

[54] **RESPIRATOR**

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[52] U.S. Cl. **128/145.6**; 128/DIG. 17; 128/145.8

[51] Int. Cl.² **A61M 16/00**

[58] Field of Search..... 123/145.8, 145.6, 145.5, 123/142, 147.2, 188, 194

[56] **References Cited**

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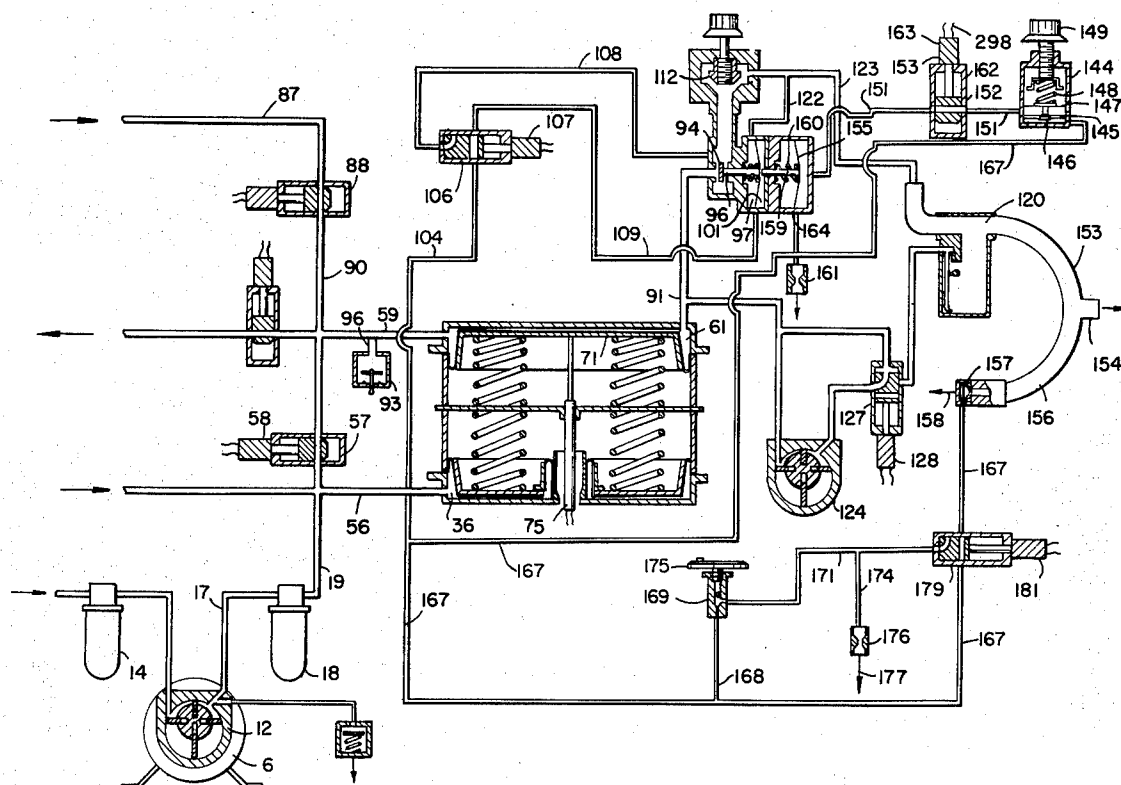
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Assistant Examiner—Henry J. Recla
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[57] **ABSTRACT**

A portable power-driven respirator controls measured amounts of air (and, if desired, admix gases, such as oxygen) to a patient during inhalation events and from the patient during exhalation events. The events are controlled pneumatically and electrically as to time and rate of occurrence, duration and relationship. Quantities, pressures and times are precisely regulated and monitored automatically with some patient override, provision for deep breaths, some manual control and with indicators and alarms. The alarms include plural inspiratory pressure alarms, some momentary without necessary continuation, and with provision to terminate inhalation under certain conditions and to put the patient effort on an adjustable pressure level with an optional decreasing inspiratory flow pattern available and with auxiliary equipment separately supplied with air so as not to interfere with the operation of the respirator itself.

