Aug. 23, 1966 C. B. ANDREASEN ETAL 3,267,935

RESPIRATORY ASSISTER

Filed May 4, 1961 5 Sheets-Sheet 1

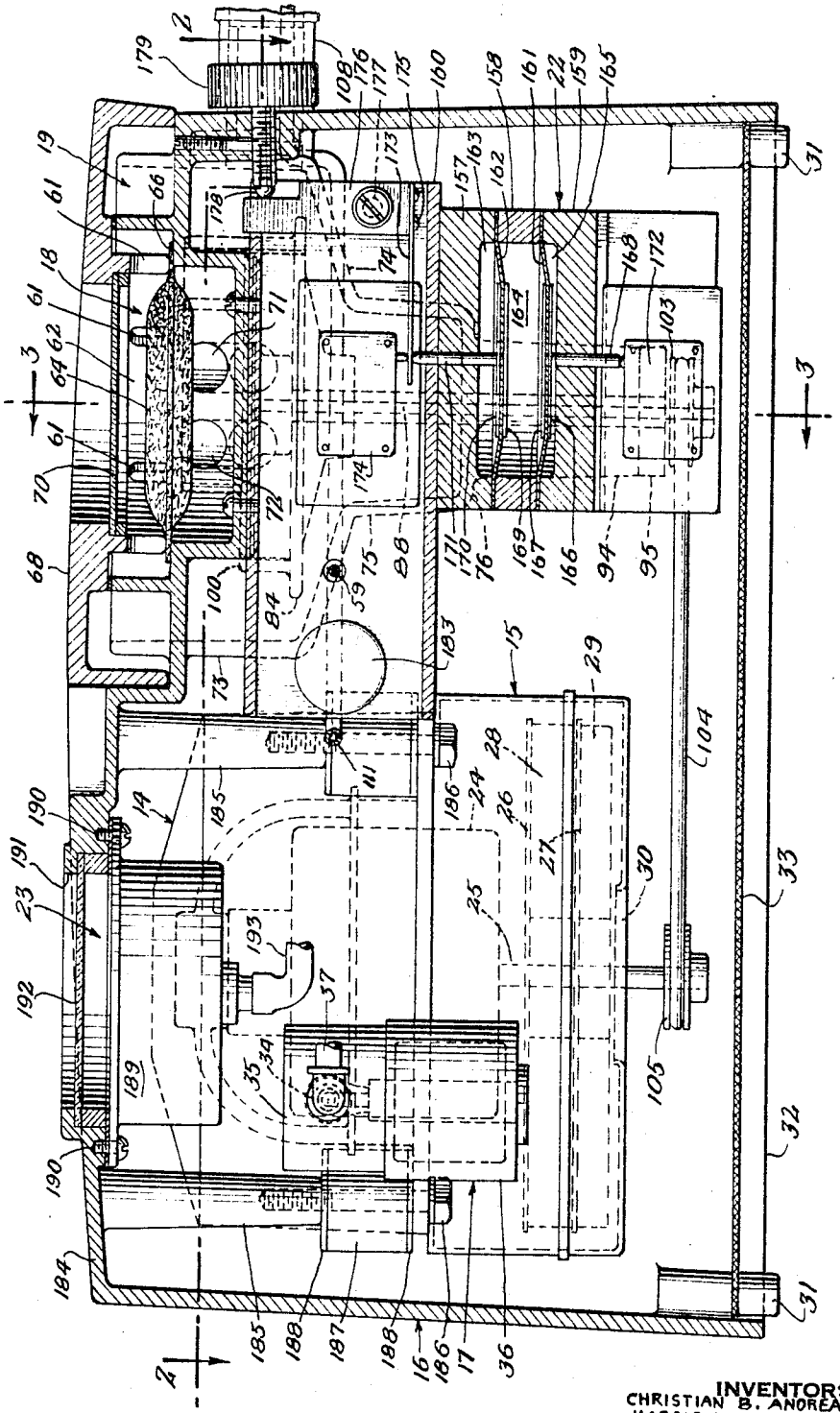

Fig. 1.

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RESPIRATORY ASSISTER

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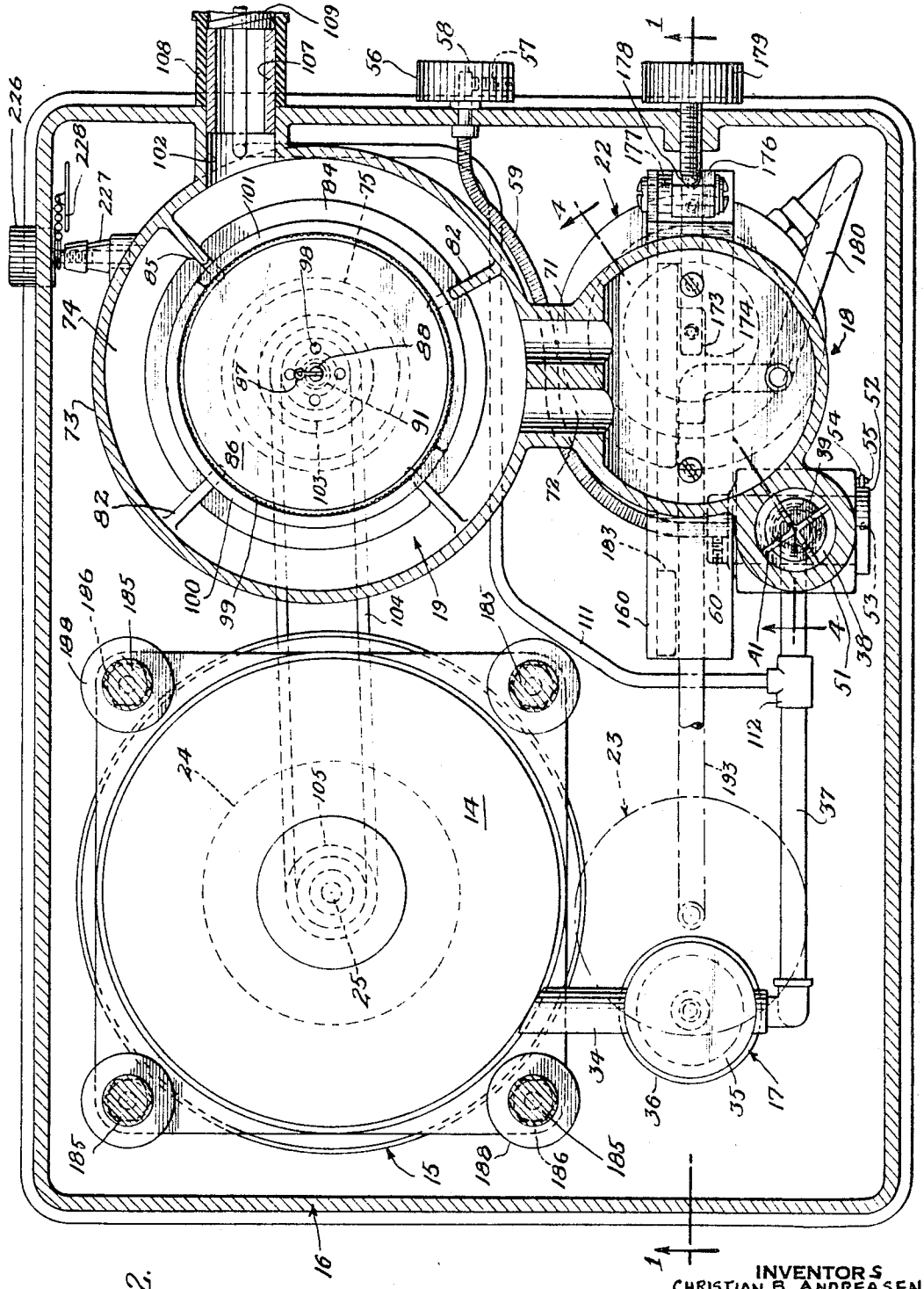

Fig. 2.

