







## RESPIRATION APPARATUS

## BACKGROUND OF THE INVENTION

## 1. Field of the Invention

The present invention relates generally to respiration device and more particularly to respiration devices which depress the abdominal muscles of the patient during the exhalation portion of the respiration cycle.

## 2. Description of Prior Art

Presently known respiration devices generally deliver air to the mouth or nose of the patient during the inhalation portion of the respiration cycle and such air is at relatively low pressures. Respiration devices, including belts having abdominal bladders, have been proposed but these devices operate on a timed cycle independent of the patients natural breathing rhythm. There are no prior art respiration devices known to applicant which include abdominal bladders which are alternately inflated and exhausted in response to the patients normal breathing cycle.

## SUMMARY OF THE INVENTION

The respirator apparatus of present invention is characterized by a jacket having a collapsible bladder for alternate inflation and deflation to selectively depress and release the abdominal muscles of a patient in response to his own breathing rhythm. A valve controlling flow from a pressure source is controlled by means responsive to the patient's inspiratory phase to inflate the bladder and, further, responsive to the patient's expiratory phase to exhaust the bladder.

The control means may include a plurality of fluid amplifiers which sense the patient's breath and amplify same to control pressurization fluid flow to and from the bladder.

Other objects and features of the invention will become apparent from consideration of the following description taken in connection with the accompanying drawings.

## DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a jacket having an inflatable bladder which may be utilized with the respiration apparatus of present invention;

FIG. 2 is a perspective view similar to FIG. 1 but in reduced scale and showing the jacket on a patient;

FIG. 3 is a schematic view of a respiration apparatus embodying the present invention;

FIG. 4 is a schematic view of a second embodiment of the respiration apparatus of present invention;

FIG. 5 is a schematic view of a third embodiment of the respiration apparatus of present invention;

FIG. 6 is a perspective view of a face mask which may be utilized with the respiration apparatus of present invention; and

FIG. 7 is a perspective view of a nosepiece which may be utilized with the respiration apparatus of present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. 2 and 5, the respiration apparatus of present invention includes a jacket generally designated, 11, having an inflatable bladder, 13, therein. Pressurization of the bladder, 13, is controlled by a control valve, generally designated 17, which is operatively connected with a pressure control system which includes a nosepiece, 21, (FIG. 7) for sensing the inspiratory and expiratory phases of the patients' respiration cycle to selectively deflate and inflate the bladder, 13, to manipulate the patients' abdominal muscles to provide breathing assistance.

Referring to FIG. 5, air pressure is supplied to the system S through a supply conduit 25 from which a control conduit 27 branches off and passes air through a filter 29. The outlet of the filter 29 is connected with a pressure regulator 31 by means of a conduit 33 and a main pressure supply conduit 35

is connected with the outlet of such regulator. A pressure sensor biasing conduit 37 branches off the main conduit 35 and passes air through a pressure reducing orifice 39, the outlet of such orifice being connected with the control port 45 of a high gain fluidic amplifier, generally designated 47, by a conduit 46.

A sensing tube 41, connected with the nosepiece 21, is also connected to the control port 45 of the amplifier 47 by a conduit 41, passage of such amplifier having its inlet connected with the main pressure conduit 35 by means of conduits 53 and 55. The conduit 53 also delivers pressure to an orifice 59 which is connected with the inlet of an auxiliary passage 61 of the amplifier 47 by means of a conduit 63, the opposite end of such a passage being open to atmosphere at 65. A bias conduit 69 branches off from the conduit 63 and includes an orifice 71 which is connected with a bias port 73 opposing the control port 45. The auxiliary passage 61 is communicative with the primary passage 51 by means of a transverse passage 79. The primary passage 51 branches into a vent outlet 81 and a pressurization outlet 83, the vent outlet being connected to a vent control port 82 of a power amplifier, generally designated 84, by means of a conduit 86.

Still referring to FIG. 5, the pressurization outlet 83 is connected with a pressurization control port 111 of a power amplifier 84 by means of conduit 115. The primary passage 125 of the amplifier 84 is connected on its inlet end with the main tube 35 by a conduit 127 and such primary passage branches into a vent outlet 129 and a pressurization outlet 131.