3 Claims, 5 Drawing Figures



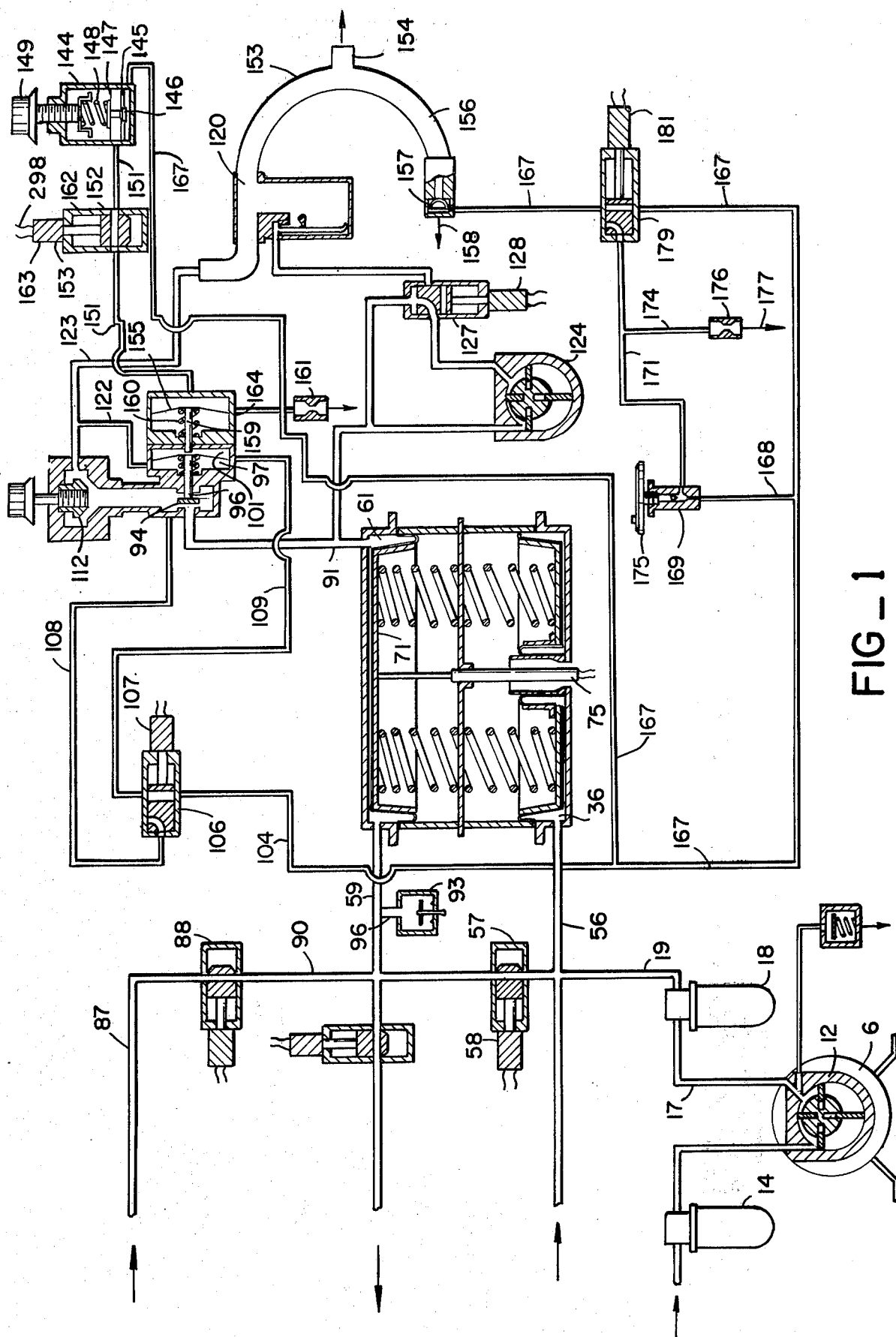


FIG-1

