nozzle.

11. In an exhalation valve for use in a respirator of the type having an inhalation phase and an exhalation phase in its operative cycle and having a patient adapter adapted to be connected to the airway of a patient, a

valve body having a venturi-like passage therein, means mounted on one end of the body adapted to directly connect one end of the passage to said patient adapter, a tubular member mounted on the other end of said body and having a passage extending therethrough and in axial alignment with the passage in the body, a nozzle mounted within said tubular member and facing the passage in said body, the other end of said passage being open directly to the atmosphere through the passage in the tubular member, said nozzle being adapted for receiving gas under pressure during the inhalation phase of the respirator to cause a jet of gas to travel from the nozzle down the passage in the body to cause molecules of air from the atmosphere to be entrained and to pass through said passage in said body, an additional nozzle mounted on said body and facing oppositely of said first named nozzle, and means for supplying gas under pressure to said additional nozzle during the exhalation phase of the respirator.

12. In an exhalation valve, a valve body having a venturi-like passage therein, a tubular member removably mounted on each end of the body and having a passage extending therethrough axially aligned with the

passage in said body, a nozzle carried by each of the tubular members and facing the end of the passage in said body on which the tubular member is mounted.

13. An exhalation valve as in claim 12 wherein piping is connected to each of said nozzles and wherein said piping extends through the side walls of the tubular members.

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K. L. HOWELL, Assistant Examiner

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