With continued reference to FIG. 5, the vent passage 129 is connected with a vent control port 135 of a second power amplifier, generally designated 127, by a conduit 139 and the pressurization outlet 131 is connected with a pressurization control port 141 of the amplifier 137 by a conduit 143. The primary passage 149 of the amplifier 137 has its inlet connected with the main tube 35 by a conduit 151 and branches into a vent outlet 153 and a pressurization outlet 155. The power amplifier 137 includes an override control port 154, connected with the main pressure line 35 by a conduit 156, including an override valve 158. The vent outlet 153 is connected with a vent control port 157 of a third power amplifier 159 by means of a conduit 161 and the pressurization outlet 155 is connected with the pressurization control port 163 by means of a conduit 165. The inlet to the primary passage 169 of the power amplifier 159 is connected with the source conduit 33 by means of a conduit 171 which has a pressure reduction orifice 173 therein. The primary passage 169 branches into a pressurization outlet 175 and a vent outlet 177, the pressurization outlet 175 being connected with the control port of a pressurization valve 181 by means of a conduit 183. The vent outlet 177 is connected with the control chamber 185 of the control valve 17 by means of a conduit 187.

The control valve 17 includes a housing 191 which forms a pressure chamber 192 having a vent port 193 that receives a poppet 195 carried on a shaft 197 which has a piston 199 on its opposite end. The piston 199 is biased downwardly into the poppet closed position by a coil spring 201 whereby such valve is normally closed. The inlet to the chamber 192 is connected with the pressurization valve 181 by a conduit 205 and the outlet of such housing is connected with the bladder 13 by a conduit 207 whereby the system S will be effective to control the valves 181 and 17 to selectively inflate and exhaust such bladder.

To provide relief in case of over-pressurization, a sensing tube 209 is connected with the sense chamber 192 and leads to a relief control port 211 of a logic amplifier, generally designated 213. The inlet to the primary passage 215 of the amplifier 213 is connected with the main tube 35 by a conduit 217 and branches into an exhaust outlet 221 and a relief outlet 223. A conduit 225 branches off the conduit 217, includes a pressure reduction orifice 227, and is connected with a bias port 229 of the amplifier 213. The relief outlet 223 of the amplifier 213 is connected with a relief control port 231 of the aforementioned power amplifier 284 by a conduit 233.

The control system S' shown in FIG. 3 is similar to the system S and includes an air inlet tube 25 which passes air through a filter 247 to a main air tube 249. The tube 249 is connected with the inlet of a variable restrictor 251, the outlet of such restrictor being connected with a power fluid amplifier, generally designated 253, by a conduit 255. The fluid amplifier 253 acts as a control valve for selectively directing pressure to the bladder 13.

The main tube 249 is connected with a pressure reduction orifice 257 by a conduit 259 and the outlet of such orifice is connected with the inlet to the primary passage 261 of a high gain fluid amplifier, generally designated 263, by means of a conduit 265. Also connected with the outlet of the orifice 257 is a conduit 269, including a pressure reduction orifice 271, such conduit being connected with the inlet of an open ended auxiliary passage 275 of the amplifier 263 by means of a conduit 277. A switching passage 278 branches off the auxiliary passage 275 and exhausts in the side of the primary passage 261. The conduit 277 is also connected with a transverse bias port 281 in the amplifier 263 by a conduit 283, including a pressure reduction orifice 285. The above described conduit 265 is also connected with a pressure reduction orifice 291 which connects with a sensing tube 293 attached to the nosepiece 21. The sense tube 293 is connected with a sense port 294 opposing the bias port 281 by a conduit 296. The primary passage 261 branches into a vent outlet 295 and an exhaust outlet 297, the vent outlet 295 being connected with a vent control port 299 of a fluid logic element, generally designated 301, by means of a conduit 303. The primary passage 305 of the element 301 has its inlet connected with the conduit 259 by means of a conduit 307 including a pressure reduction orifice 309. The outlet of the primary passage 305 forms a pressurization outlet 311 and a vent outlet 313 branches therefrom. An auxiliary vent control port 310 is adjacent the control port 299 and both such ports exhaust out an opposed passage 312. Connected between the pressure source conduit 265 and the port 310 is a conduit 314, having an override valve 315 therein.