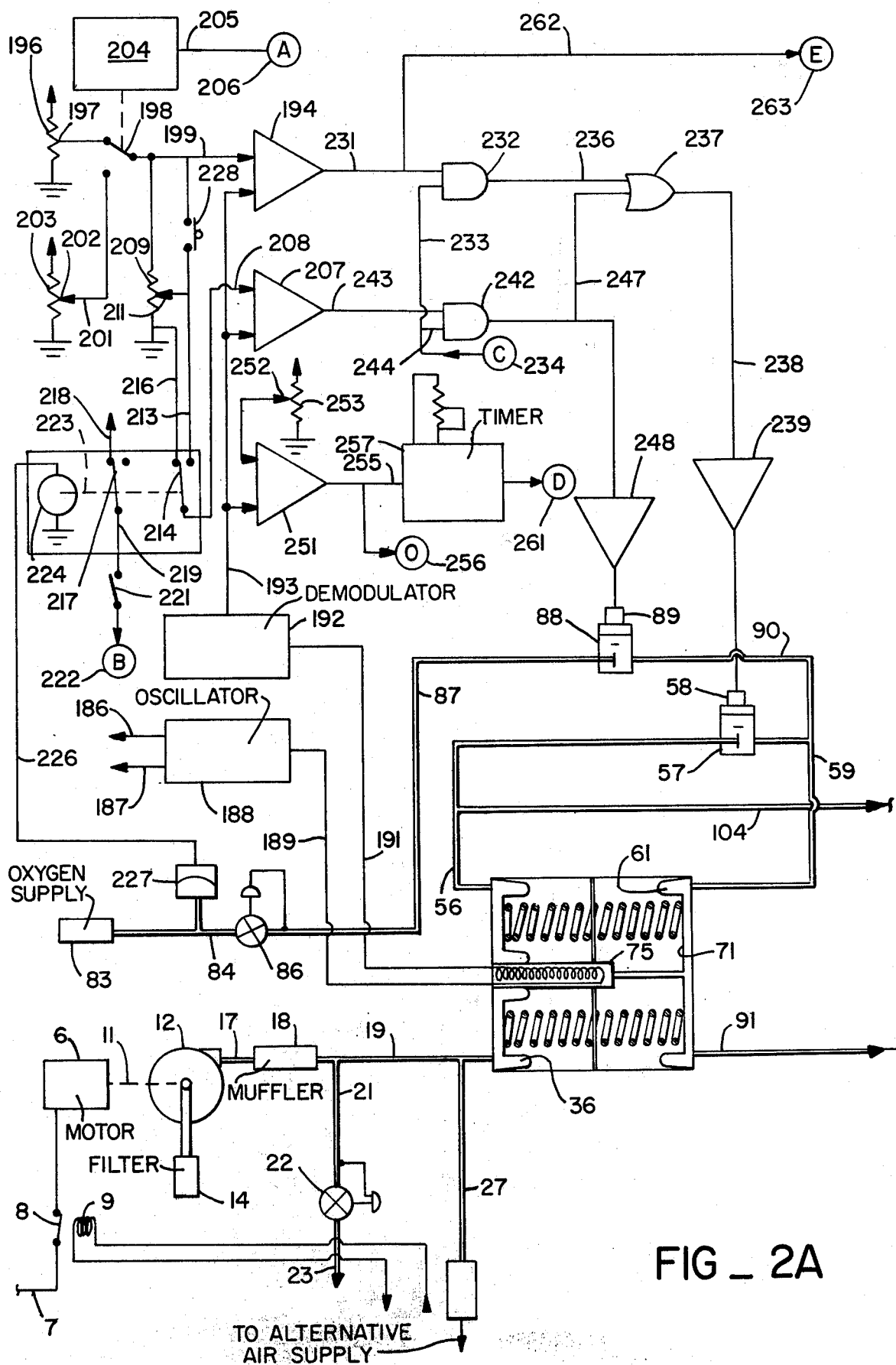
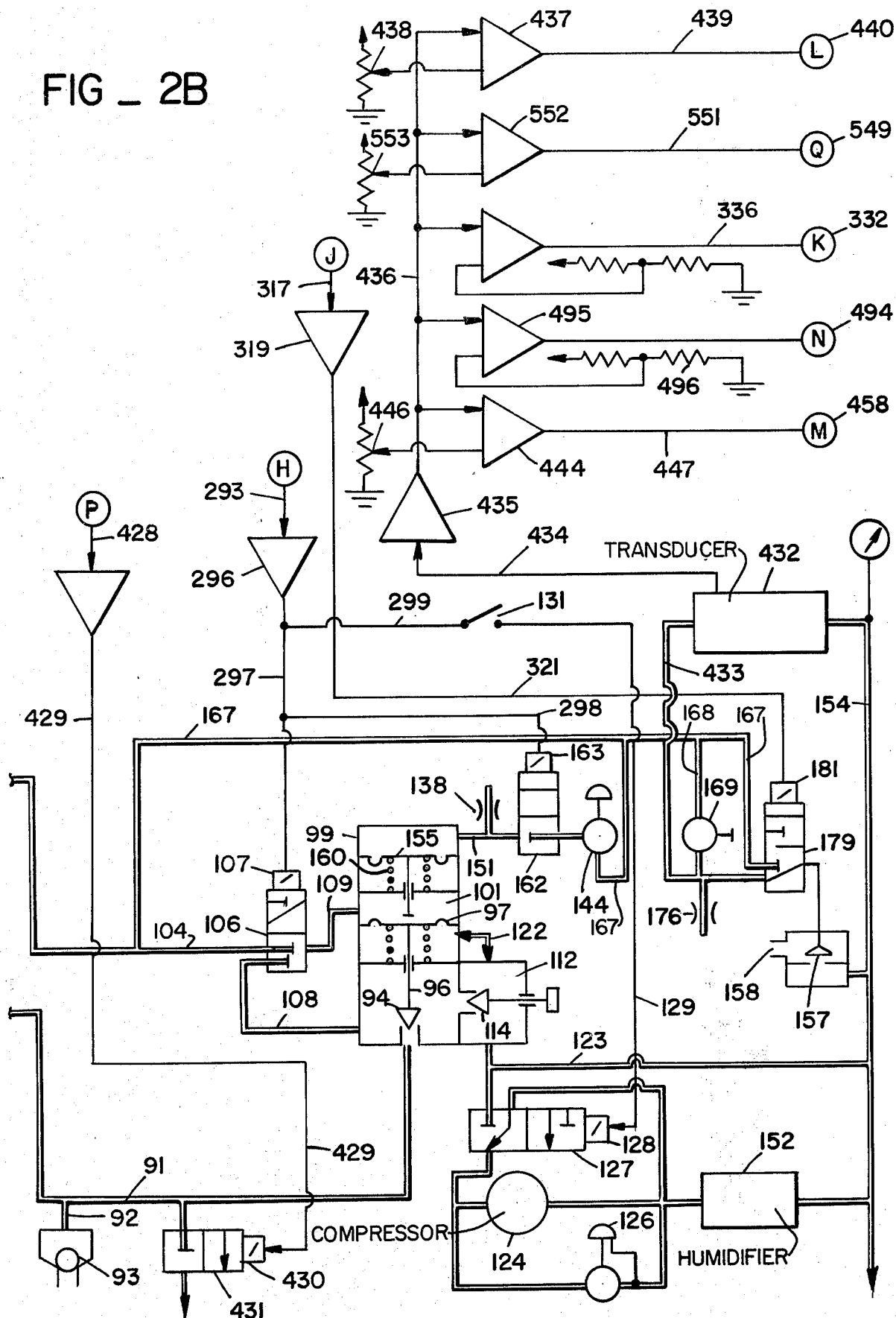