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RESPIRATORY ASSISTER

Filed May 4, 1961 5 Sheets-Sheet 3

Fig. 3.

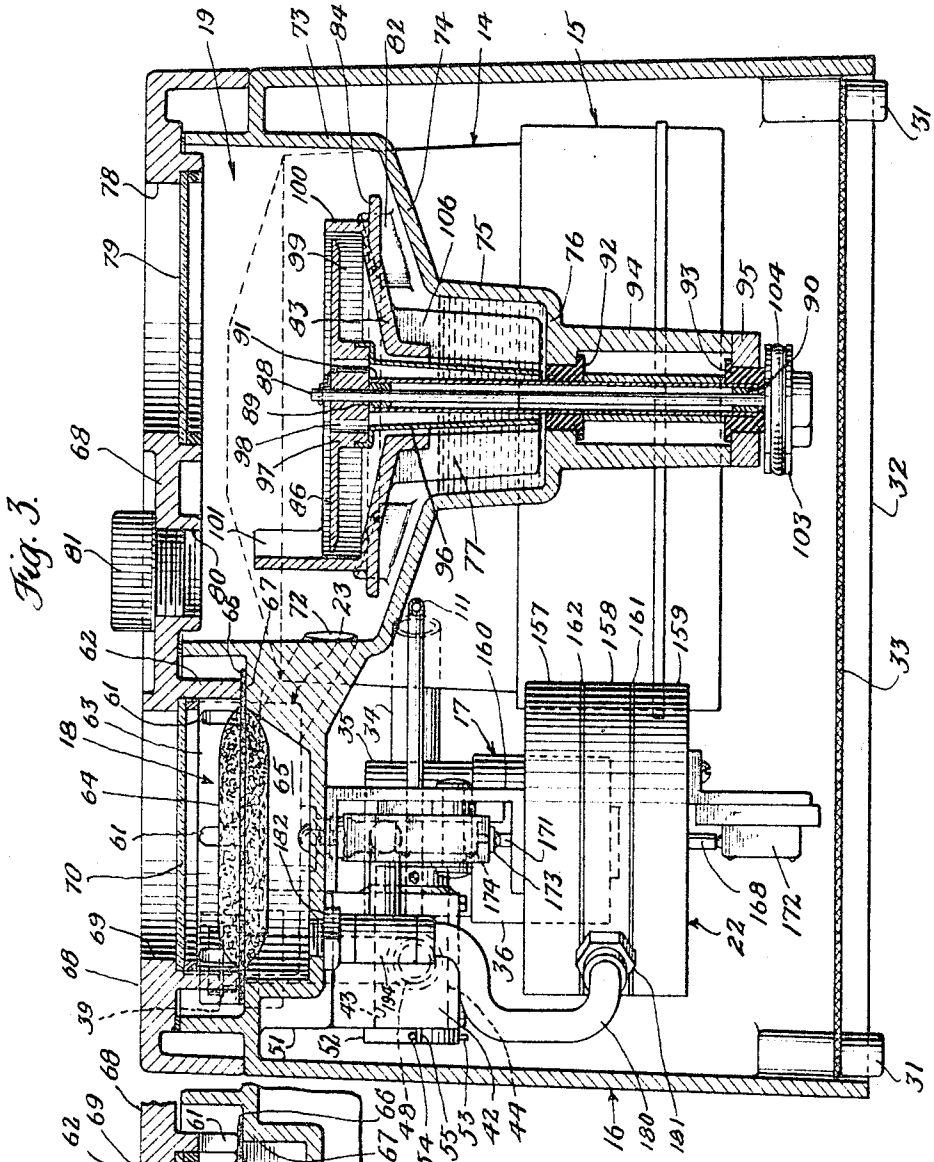
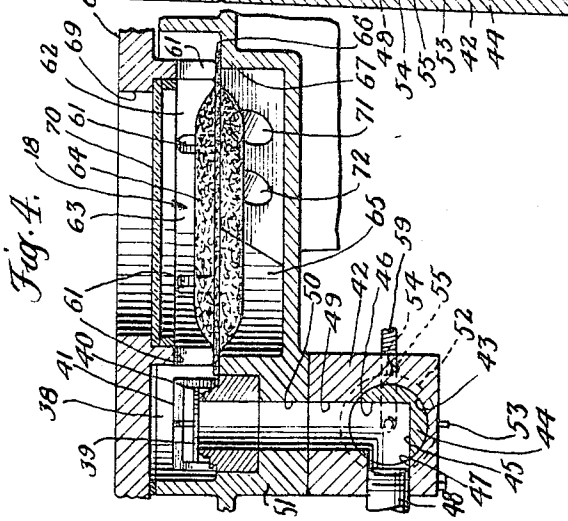


Fig. 4.



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Aug. 23, 1966 C. B. ANDREASEN ETAL 3,267,935

RESPIRATORY ASSISTER

Filed May 4, 1961 5 Sheets-Sheet 4

Fig. 5

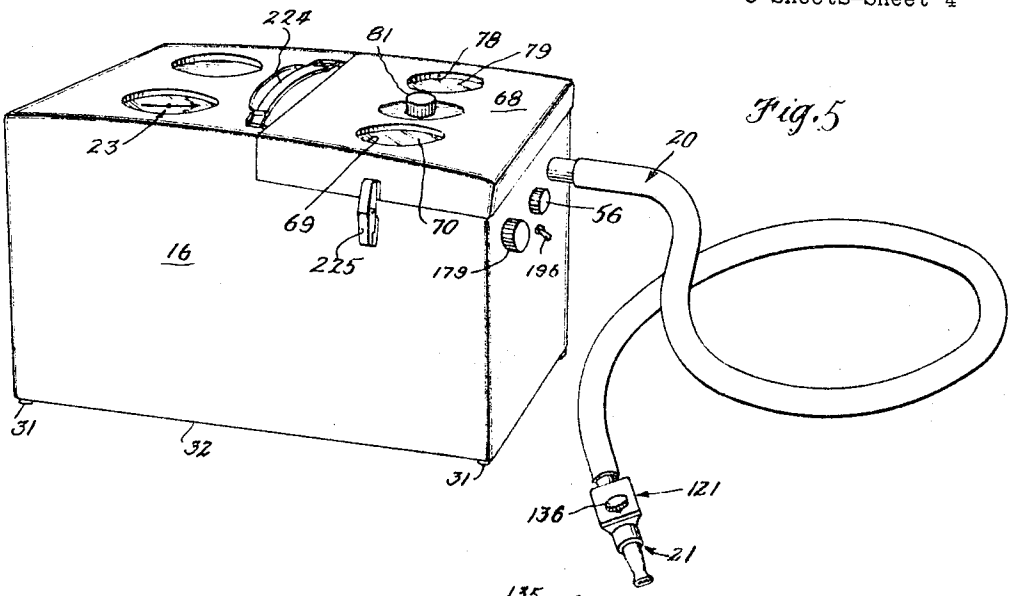


Fig. 6.

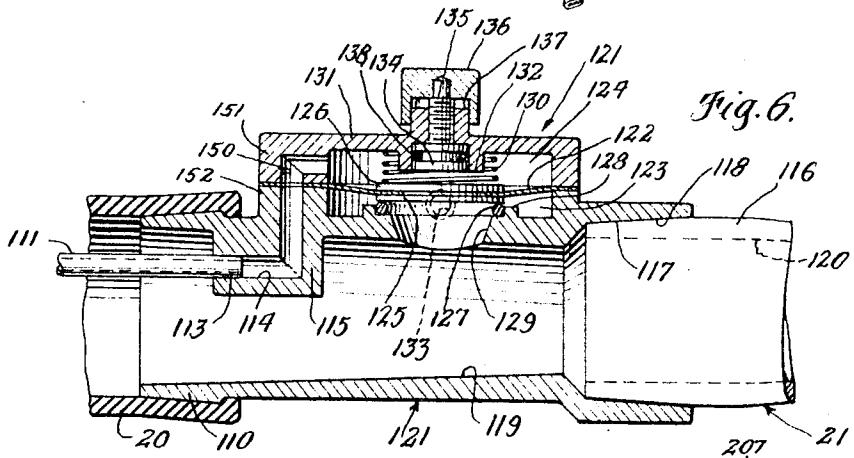


Fig. 7.