The pressurization outlet 311 is connected with a pressurization control port 315 of a power amplifier, generally designated 317, by means of a conduit 319 and the vent outlet 313 is connected with a vent control port 321, by means of a conduit 323. The amplifier 317 includes a primary passage 325 which has its inlet connected to the supply conduit 259 by means of a conduit 329 including a pressure reduction orifice 331. The primary passage 325 branches into a vent outlet 333 and a pressurization outlet 335, the vent outlet 333, being connected with a vent control port 337 of the above-mentioned amplifier 253 by means of a conduit 329. The pressurization outlet 335 of the amplifier 317 is connected with a pressurization control port 341 opposing the vent control port 337 by means of a conduit 343. The primary passage 346 of the amplifier 253 branches into an exhaust outlet 347 and a pressurization outlet 349, the outlet 349 being connected with the bladder 13 by means of a conduit 207.

The system S'' shown in FIG. 4 effects cyclic pressurization and venting of the bladder 13 and includes a pressure supply conduit 25 which connects with the filter 247, the outlet of the filter 247 being connected with a variable restrictor 355 by means of a main tube 357. The outlet of the restrictor 355 is connected with the inlet of a normally open pressurization valve 363, a conduit 365 being connected with the outlet of the valve 363 and communicating with the tube 207 leading to the bladder 13.

A conduit 369 branches off the main tube 357 and is connected with a pressure reduction orifice 371, the outlet of such orifice being connected with a primary passage 373 of a fluidic logic element, generally designated 375 by means of a conduit 377. The outlet of the orifice 371 is also connected with the inlet of a primary passage 381 of power type fluidic control amplifier, generally designated 388, by means of conduits 385 and 387. The primary passage 381 of the amplifier 383 branches into an exhaust outlet 389 and a vent outlet 391,

a conduit 393 being connected with the outlet 389 and exhausting to atmosphere through a restrictor orifice 395. A conduit 397 is connected with the vent outlet 391 and connects with a vent control port 399 in the fluid amplifier 375. A feedback conduit 403 is connected with a conduit 397, includes a variable pressure reduction orifice 405 and a reservoir 407, the conduit 403 connecting with a pressurization control port 409 of the amplifier 383. Similarly, a feedback conduit 413 is connected with the conduit 393, leading from the exhaust outlet 389 includes a variable orifice 415 and a reservoir 417, such conduit 413 being connected with a vent control port 419 opposing the pressurization port 409.

The outlet of the primary passage 373 of the amplifier 375 forms a pressurization outlet 423 and a vent outlet 425 branches therefrom. The logic amplifier 375 includes an auxiliary control port 424 connected with the pressure conduit 385 by a conduit 426 including an override valve 428. The pressurization 423 is connected with a pressurization control port 427 of a power amplifier, generally designated 429, by means of a conduit 431. The vent outlet 425 of the amplifier 375 is connected with the vent control port 435 opposing the pressurization port 409 by means of a conduit 437. The primary passage 441 of the amplifier 429 has its inlet connected with the main conduit 369 by means of a conduit 443, including a pressure reduction orifice 445. The primary passage 441 of the amplifier 429 branches into a vent outlet 447 and a pressurization outlet 449, the vent outlet 447 being connected with the control port of a vent valve 450, by a conduit 451. The vent outlet 449 of the amplifier 429 is connected with the inlet of a primary passage 453 of a passive fluidic element 455, by means of a conduit 457. The outlet of primary passage 453 defines a vent outlet 461 and branches into an exhaust outlet 463, the vent outlet being connected with the control port of the pressurization valve 363 by means of a conduit 465.

Referring to FIG. 7, it will be noted that the nose piece 21 comprises a hollow, close ended tube, having an elastic band 481 connected to its opposite ends to hold the nose piece on the patients' head in the position shown. The nose piece 21 includes a pair of upwardly projecting open ended nostril tubes 483 and 485 for projection into the patients' nostrils to sense inhalation and exhalation.