FIG - 2A

FIG _ 2B



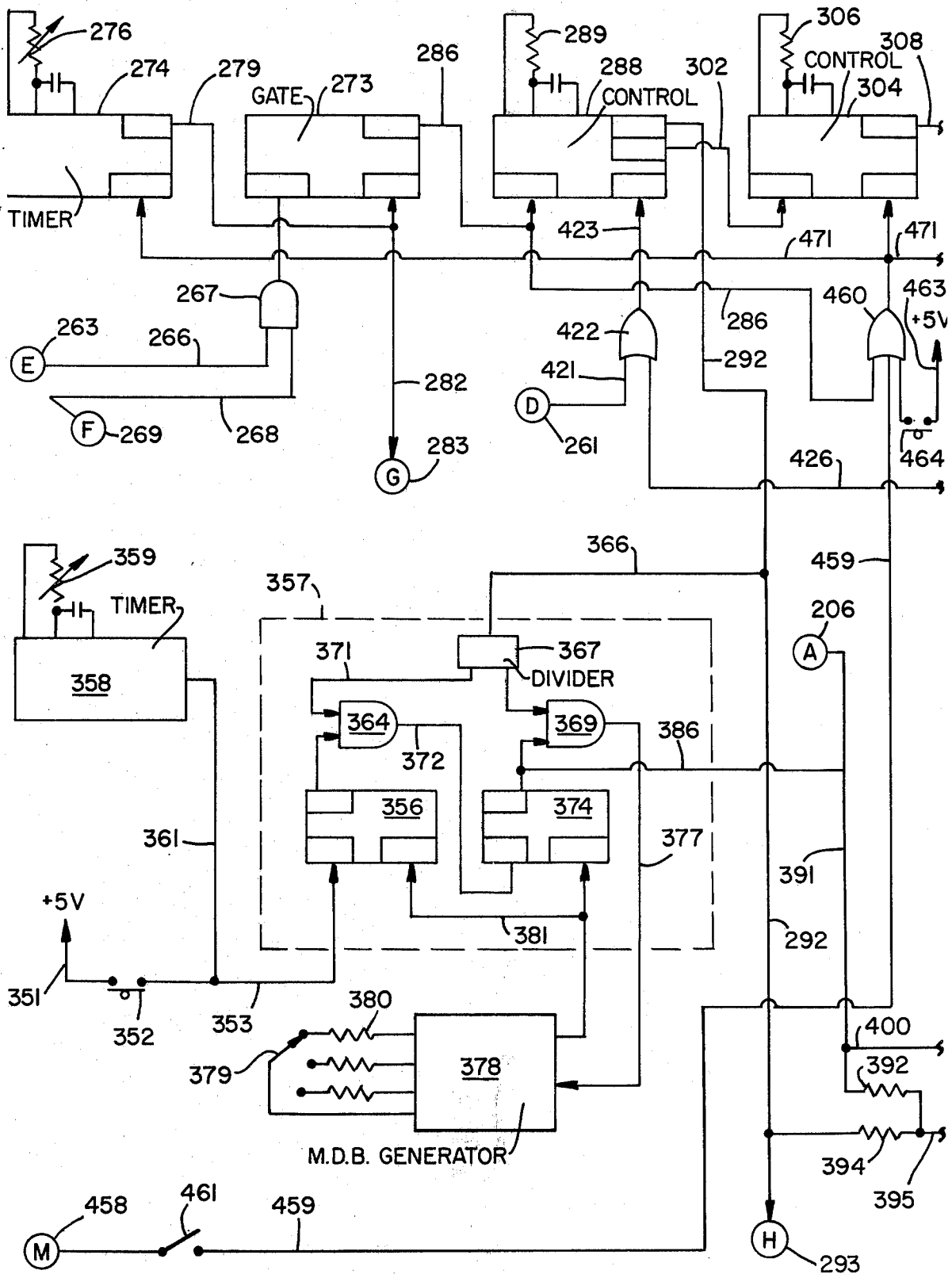