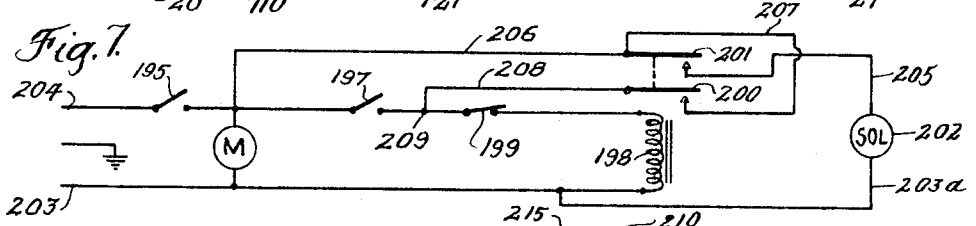
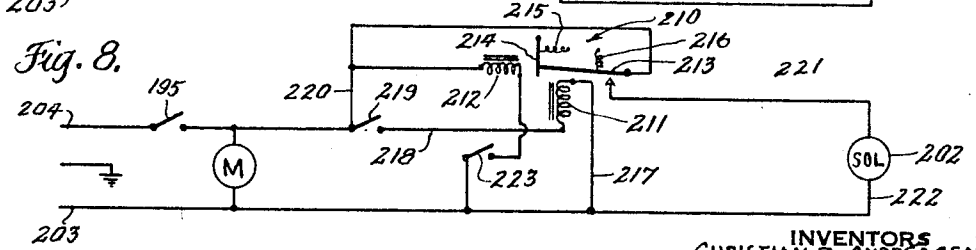


Fig. 8.



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RESPIRATORY ASSISTER

Filed May 4, 1961 5 Sheets-Sheet 5

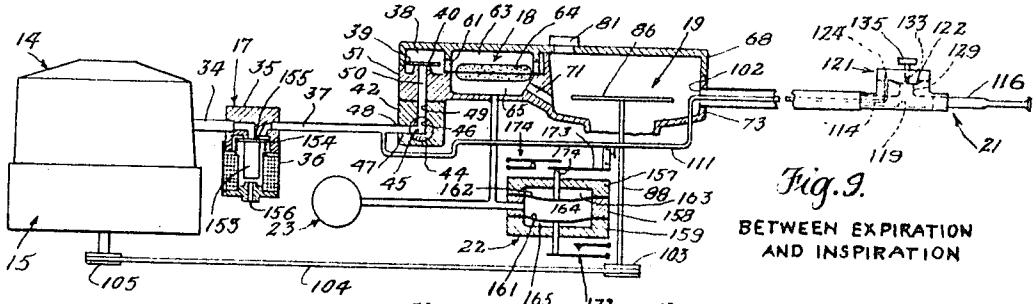

Fig. 9.

BETWEEN EXPIRATION AND INSPIRATION

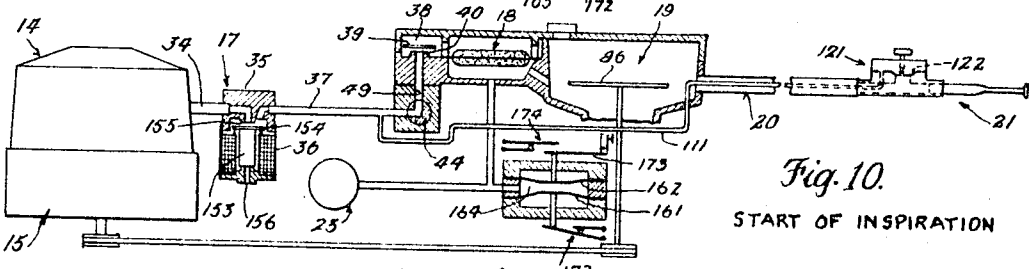

Fig. 10.

START OF INSPIRATION

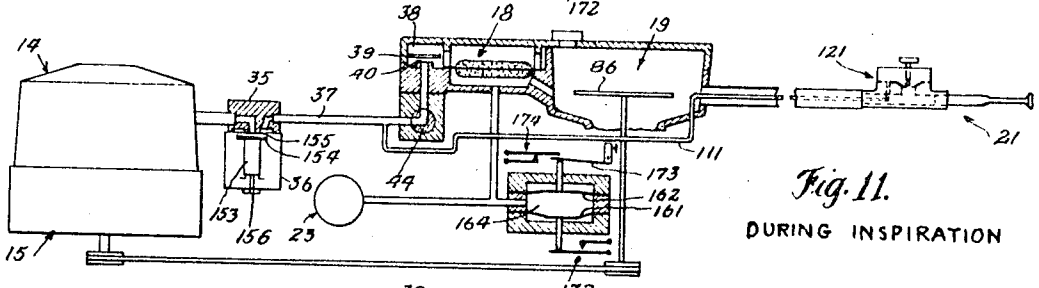

Fig. 11.

DURING INSPIRATION

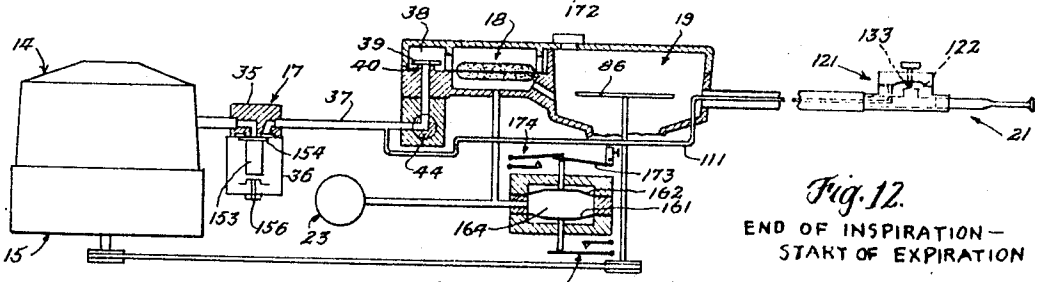

Fig. 12.

END OF INSPIRATION— START OF EXPIRATION

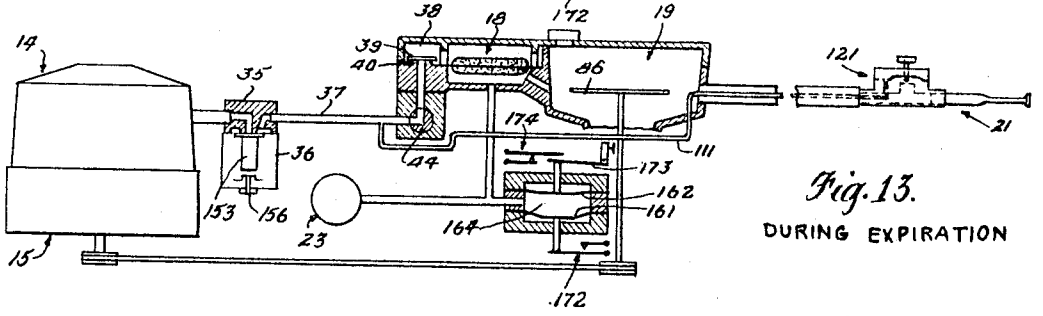

Fig. 13.