The mouthpiece, generally designated 487, shown in FIG. 6 includes a flexible cup-shaped enclosure 489 having an elastic band 491 attached thereto. The cup-shaped portion 489 includes a sensing port 493 disposed in front of the nose of the patient and connected through the sensing tube 41 to a sensing amplifier of either the system S or S'. The portion 489 includes a pair of exhaust ports 495 disposed on opposite sides of the sensing port 493 for exhausting exhaled air when the bladder 13 is inflated.

In operation, the jacket 11 is placed on the patient, as shown in FIG. 2 and the nose piece 21 arranged as shown in FIG. 7. Referring to FIG. 5, air is then provided to the system S through the supply conduit 25 to the inlet port of the normally closed pressurization valve 181. Air flow from the pressure regulator 31, through the main conduit 35, is communicated through the conduits 53 and 55 to the primary passage 51 of the high gain amplifier 47. Air pressure is also supplied to the auxiliary passage 61 through conduit 63 and, under the influence of air, introduced through the bias port 73, is directed out the exhaust 65 as long as no positive pressure signals are received at the sensing port 45 in communication with the nose piece 21. With the air flow in the auxiliary passage 61 passing out the exhaust 65 air flow through such primary passage is directed to the vent port 81 and communicated through the conduit 86 to the vent control port 82 of the bistable amplifier 84. Such control signal in the port 82 directs the flow through the primary passage 125 to the vent exhaust port 129 through conduit 139 to the vent control port 135 of the bistable amplifier 137. The positive signal at the port 135 directs flow from the primary passage 149 to the vent exhaust port 153, through conduit 161, to the vent control port 157 of the fluid amplifier 159. The positive signal at the

control port 157 directs flow through the primary passage 169 to the vent exhaust port 177, through conduit 187, to the control chamber 185 of the control valve 17 thereby driving the piston 199 upwardly to raise the poppet 195 off its seat and vent the bladder through tube 207. Since flow from the power amplifier 159 is directed to the conduit 187, the conduit 183 to the pressurization valve 181 will not be pressurized, thereby enabling such valve to remain closed an blocking flow from the source tube 25 to the control valve chamber 192.

Still referring to FIG. 5, when the patient completes the inspiration portion of the respiration cycle and commences aspiration, he will provide a positive pressure at the open end of the nostril tubes 483 and 485, thereby inducing a positive pressure at the sensing port 45 of the amplifier 47 and directing flow in the auxiliary passage 61 through the transverse passage 79 to the primary passage 51. Such transverse flow, in the primary passage 51 will switch flow from the vent outlet 81 to the pressurization outlet 83 and through the conduit 115, to the control port 111 of the power amplifier 113. The positive signal at the port 111 directs flow through the primary passage 125 to the pressurization outlet 131, through conduit 143 to pressurization control port 141 of the power amplifier 137. The positive signal at the control port 141 directs flow in the primary passage 149 to the pressurization outlet port 155, through conduit 165, to the control port 163 of the amplifier 159. The positive signal at the port 163 directs flow in the primary passage 169 to the pressurization exhaust passage 175 and through conduit 183 to the normally closed pressurization valve 181, thereby opening such valve and communicating pressure from the source conduit 25 to the control valve 17 through conduit 205. Such switching of the power amplifier 159 discontinues flow through the vent exhaust port 177, thereby relieving the pressure in chamber 185 of the control valve 17, enabling the poppet 195 to seat whereby the bladder 13 will be pressurized through the tube 207.

While the poppet 195 is seated on the exhaust port 193, the pressure within the chamber 192 of the valve 17 will be communicated through sensing line 209 to the sensing port 211 of the amplifier 213. Also, pressure through the conduit 217 will pass through the orifice 227 and provide a predetermined bias at the bias port 229. If the control valve 17 should fail closed, then when the pressure in the sense line 209 exceeds the bias provided at the control port 229, the flow through the primary passage 215 of the amplifier 213 will be diverted out of the relief port 223, through the conduit 233 to the control port 231 of the amplifier 84, thereby directing flow through the primary passage 125 to the outlet port 129. Such switching of the amplifier 113 will effect closing of the pressurization valve 181 and opening of the control valve 17 as described hereinabove.