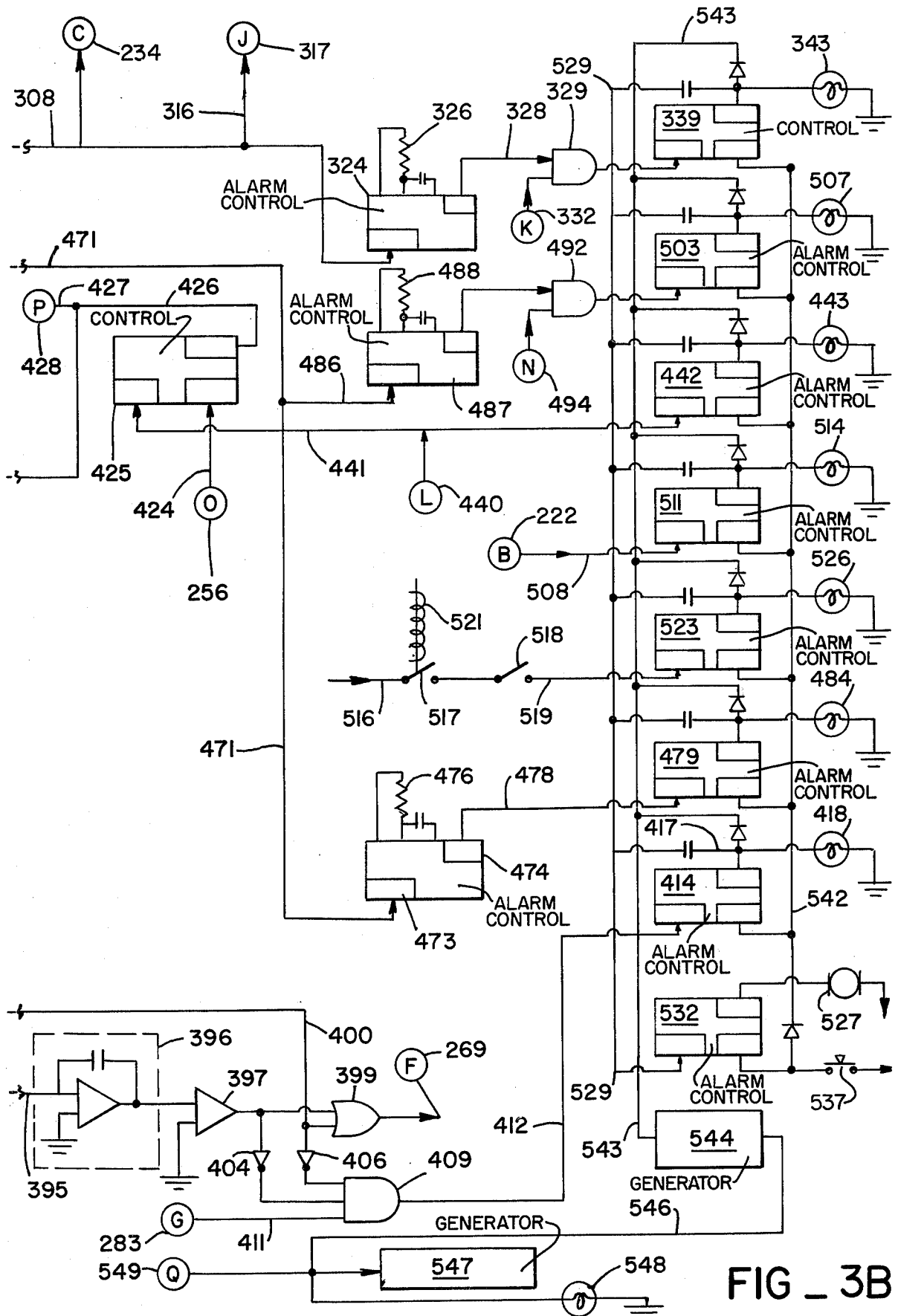