DURING EXPIRATION

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United States Patent Office 3,267,935 Patented August 23, 1966

3,267,935

RESPIRATORY ASSISTER

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Filed May 4, 1961, Ser. No. 107,756
9 Claims. (Cl. 128—29)

This invention relates to a device for assisting respiration, more particularly, to an intermittent positive pressure breathing device.

By an intermittent positive pressure breathing device is meant, a respiratory assister which delivers air under pressure to a patient (through a suitable mask or mouthpiece) during inspiration and also, preferably, provides for expiration against a positive pressure. The maintenance of positive pressure during exhalation is of assistance in maintaining the airways to the alveoli in open condition so that effective ventilation can take place.

Clinical studies have demonstrated the value of intermittent positive pressure breathing in the treatment and pulmonary rehabilitation of patients with respiration distress such as dyspnea, hard racking cough and tenacious sputum. Included in the conditions which can be improved by the use of the intermittent positive pressure breathing apparatus of the invention are, chronic pulmonary emphysema, chronic bronchitis, pulmonary fibrosis, bronchial asthma, bronchiectasis, pulmonary edema, pneumoconiosis, cor pulmonale, bronchitis fibrosa obliterans, and pulmonary arteriosclerosis.

The beneficial results obtained by intermittent positive pressure breathing include the following:

(1) Ventilation is substantially improved without increase in the work of breathing; the minute volume, vital capacity and maximum breathing capacity are increased and the residual volume is decreased.

(2) The alveoli are more uniformly and effectively ventilated, thus improving the gaseous interchange and raising the oxygen content of the blood.

(3) Improved alveolar ventilation also aids in the elimination of carbon dioxide, which is of special value because of the tendency of patients suffering from respiratory insufficiency to develop a respiratory acidosis. Improved elimination of carbon dioxide helps to restore sub-normal sensitivity of the respiratory center and aids pulmonary circulatory compensation.

(4) Oxygen or oxygen and helium mixtures can conveniently and efficiently be administered.

(5) Bronchial drainage can be encouraged by utilizing a peak expiratory flow rate greater than the peak inspiratory flow rate.

(6) A more efficient cough reflex is established.

(7) An effective dissemination of aerosols is provided, which aids in the medication of the bronchial mucous membranes, and this reduces bronchial resistance by relieving congestion of the membranes, loosening mucous plugs and reducing bronchospasm.

(8) An effective form of deep breathing exercise is performed, which helps to maintain tone in the muscles of respiration.

The above beneficial effects of treatment with the intermittent positive pressure breathing apparatus of the invention cause marked symptomatic improvement in many patients. Breathing becomes easier, the exercise tolerance is increased, coughing and wheezing are reduced, appetite improves, expectoration is easier, and respiratory infections are less frequent and less severe.

Prior intermittent positive pressure breathing devices have been generally deficient in subtlety of control and sensitivity to patient breathing initiative, and have employed relatively large and complicated apparatus depending for its operation upon an assured source of pressure gas, such as an air compressor, a tank of oxygen, etc. Such prior devices have thus not been readily available on a practical basis to most patients. Indeed, positive pressure breathing has normally only been able to be done in a physician's office, a clinic or a hospital.

The invention provides a respiratory assister, useful in the rehabilitation of patients suffering from chronic respiratory insufficiency, the assister being in the form of a compact and pneumatically self-contained unit which is easily and conveniently portable and can be readied for operation at any location by simply plugging in an ordinary electric cord. The invention provides for the supply of a stream of air (with or without aerosolized medication and/or humidification) under controlled pressure during inspiration, for a predetermined maximum inspiratory pressure, and for cycling at the will of the patient and in response to even slight inspiratory effort on the part of the patient. The invention provides separate and safe controls over inspiratory flow, maximum inspiratory pressure, and expiratory flow.

The primary object of the present invention is the provision of a portable and pneumatically self-contained positive pressure breathing device having a sensitivity to patient breathing initiative and a subtlety of control not heretofore available. It is, thus, contemplated that the invention be easily transportable by the patient to his home, or office, or on trips, etc. so that the benefits of positive pressure breathing are readily accessible.

A further object of the invention is the provision of positive pressure breathing apparatus integrally incorporating means for aerosolized medication and/or humidification.

Still further the invention has as an object the provision of a positive pressure breathing device which delivers only thoroughly filtered air to a patient.

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

FIGURE 1 is a sectional elevational view taken on the line **1**, **1** of FIGURE 2 but with the gauge and solenoid valve shown in elevation;

FIGURE 2 is a plan section taken on the line **2**, **2** of FIGURE 1 but with the motor housing appearing in full plan view;

FIGURE 3 is a vertical cross-sectional view taken on the line **3**, **3** of FIGURE 1 with the leaf spring assembly and the diaphragm structure appearing in full elevation;

FIGURE 4 is a fragmentary cross-sectional view taken on the line **4**, **4** of FIGURE 2;

FIGURE 5 is a perspective view of the invention, on a reduced scale;

FIGURE 6 is an enlarged sectional view of the exhaust valve associated with the patient's mouthpiece;

FIGURES 7 and 8 are wiring diagrams showing two embodiments of the invention; and

FIGURES 9 through 13 are diagrammatic views showing the conditions of parts of the apparatus during the different phases of the operation thereof.

The various parts of the invention are preliminarily identified in general terms. The motor housing **14** is directly associated with a fan housing **15** which is mounted within the casing **16**. Also mounted within the casing are the main air flow valved device **17**, the air filter **18**, the aerosol chamber **19**, the diaphragm control apparatus **22**, and the pressure gauge **23**. The unit includes an air delivery hose **20** and mouthpiece device **21**.

In more detail, in FIGURE 1, the motor housing **14** houses an electric motor **24** having a drive shaft **25** which

protrudes downwardly through the fan housing **15**. On the motor shaft **25**, the fan, including discs **26** and **27**, is mounted for rotation. The discs **26** and **27** carry fan blades **28** and **29**, respectively. During rotation of the fan, air is sucked into the bottom of the fan housing **15** through the aperture **30**. It is here noted that the casing **16** includes appropriate rubber legs **31** which may rest on the floor or a table and which hold the bottom surface **32** of the casing **16** out of contact with the supporting surface. The crack beneath the casing **16** provides for the ingress of air into the bottom of the unit, from which the air passes upwardly through the foraminous cover plate **33** and through the aperture **30**, as above described.

Under the action of the fan blades **28** and **29**, a positive pressure is built up within the fan housing **15** and air under pressure is delivered (see FIGURE 2) through the air flow conduit means **34** to the main air valve **17**.

The main air valve **17** includes a valve housing **35** and a solenoid **36** associated therewith and adapted to open and close the main valve upon energization and deenergization, as described more fully below.

From the main valve **17** the stream of air under pressure flows through the conduit **37** of the inspiratory flow control device **42** (described below) and into the check valve chamber **38** (see FIGURES 2 and 4). The check valve chamber **38** includes a valve disc **39** adapted to seat against the valve seat **40**, the disc **39** being held within the disc cage **41**. The check valve **39** is oriented so as to permit flow in direction from the fan toward the patient and to prevent flow in the opposite direction.

The inspiratory flow control block **42** is provided with a bore **43** within which the rotatable cylinder **44** is mounted. The cylinder **44** has intersecting bores **45** and **46** providing a flow passage through the cylinder. When the cylinder **44** is in the angular position illustrated in FIGURE 4, the bore **45** is aligned with the corresponding bore **47** in the block **42** into which the end **48** of the pipe **37** (FIGURE 2) is screwed. The bore **46** is, in this position, aligned with bore **49** in block **42** which is, in turn, aligned with bore **50** in the lower valve housing **51**.