In operation of the control system S' shown in FIG. 3, during inhalation only, the bias affected by bleeding through the orifice 219 will be sensed at the sensing port 294, of the amplifier 263, thereby enabling flow through the open ended auxiliary passage 275 to atmosphere. When the air in the passage 275 is exhausting in this manner and not passed through the transverse passage 278, the air in the primary passage 261 will pass out the vent outlet 295, through the conduit 303, to the vent control port 299 of the logic amplifier 301. The positive pressure at the control port 299 will direct the flow in the primary passage 305 to the vent outlet 313, through conduit 323, and to the vent control port 321 of the power amplifier 317. The positive signal at the port 321 will direct flow in the primary passage 325 to the exhaust port 333 to the control port 337 of the amplifier 253 by means of the conduit 329. The positive signal at the control port 337 will direct flow in the primary passage 346 out the vent port 347, thereby enabling air to bleed back the line 209 from the bladder 13, to cause deflation.

Still referring to FIG. 3, when the patient commences the aspiratory portion of his respiration cycle, a positive signal will be introduced to the orifice 294 of the amplifier 263, thereby directing flow in the auxiliary passage 275 through the transverse passage 278 to the primary passage 261 to direct flow

therethrough to the exhaust port 297. Exhausting air out the exhaust port 297 will relieve pressure on the conduit 303, thereby enabling the flow through the primary passage 305 on the amplifier 301 to seek its preferred path out the pressurization port 311, through conduit 319 to the sensing port 315 of the amplifier 317. The positive signal at the control port 315 will direct flow in the primary passage 325 out the pressurization port 335, through the conduit 343 to the sensing port 341 of the amplifier 253. The positive signal at the port 341 will direct flow in the primary passage 346, out the pressurization port 349, through the conduit 209 to the bladder 13, thereby inflating such bladder to assist the patient in exhaling. As an additional feature, the override valve 316 may be opened to provide a pressure signal at the port 310 to direct flow in the primary passage 305 of the amplifier 301 to the vent port 313 thereby venting the bladder 13.

The control system S'' shown in FIG. 4 affects inflation and deflation of the bladder 13 periodically independent of the patient's breathing rhythm. This is accomplished by the air being introduced from the main tube 357 to the cycling amplifier 383 through conduits 369, 377, and 385. Assuming the amplifier 383 was initially in its vent mode directing flow into the primary passage 381 out the vent port 391, through the conduit 397, and to the control port 399 of the amplifier 375, the system S'' would vent for a predetermined time and then switch over to the pressurization mode. While the system S'' is venting, a positive signal is received at the control port 399 to direct flow in the primary passage 373 out the port 425, through the conduit 437 to the control port 435 of the amplifier 429. The positive signal at the control port 435 directs flow in the primary passage 441 to the vent port 449, through the conduit 457 and to the primary passage 453. Air flow is directed through the primary passage 453 to the control port of the pressurization valve 363, thereby closing such normally open valve to block flow from the supply conduit 359 to the bladder 13. Directing flow through the amplifier 429 to the vent outlet relieves pressure to the control port of the vent valve 450, thereby enabling such valve to assume its normally open position to cause the bladder 13 to vent out the exhaust port 473.

During this vent portion of the cycle, a portion of the air passing out the vent port 391 of the control amplifier 383 bleeds through the return conduit 403, through the orifice 405 and into the reservoir 407. When the reservoir 407 becomes sufficiently pressurized to cause a predetermined flow in the control port 409 of the amplifier 383, the flow through the primary passage 381 will switch and be directed into the pressurization exhaust port 389, thereby switching the system to its pressurization stage. Flow out the exhaust port 389, is restricted by the restrictor 395, thereby causing air to bleed back through the return conduit 413 and restrictor 415 to the reservoir 417. When the reservoir 417 become sufficiently pressurized to cause a predetermined amount of airflow through the control port 419, the flow of the primary passage 381 will be switched back to the vent port 391, thereby switching the system back to its vent phase.

It is noted that the amplifier 455 merely serves as a passive element and enables rapid bleedoff of the air from the pressurization valve 363, thereby causing it to close rapidly.

From the foregoing it will be apparent that the respiration apparatus of present invention is straight-forward in design, economical to manufacture, and provides effective and efficient means for assisting a patient in breathing. Further, the device is responsive to the patient's breath and will not cause him to breathe in an abnormal rhythm, thereby tending to induce panic. Further, the device is responsive to relatively low sensing pressures, whereby it will respond rapidly and positively.