FIG _ 3A



RESPIRATOR

A respirator closely related to the disclosure herein is shown in the copending application of the present inventors entitled "Respirator" filed Apr. 26, 1973 with Ser. No. 354,673, now U.S. Pat. No. 3,840,006 issued Oct. 8, 1974. That application is referred to for details not repeated herein. For ease in correlation, the reference numerals herein, with a few exceptions, are generally the same as in that application.

The respirator of the mentioned application has been subjected to practical useage for a considerable period, and it is now desired to retain the valuable features thereof and to improve and to augment the satisfactory operation thereof.

It is therefore an object of this invention to provide an improved portable power-driven respirator especially for human use.

Another object of the invention is to provide a respirator in which the alarm system is substantially improved.

Another object of the invention is to provide a respirator in which the inhalation event is especially carefully controlled.

A further object of the invention is to provide an arrangement in which the patient effort effect may be readily adjusted.

A still further object of the invention is to provide a respirator with a variable inspiratory flow pattern, particularly one which has a decreasing flow pattern with time.

A still further object of the invention is to provide a respirator which is capable of operation with auxiliary equipment in such a fashion that whether or not the auxiliary equipment is used, the operation of the respirator itself remains unchanged.

A further object of the invention is in general to provide an improved respirator.

Other objects, together with the foregoing, are attained in the embodiment of the invention described in the accompanying description and illustrated in the accompanying drawings, in which:

FIG. 1 is a diagram showing the pneumatic circuitry of the respirator;

FIG. 2A is the left-hand portion of a schematic layout showing various of the pneumatic and electrical circuits of the respirator, while FIG. 2B is a similar view complementing the showing in FIG. 2A and showing the right-hand portion of the layout partially shown in FIG. 2A; and

FIG. 3A is a further diagrammatic showing of circuitry utilized in connection with the respirator, and FIG. 3B, when placed to the right of FIG. 3A, completes the diagrammatic showing of the circuitry of FIG. 3A.

The respirator pursuant to the invention can be and has been embodied in a number of different forms, and at the present time it is preferred that the form disclosed herein be utilized. In this instance there is provided an electric motor 6 connected to a suitable source of alternating current through a circuit 7 including a main switch 8 adapted to be opened and closed by a coil 9 under control from a separate point. It is preferred that the motor 6 be designed to run on 117 volts alternating current for most uses, and it is also normal to have a separate motor drive and a separate initial mechanism powered by a 12-volt direct current battery

for ambulance use of the respirator. When the battery source is utilized, the switch 8 is opened by appropriate energization of the coil 9.