From the enlarged flange **52** on the cylinder **44**, the stop pins **53** and **54** protrude in radial direction at 90° to each other. A cooperating abutment pin **55** is provided protruding from the block **42** in position to abut the pin **54** in the extreme angular position of the cylinder **44** which is illustrated in FIGURE 4, and to abut the pin **53** when the cylinder **44** is rotated 90° in a counterclockwise direction. When the cylinder **44** is rotated so that the pin **53** abuts the pin **55**, the flow passage through the cylinder **44** will be occluded because the end of the bore **45** will be disposed toward the wall of the bore **43** instead of toward the bore **47**.

From the foregoing it will be seen that angularly positioning the cylinder **44** intermediate the extreme positions provides for a greater or lesser interference with the flow of air through the bores **45** and **46**. By this means a sensitive control of inspiratory flow is attained.

The angular position of the cylinder **44** is determined by the control knob **56** (FIGURE 2) secured by a set screw **57** to the flexible shaft **58** passing through the wall of the casing **16**, through the flexible cable **59** and into an aperture in the end of the cylinder **44**, in which aperture the flexible shaft **58** is secured by means of the set screw **60**. The flexible shaft **58** provides a direct mechanical interconnection between the rotatable knob **56** and the rotatable cylinder **44**.

From the check valve chamber **38** the stream of air under pressure flows through the apertures **61** in the retaining ring **62** into the upper portion **63** of the filter chamber **18**. A pad of filter medium **64**, such as glass fibers, separates the upper portion **63** from the lower filter chamber portion **65** so that the entire air stream must pass downwardly through the filter material **64**. The edge of the pad **64** is squeezed, as shown at **66**, between the retaining ring **62** and the shoulder **67** of the lower chamber **65**.

The retaining ring **62** depends from a removable cover plate **68** having a large aperture **69** therethrough. The aperture **69** is covered by a sight glass **70** so that the operator can readily observe the relative cleanliness of the filter pad **64** by looking downwardly through the aperture **69** and the sight glass **70**.

From the lower filter chamber **65** the stream of filtered air flows through the channels **71** and **72** into the aerosol chamber **19**.

The aerosol chamber **19** is formed by a generally cylindrical upper side wall **73**, an inwardly sloping bottom wall **74**, reservoir walls **75**, and bottom wall **76**. The reservoir wall **75** and bottom wall **76** form a cup-shaped extension below the central portion of the aerosol chamber **19** and provide for a reservoir of water and/or liquid medication, indicated at **77**.

The top cover **68** extends over the aerosol chamber **19** and, above the aerosol chamber, includes an aperture **78** provided with a sight glass **79** so that the operator can observe the functioning of the aerosol device by looking downwardly through the aperture **78** in the sight glass **79**. A fill orifice **80** is provided in the cover plate **68** and, when not in use, is plugged by a threaded plug **81**.

A series of radial fins **82** protrude upwardly from the sloping wall **74** and support the disc housing **83** having a horizontal flange **84** slotted as at **85** (FIGURE 2) to accommodate the fins **82** and position the disc housing **83**.

Within the disc housing **83** there is provided a thin circular disc **86** keyed, as by key member **87**, to disc shaft **88** journalled in upper bearing **89** and lower bearing **90**. The upper bearing **89** and lower bearing **90** are carried in hollow bearing shaft **91** which is supported in spaced rubber grommets **92** and **93** which are, in turn, supported by the cylindrical standard **94** and bottom cap **95**. It is to be understood that the shaft **88** rotates and that the bearings **89** and **90**, and the shaft **91** are fixed against rotation.

A tapered sleeve member **96** extends downwardly from a collar **97** depending from the underside of disc **86**. Apertures **98** pass through the collar **97** and communicate with the interior of the sleeve **96**. When the disc is rotated, water flows up the tapered sleeve **96**, through the apertures **98** and onto the upper surface of the disc **86**. The water rapidly spreads into a thin film on the upper surface of the disc **86** and is hurled outwardly by centrifugal force. The water film breaks into small particles which leave the disc tangentially at high velocity and strike the serrations **99** around the inside of ring **100**. Upon striking the serrations **99** the particles of water split into minute particles most of which are small enough to be suspended in the air. The larger particles are removed from the air prior to the delivery thereof to the patient by striking the top plate or walls of the aerosol chamber **19**. To assist in the removal of larger particles, the shroud **101** extends substantially half way around the ring **100** and protrudes upwardly therefrom in position to prevent the air stream from flowing relatively directly through the aerosol chamber **19** and out of the exit passage **102**. Relatively direct flow through the chamber **19** might result in the entrainment of liquid particles of larger than desired size. The shroud **101** prevents particles of larger than desired size from being hurled directly out of the exit passage **102** by the whirling disc, because the tangential paths from the disc directly to the exit passage **102** are blocked by the shroud **101**.

The disc **86** and disc shaft **88** are rotated by means of the pulley **103** mounted on the lower end of the shaft **88**, the belt **104**, and the pulley **105** mounted on the lower end of the motor shaft **25**.

Radial vanes **106** protrude downwardly from the disc housing member **83** and minimize rotation of the body of water in the reservoir. Rotation of the water would tend to result in the centrifugal distribution of the water in a

cup or whirlpool and this would interfere with water flow up through the tapered sleeve **96**.

The grommet **92** provides an effective water seal to prevent the water in the reservoir from leaking out around the bearings.

The filtered and aerosolized stream of air under pressure is delivered from the aerosol chamber **19** through the exit opening **102** and the exit connector **107** which is adapted to be connected with a length of flexible plastic or rubber tubing **108** preferably incorporating a helical reinforcing wire **109**. The delivery tubing **108** (see FIGURE 6) leads to the connector fitting **110** of the patient's mouthpiece device **21**.

As best seen in FIGURES 2 and 6, a small conduit **111** is branched from the conduit **37** by means of a T connector **112**. The small conduit **111** extends out of the unit inside of the tubing **108** and the outer end **113** thereof fits into the passage **114** provided through the wall **115** of the mouthpiece assembly.

The mouthpiece **116** is tapered as at **117** to provide a friction fit with the tapered aperture **118** in the mouthpiece device **21**. A bore **119** extends through the mouthpiece device **21** and thus interconnects the hose **108** and the bore **120** of the mouthpiece **116**.

An exhaust valve generally indicated at **121** is provided on the mouthpiece device **21**. The exhaust valve **121** includes a valve chamber divided by means of the flexible diaphragm **122** into a first, or lower, compartment **123** and a second, or upper, compartment **124**. The diaphragm **122** carries, centrally, discs **125** and **126** mounted in aligned position against opposite faces thereof. The lower disc **125** serves as a valve member and, for this purpose, is adapted to seat against the O ring **127** retained in position by means of the shoulder **128**. The bore **129** provides for the exposure of the compartment **123** to the pressure within the bore **119** of the mouthpiece device **21** and thus to exposure to the pressure within the patient's lungs.

The diaphragm **122** and discs **125** and **126** are biased toward the downward position by means of a compression spring **130** which abuts the upper surface of the disc **126** and the roof **131** of the upper chamber **124**. The spring is retained in position by means of the shoulder **132**.

An exhaust vent **133** vents the lower chamber **123** to atmosphere. When the disc **125** is in the downward position against the seat **127**, the flow of air from inside of the mouthpiece device **21** (and thus from inside the patient's lungs) into the compartment **123** is prevented. However, when the disc **125** is cracked off of the seat **127**, air can exhaust from the patient through the bore **129** and the chamber **123** and out through the exhaust vent **133**. The exhaustion of air through the vent **133** takes place when the pressure differential across the diaphragm **122** is such as to result in the upward displacement of the diaphragm from the position shown in FIGURE 6.

Abutment means **134** in the form of an enlargement at the end of a threaded member **135** is positioned to limit the upward travel of the disc **126**. By rotating the control knob **136** the relative position of the threaded member **135** within the collar **137** is adjusted to provide for the extension of the abutment means **134** downwardly to a greater or lesser degree. The knob **136**, threaded member **135** and abutment means **134** will remain in the adjusted position because of the frictional retarding force developed by the O ring **138** which engages the abutment means **134** and the wall of the surrounding shoulder **132**.