Various modifications and changes may be made with regard to the foregoing detailed description without departing from the spirit of the invention or the scope of the following claims.

We claim:

1. Respiration apparatus comprising:

a jacket to be worn by a patient and including a bladder disposed therein;  
 pressurization means;  
 conduit means connecting said pressurization means with said bladder;  
 control valve means in said conduit means for controlling flow of pressurization fluid to and from said bladder;  
 a sensing device for periodically producing a positive pressure signal; and  
 control means connected with said sensing device for controlling said control valve means, said control means including a first fluid amplifier formed with a primary passage having a fluid inlet connected with said pressurization means, a pressurization outlet connected with said bladder and a vent outlet, said control means further including directing means connected with said sensing device and responsive to said pressure signal to direct pressurization fluid in said primary passage out said pressurization outlet to inflate said bladder and responsive to an absence of said pressure signal to direct fluid in said primary passage out said vent outlet to enable said bladder to deflate.

2. Respiration apparatus, as set forth in claim 1 wherein said sensing element includes;  
 a mask for covering the nose of the patient and formed with a sense port confronting the patient's nose and including an exhaust opening spaced from said sense port, whereby positive and negative pressure fluctuations will be communicated directly from the nostrils to said sense port and resultant exhaled air will be exhausted out said exhaust opening and inhaled air will be admitted therethrough.

3. Respiration apparatus as set forth in claim 1 wherein: said control means includes relief means for sensing the pressure in said bladder and actuating said valve means at a predetermined pressure to deflate said bladder.

4. Respiration apparatus as set forth in claim 1 wherein: said control system includes a first fluid logic element having a primary passage defining a vent outlet and a pressurization outlet, said logic element also having a control port, said control system further including a first fluid power amplifier having a primary passage defining a vent outlet and a pressurization outlet, said power amplifier also including a vent control port and a pressurization control port, said control system further including conduit means connecting said pressurization outlet of said first fluid amplifier with said control port of said logic element, said pressurization outlet of said logic element with said pressurization control port of said power amplifier, and said vent outlet of said first fluid amplifier with said vent control port of said power amplifier.

5. Respiration apparatus as set forth in claim 4 wherein:

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said control system includes a second power amplifier having a primary passage defining a vent outlet and a pressurization outlet, said second power amplifier also having a vent control port and a pressurization control port for directing flow in said primary passage of said second power amplifier, said conduit means connecting said pressurization outlet and vent outlet of said first power amplifier with said pressurization control port and vent control port, respectively, of said second power amplifier.

6. Respiration apparatus as set forth in claim 5 wherein: said control system includes a third power amplifier having a primary passage defining a vent outlet and a pressurization outlet, said third power amplifier also having vent and pressurization ports for directing flow in said primary passage of said third power amplifier, said conduit means further connecting said vent outlet and said pressurization outlet of said second power amplifier with said vent control port and said pressurization control port, respectively, of said third power amplifier.

7. Respiration apparatus as set forth in claim 1 wherein: said sensing device includes a face element for placing on a patient's face to sense his respiration to produce said pressure signal whereby the patient's respiration cycle may be sensed to alternately inflate and deflate said bladder in response to said patient's natural respiration cycle.

8. Respiration apparatus as set forth in claim 1 wherein: said bladder is mounted in the central, lower front torso portion of said jacket to apply pressure to the abdomen and lower chest of said patient.

9. Respiration apparatus comprising:  
 a jacket to be worn by the patient and including a bladder for disposition on the front of the torso;  
 pressurization means;  
 conduit means connecting said pressurization means with said bladder;  
 control valve means in said conduit means and including a vent port; and  
 control means for controlling said valve means and including power amplifier means having a primary passage defining a pressurization outlet and a vent outlet, said amplifier means also including a pressurization control port and a vent control port, said control means further including first and second feedback conduits connecting said pressurization outlet and vent outlet with said pressurization port and control port, respectively, said feedback conduits being formed with reservoir means, whereby pressurization fluid fed back through said conduits will effect periodic switching of flow in said primary passage between said pressurization outlet and said vent outlet to periodically pressurize and deflate said bladder.