By adjusting the position of the abutment means **134**, the degree of possible displacement of the diaphragm and disc assembly off of the seat **127** is controlled, and provides for a greater or lesser interference with the outflow of air from the patient through the exhaust vent **133**. The control knob **136** and associated parts thus provide a sensitive expiratory flow control.

The passage **114** interconnects with a similar passage **150** in the cap **131** of the exhaust valve **121**. The diaphragm **122** is clamped around its periphery between the flange **151** on the cap **131** and the flange **152** on the body of the valve structure. The diaphragm is apertured to provide communication between the passage **114** and the passage **150**. The passage **150** opens into the upper chamber **124**. The small conduit **111** and the passages **114** and **150** thus provide for the exposure of the compartment **124** and the upper side of the diaphragm to the pressure in the air flow line **37** between the main valve **17** and the inspiratory flow control block **42**.

As best seen in FIGURE 9, the main air valve **17** includes a solenoid follower **153** which carries a valve disk **154** adapted to seat, in the upper position, against the seat **155** and thereby occlude flow from the fan through the conduit **34**. In the upward position in which flow from the fan is occluded, the vent **156** is uncovered and communicates with the open end of the conduit **37**. The conduit **37**, from the check valve disc **39** to the main air valve **17**, is thus vented to atmosphere when the main air valve is in the closed position.

Since the small pressure line **111** connects into the line **37**, the line **111** and thus the upper compartment in the exhaust valve **121**, will be vented to atmosphere when the main air valve is in the closed position. This arrangement relieves the pressure on the upper side of the exhaust valve diaphragm **122**. Pressure from the patent's lungs during the start of the expiration phase will lift the diaphragm **122** and the disc **125** off the seat **127** and permit the expired air to exhaust through the vent **133**.

However, as soon as the main air valve is opened by the operation of the solenoid, pressure air flows through the small line **111** and fills the upper compartment in the exhaust valve and thereby assists in seating the disc **125** on the seat **127** and thus occluding the exhaust vent **133**.

When the main air valve is in the open position, see FIGURE 10, the vent **156** is closed by the bottom surface of the solenoid follower **153**.

Attention is now turned to a particularly important part of the invention. As seen in FIGURE 1, the diaphragm structure **22** includes an upper housing **157**, an intermediate housing **158**, and a lower housing **159** which are assembled together and supported by the channel member **160**. A first or lower diaphragm **161** and a second or upper diaphragm **162** are arranged in spaced relation within the diaphragm structure with the peripheries of the diaphragms held firmly between the members **157–159**. The diaphragms **161** and **162** thus divide the interior of the diaphragm structure **22** into an upper space **163**, an intermediate space **164**, and a lower space **165**.

The diaphragm **161** carries central discs **166** and **167** on the lower and upper faces thereof and also follower pin **168** depending therefrom. Upward diaphragm **162** has similar discs **169** and **170** against the lower and upper faces thereof and an upstanding follower pin **171**.

The follower pin **168** of lower diaphragm **161** is adapted to actuate the mirco switch **172** which is electrically interconnected with the solenoid **36** of the main air valve. The follower pin **171** of the upper diaphragm **162** impinges on the spring finger **173** which, in turn, actuates the micro switch **174** also electrically connected with the solenoid **36**.

A spring finger **173** is secured by screws **175** to block **176** mounted for rotation about the pin **177** secured to the channel member **160**. The upper end of block **176** is in contact with the threaded pin **178**, to the other end of which the control knob **179** is affixed. Rotation of the control knob **179**, by means of the threads on the pin **178**, adjusts the force exerted against the upper end of the block **176** and, since block **176** is pivoted at **177**, this results in the application of a greater or lesser yielding force against the pin **171** via the spring finger **173**.

The spring finger 173 and associated control structure thus provided a direct and accurate control of the force applied to the upper diaphragm 162 in direction urging said diaphragm away from the micro switch 174.

The space 164 (FIGURE 1) between the diaphragms 161 and 162 is exposed to the pressure in the chamber 65 below the filter member 64 by means of the conduit 180 (FIGURE 3) and the associated connectors 181 and 182.

Relay means 183 may conveniently be mounted on the channel member 160 and function in a manner described more fully below.

The motor and fan housings 14 and 15 are secured to the top 184 of the casing by means of the downwardly projecting standards 185, the bolts 186, the rubber vibration absorbers 187 and the washers 188.

The pressure gauge 23 housed in housing 189 is secured to the underside of the top 184 by screws 190 and is aligned with an aperture 191 through the top which is covered with sight glass 192. The pressure gauge, by means of the conduit 193 interconnecting with the T member 194, is exposed to the pressure within the lower filter chamber 65 and thus gives a visual indication of the pressure to which the patient is exposed.

Attention is now turned to the wiring diagrams of FIGURES 7 and 8. The motor 24 is connected to line voltage through the main switch 195 controlled by the toggle 196 (FIGURE 5).

In the embodiment of FIGURE 7, the relay 183 is comprised of a coil 198 which is connected to the power source 203–204 through switch 197 shown in open condition and switch 199 shown in closed condition. The coil 198 actuates the ganged switches 200 and 201. One side of the solenoid 36 is connected with one side 203 of the line by means of the lead 203*a*. The other side of the solenoid 36 is connected, through lead 205, switch 201 and lead 206 with the other side 204 of the line. The coil 198 is connected to the side 204 of the line by means of the lead 206, the lead 207, the switch 200, and the lead 208 which is connected at 209 between the switches 197 and 199. The other side of the relay is connected to the side 203 of the line.

The embodiment of FIGURE 7 operates as follows. The operator first closes the switch 195 by means of the toggle 196. With the mouthpiece 21 in the patient's mouth, the initial inspiratory effort of the patient causes a drop in pressure within the chamber 164 between the control diaphragms 161 and 162. The lower diaphragm 161 flexes upwardly in response to the drop in pressure. The upper diaphragm 162 remains in the downward position because of the urging of the spring finger 173. Upon the upward flexing of the diaphragm 161, the micro switch 172 is actuated to close switch 197 (FIGURE 7). Upon closing of the switch 197, the relay 198 is energized and closes the switches 200 and 201. Thereafter, continued energization of the relay 198 and the solenoid 36 are independent of the condition of switch 197, since the relay 198 holds the switches 200 and 201 in closed condition and switch 197 is bypassed by the lead 206. Eventually the pressure in the chamber 164 between the diaphragms 161 and 162 builds up to a point where the upper diaphragm is flexed upwardly to a position in which the micro switch 174 is actuated to open the switch 199. As soon as the switch 199 is opened, the relay 198 is deenergized, the switches 200 and 201 return to open condition, and the solenoid 36 is deenergized.

FIGURE 8 illustrates another electrical circuit according to the invention. The latching relay 210 includes a latching coil 211 and a release coil 212. The latching coil 211 is adapted, upon energization, to close the switch 213. Upon closing of the switch 213, the latch 214 is moved, by means of the spring 215, into a position in which it holds the switch 213 in closed condition. Energization of the release coil 212 removes the latch 214 from the path of switch 213 and permits the switch to open under the action of the spring 216.

One side of the latching coil 211 is connected by lead 217 with one side 203 of the line. The other side of the coil 211 is connected by the lead 218 to the other side 204 of the line through the switch 219. The switch 219 assumes the closed condition upon actuation of the micro switch 172 by downward flexing of the lower diaphragm 161. When the switch 219 is closed, and thus the switch 213 is closed, the solenoid 36 is connected across the line by means of lead 220, switch 213, lead 221, and lead 222. The solenoid will continue to be energized, independent of the condition of the switch 219, because of the action of the latch 214 which holds the switch 213 in closed condition even if the latching coil 211 is deenergized.

The buildup of pressure between the diaphragms eventually flexes the upper diaphragm 162 to the point where the micro switch 174 is actuated to close the switch 223 and energize release coil 212. At this point the latch 214 is moved out of the way of the switch 213 and the switch 213 opens and deenergizes the solenoid 202.

Attention is now turned to the diagrammatic views in FIGURES 9–13 which illustrate the different conditions of the equipment during operation. As indicated on these figures, FIGURE 9 illustrates the condition during the pause after expiration has ended and before inspiration begins, FIGURE 10 illustrates the condition at the very beginning of the next inspiration, FIGURE 11 illustrates the condition during inspiration and before the full maximum positive pressure has been developed in the patient's lungs, FIGURE 12 illustrates the condition at the end of inspiration and the start of expiration, that is, the point of attainment of the maximum predetermined pressure in the patient's lungs, and FIGURE 13 illustrates the condition of the equipment during expiration.

Initially, it is mentioned that the device can be readily carried by the handle 224 (FIGURE 5) to any location convenient for the patient. The condition of the filter member 64 can be observed through the sight glass 70 and, in the event that the filter appears to be dirty and requires changing, the cover plate 68 can be released from the catches 225 (one of which appears in FIGURE 5). Removal of the cover raises the ring 62 and a clean filter pad 64 can be inserted. Replacement of cover 68 brings the ring 62 into engagement with the edges of the filter pad and holds the pad in proper position.

The plug 81 may be unscrewed to expose the fill opening and water and/or liquid medication can be poured into the aerosol chamber 19.

If it is desired to supplement the air flowing to the patient with oxygen and/or helium, this can conveniety be done by removing the plug 226 (FIGURE 2) and attaching a source of the desired supplementary gas to the nipple 227 which communicates with the interior of the aerosol chamber 19. When not in use, the plug 226 is retained against loss by means of chain 228.

When the filter is clean and in position, appropriate liquid is in the reservoir, and, if desired, a source of oxygen or other supplementary gas is connected to the aerosol chamber, the unit is plugged into an ordinary source of house voltage by a conventional cord and plug (not show). The unit is turned on by means of the toggle switch 196 and the mouthpiece device 21 is gripped in the patient's mouth. The motor is now in operation and rotates the fan and aerosol disc so that pressure air and aerosolized liquid are developed. Proper functioning of the aerosol device can be observed through the sight glass 79, that is, it can be observed whether or not the disc 86 is revolving and whether or not fog or mist is being generated in the aerosol chamber 19.

In FIGURE 9, the main air valve 17 is in closed condition so that the conduit 34 is occluded. In this condition the conduit 37 is vented to atmosphere through vent 156. The upper compartment 124 of the exhaust valve 121 is also vented to atmosphere via the small pipe 111, conduit 37, and vent 156. The diaphragm 122 is yieldingly held in the downward position by the spring 130 (and also by

the force of gravity). Since the diaphragm **122** is in the downward position, the exhaust vent **133** is occluded. The diaphragms **161** and **162** are in the downward positions, the diaphragm **161** being urged toward the downward position by the force of gravity and the diaphragm **162** being yieldingly held in the downward position by the spring finger **173**. The switch **172** is open and the switch **174** is closed. The check valve **39** is in closed condition.

Attention is now directed to FIGURE 10. As the patient begins to inhale, a slight negative pressure is developed in the patient's lungs by reason of the mechanical expansion thereof by the chest muscles. The slight negative pressure in the patient's lungs is applied to the chamber **164** between the diaphragm **161** and **162**, and causes the lower diaphragm **161** to flex upwardly, as shown in FIGURE 10, and permits the switch **172** to close. The diaphragm **162** remains in the downward position.

The closing of the switch **172** effects energization of the solenoid **36** so that the main air valve **17** opens and permits pressure air to flow from the conduit **34** into the conduit **37**. At the same time, the vent **156** is closed. Pressure air is delivered from the conduit **37**, via the small conduit **111**, to the upper side of the diaphragm **122**, and aids in holding the diaphragm in the downward position. Pressure air is also delivered through the bore **49** and lifts the check valve **39** off of its seat **40** so that the pressure air flows in above the filter, down through the filter, and into the aerosol chamber **19**. From the aerosol chamber **19** the filtered and aerosolized air flows through the flexible hose **20** and into the patient through the mouthpiece **21**.

Attention is now turned to FIG. 11. At a point during inspiration shortly after that illustrated in FIG. 10, the parts assume the positions shown in FIG. 11. The pressure air has now developed a positive pressure in the chamber **164** between the diaphragms **161** and **162**. The diaphragm **161** has been flexed to the downward condition and the switch **172** has reopened. No change in the energization of the solenoid **36** takes place because of the special electrical circuit employed, as above described. The diaphragm **162** was flexed slightly upwardly but has not yet reached the point at which the switch **174** will open. During the condition of FIG. 11 pressure air is being fed into the patient's lungs.

FIG. 12 shows the condition of the parts at the moment when the pressure built up in the patient's lungs and in the chamber **164** between the diaphragms has reached the desired predetermined maximum level. At this point the downward urging of the spring finger **173** is overcome so that the switch **174** is opened and the solenoid **36** deenergized. The main air valve **17** thus returns to closed condition, as does the check valve **39**.

It is here pointed out that the exhaust valve **121** remained closed during the entire inspiratory phase, including the condition shown in FIG. 11. Positive closing of the exhaust valve **121** is facilitated by the fact that the exhaust valve diaphragm **122** (FIG. 6) is exposed to pressure differentially when in the downward position. Although the diaphragm **122** is exposed to the pressure air on both the upper and lower sides, the area on the upper side exposed to the pressure is substantially greater than the area on the lower side exposed to the pressure, with the result that there is a net downward force.

In FIG. 12 the upper side of the exhaust valve **121** is vented to atmosphere through the conduit **111**, the conduit **37** and the vent **156**. Since the air within the patient and the rest of the apparatus is still at a positive value, the diaphragm **122** of the exhaust valve will flex upwardly as shown in FIG. 12 and expose the vent **133**. Since the check valve **39** is closed and there is no other way for the gas to flow, the gas within the patient's lungs will flow outwardly through the exhaust vent **133** during expiration. This effects an important safety feature of the invention, namely, contaminated air from the patient's lungs cannot flow backwardly into the aerosol or filter chambers. As a result, the unit can be used for successive patients, after sterilization of the mouthpiece only, without fear of cross infection.

FIGURE 13 illustrates the parts during expiration. The exhaust valve **121** remains in open condition so that the air is exhausting from the patient's lungs to atmosphere. The pressure in the chamber **164** has fallen to the point where the upper diaphragm **162** has begun to flex downwardly and the switch **174** has returned to closed condition. The lower diaphragm **161** is in the downward position. As soon as expiration is completed, the exhaust valve **121** will return to the closed position, because the combined force of gravity and the spring **130** (FIG. 6) will then take over the function of positioning the diaphragm **122** in the absence of positive pressure against the bottom side of the diaphragm. The diaphragm **162** will also complete its return to the downward position. All of the parts are ready to recycle and the next inspiratory phase will be triggered by the initial inspiratory effort of the patient.

The physician will advise the patient of the desired maximum pressure to be used by the patient. Manipulation of the control knob **179** coupled with observation of the pressure developed, as indicated by the pressure gauge **23**, will thereafter enable the patient to administer positive pressure breathing to himself in exactly the degree desired by his physician.

Furthermore, by relative manipulation of the inspiratory flow control knob **56** and the expiratory flow control knob **136**, the relative rates of inspiration and expiration can be adjusted. It is often desirable to adjust the inspiratory and expiratory rates so that the peak expiratory rate exceeds the peak inspiratory rate since this arrangement facilitates bronchial drainage.

Treatment is generally desirably administered for a period of about twenty minutes at a time. At the beginning of treatment by positive pressure breathing, it is usually desirable to administer the treatment several times a day, this frequency being continued for at least about three weeks, or as long as the patient continues to show improvement. Thereafter, maintenance of the improved condition of the patient can usually be accomplished by less frequent administrations of positive pressure breathing.

In general, a pressure of about 20 cm. of water is desirable; patients with pulmonary fibrosis may need a higher pressure for a beneficial response, and those with a history of spontaneous pneumothorax are generally treated are generally treated with a lower pressure.

The emphysematous patient usually finds an early morning treatment particularly helpful in aiding elimination of retained secretions and promoting effective alveolar aeration. The asthmatic patient may find bedtime treatment the most useful. Patients who have developed respiratory acidosis may need several full treatments a day for a considerable time to get rid of accumulating carbon dioxide.

Stated in brief, the invention provides, for the first time, a portable and pneumatically self-contained positive pressure breathing device with a subtlety and accuracy of control not heretofore available. Furthermore, the invention provides for thorough filtration of the air delivered to the patient, and for aerosolized medication and humidification and for the utilization of supplementary oxygen as may be needed.

The inertia of the check valve **39**, when in the closed position of FIG. 9, must be sufficient to insure that the valve remains closed at the start of inspiration during the short interval necessary to effect upward flexure of the diaphragm **161**. If the valve **39** opened instantly at the start of inspiration, air could flow in through the vent **156** and impair the proper functioning of the unit.

The control knobs **56**, **179** and **136** can, if desired, be made readily removable so that the physician can preset the controls and then remove the knobs. Improper ad-

justment of the controls by the patient can thereby be avoided.

We claim:

1. A respiratory assister having a portable casing in which are housed the parts of a pneumatically self-contained assembly including fan means for generating a stream of air under pressure above atmospheric, and motor means for driving the fan means, the assembly comprising a patient's delivery device, conduit means for connecting the fan means with the patient's delivery device, a main control valve disposed in the conduit means, an exhaust port for connecting the conduit means to atmosphere at a point between the main control valve and the patient's delivery device, an exhaust port valve responsive to expiration by the patient to open the exhaust port, a fluid pressure device for urging the exhaust valve toward closed position during inspiration by the patient and including a fluid pressure control line having a point of connection with the conduit means between the main valve and the exhaust port, a check valve in the conduit means between said connection point and the exhaust port, said check valve being oriented to permit air flow in the direction from the fan toward the patient's delivery device and to prevent air flow in the opposite direction, control mechanism for the main control valve including a first diaphragm moveable to a control position in response to a build-up of pressure in the conduit means between the check valve and the patient's delivery device, a second diaphragm movable to a control position in response to a build-up of pressure in the conduit means between the check valve and the patient's delivery device to close the main valve, a pneumatic connection between said diaphragms and the conduit means, means interconnecting said diaphragms and said main control valve for opening the main valve when the first diaphragm moves to its control position and for closing the main valve when the second diaphragm moves to its control position, a port for venting the fluid pressure control line; and means associated with the main valve to open the port upon closure of the main valve and to close the port upon opening of the main valve.

2. A construction according to claim 1 in which the control mechanism for the main air valve comprises a solenoid, said first control diaphragm in the control position effects energization of the solenoid, the solenoid being connected in an electric circuit such that, after initial energization of the solenoid, continued energization of the solenoid is independent of the position of said first control diaphragm, the construction further including means for terminating the energization of the solenoid, said second control diaphragm, upon reaching a control position, being effective to actuate said means and de-energize the solenoid.

3. A construction according to claim 2 in which the electric circuit includes a first switch operable by said first diaphragm and a relay controlled by said switch, said elements being arranged so that the assumption by the first control diaphragm of the flexed position closes said first switch and energizes said relay, said relay upon energization, causing energization of said solenoid, holding circuit means for maintaining said solenoid energized irrespective of energization of the relay, and a second switch, said second switch being in said holding circuit and controlled by said second diaphragm, the second diaphragm being operable to open said second switch to de-energize the relay upon movement of the diaphragm to control position.

4. A construction according to claim 2, further including a first switch controlled by said first diaphragm and a latching relay having a latching coil and a release coil, said latching coil being energized by said switch when the first diaphragm moves to control position, a second switch, said second switch being controlled by said second diaphragm and being connected to said release coil to energize said coil when the second diaphragm moves to control position, said latching relay being connected to the solenoid to energize the solenoid when in the latched condition.

5. A construction according to claim 1 and further including yielding means urging the second control diaphragm away from a control position, and control means for adjusting the urging force applied by said yielding means.

6. A construction according to claim 1 in which the pair of flexible control diaphragms are held in space relation around the peripheries thereof, and in which the space between the control diaphragms is exposed to the pressure in the patient's delivery device.

7. A construction according to claim 6 further including adjustable spring means for yieldably urging the second of said control diaphragms away from the flexed position, and further including control means for adjusting the force applied to the diaphragm by said spring means.

8. A respiratory assister having a portable casing in which are housed the parts of a pneumatically self-contained assembly including fan means for generating a stream of air under pressure above atmospheric, and motor means for driving the fan means;

the assembly comprising a patient's delivery device, conduit means for connecting the fan means with the patient's delivery device, a main control valve disposed in the conduit means,

an exhaust port for connecting the conduit means to atmosphere at a point between the main control valve and the patient's delivery device, an exhaust port valve responsive to expiration by the patient to open the exhaust port,

a fluid pressure device for urging the exhaust valve toward closed position during inspiration by the patient and including a fluid pressure control line having a point of connection with the conduit means between the main valve and the exhaust port,

a check valve in the conduit means between said connection point and the exhaust port, said check valve being oriented to permit air flow in the direction from the fan toward the patient's delivery device and to prevent air flow in the opposite direction,

control mechanism for the main control valve including pressure responsive means, responsive to a pressure drop in the conduit means between the check valve and the patient's delivery device to open the main valve, said pressure responsive means being further responsive to a build-up of pressure in the conduit means between the check valve and the patient's delivery device to close the main valve,

a port for venting the portion of the conduit means between the main valve and the check valve means connected with said main valve and controlled thereby to open the port to effect such venting upon closure of the main valve.

9. A respiratory assister comprising, as a portable assembly, an air supply system including a fan and a motor therefor, a device for delivering air to a patient, and conduit means interconnecting the delivery side of said fan and the patient delivery device, main valve means interposed in the conduit means and adapted to controllably assume a delivery condition in which air is permitted to flow through the conduit means and a closed condition in which air flow through the conduit means from the fan is occluded, an aerosol device interposed in the conduit means between the main valve means and the patient delivery device, the aerosol device including means for generating a suspension of liquid particles in the air flowing through the unit and into the patient, the conduit means having an exhaust port located between the aerosol device and the patient delivery device providing for patient expiration to a zone external of the air supply system, a check valve in said conduit between the main valve means and the exhaust port, said check valve being oriented to permit air flow in the direction

from the fan toward the patient's delivery device and to prevent air flow in the opposite direction, an exhaust port valve responsive to patient expiration to open the exhaust port, a fluid pressure device for urging the exhaust port valve toward closed position during inspiration by the patient and including a fluid pressure control line having a point of connection with the conduit means between the main valve means and the check valve, pressure responsive control mechanism, a fluid pressure connection between the pressure responsive mechanism and the conduit means at a point between the check valve and the patient delivery device, said pressure responsive control mechanism being operable to assume a first control condition in response to a drop in pressure in said conduit means and a second control condition in response to a build-up of pressure in the conduit means to effect the open condition by the main valve means when in said first control condition and to effect the closed condition

by the main valve means when in said second control condition, a vent for said pressure control line and means connected to said main valve means for opening the vent when the main valve means is closed and for closing the vent when said main valve means is opened.

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