When in operation, the motor 6 through a shaft 11 drives a compressor 12 receiving a supply of atmospheric air through a filter 14 and discharging through an outlet 17 and a muffler 18 into a supply line 19. From the line 19 a duct 21 leads through an air supply pressure regulator 22 to a suitable vent 23. Air under pressure which may be alternatively supplied from the battery-powered unit is transferred through a duct 27 into the line 19. Flow is then into an accumulator chamber 36 designed to act as a reservoir and expandible and contractable under air pressure on one side of a movable, boundary diaphragm and in accordance with spring pressure on the other side of the diaphragm. Air from the reservoir 36 can flow into a duct 56 and through an air valve 57 having an operator 58 thereon into a line 59 opening into a variable chamber 61 also under spring pressure and having a diaphragm 71, the position of which is effective to control the response of a transducer 75, so that the position of the diaphragm 71 is reflected in an electrical change in the circuit of the transducer 75.

Air from the chamber 61 can flow out through a duct 91 to an inhalation or inspiratory flow rate valve 99 (FIG. 2B). To make sure that there is always a supply of air which can move in the duct 91, even though the volume controller and its connections may be inoperative, an atmospheric line 92 connects with the duct 91 and is provided with a check valve 93. Normally the valve 93 is closed under the customary super-atmospheric pressure in the line 91 but can open and admit atmospheric air to the line 91 if the pressure in the line 91 is low. The line 91 in entering the valve 99 encounters a poppet 94 connected through a stem 96 to a diaphragm 97 forming part of the boundary of a chamber 101. A line 104 connected through the duct 56 to the chamber 36 supplies an inhalation pilot operator valve 106 having an operator 107 and at one end joined through a line 108 to the downstream side of the poppet 94, and also connected through a line 109 to the chamber 101.

Also communicating with the chamber on the downstream side of the poppet 94 is a chamber 112 entrance to which is controlled by an adjustable poppet 114. The chamber 112 is in communication with the under side of the diaphragm 97 through a duct 122 and also is in communication with a line 123 extending into a yoke 153 (FIG. 1) joined to an airway tube 154 extending to the patient inhalation apparatus.

A nebulizer 120 may be supplied with air from the line 123 or may be separately supplied with air from a compressor 124 having a pressure relief valve 126 (FIG. 2B) connected thereto. Air supply to the nebulizer from the compressor or from the line 123 is controlled by a valve 127 connected to the line 123 and having an actuator 128 in an electric line 129 controlled by a switch 131 electrically connected and later described. The nebulizer may thus be supplied from the compressor with air entirely separately and distinctly from the air or air-oxygen mixture supplied directly to the patient through the line 123. In this way operation or non-operation of the nebulizer can be arranged not to affect the operation of the rest of the respirator. The yoke 153 and the airway 154 have an exhalation branch 156 (FIG. 1) leading through an air-expandible exhalation valve 157 to the atmosphere through a vent

158.

Air for operating the exhalation valve 157 is derived from the accumulator chamber or reservoir 36 through 56 and through the line an air line 167 having a branch 168 extending through a positive end exhalation pressure 169 provided with a manual regulator 173. The valve 169 is joined through a line 171 to an exhalation pilot valve 179 having an electric operator 181. The line 171 has a branch 174 leading through a bleed orifice 176 to a line 177 extending to the atmosphere.

Means are particularly provided for varying the inspiratory flow rate during a breathing cycle and particularly to make the flow rate decrease as a cycle of inspiration continues. The air line 167 extends to a taper valve 144 including an apertured plate 145 having a valve 146 controlled by a flexible diaphragm 147 against which a spring 148 bears. A manual knob 149 controls the pressure of the spring and consequently flow through the orifice plate 145 and into a line 151 controlled by a valve 162 having an operator 163. When the valve 162 is open, air flows through the line 151 into an actuator chamber 164 of the valve 99 having a diaphragm 155 therein provided with a stem 159 adapted to move the valve 94 by pressing on its stem 96. A spring 160 opposes air pressure on the opposite side of the diaphragm 155. This air pressure is normally bled off through an orifice body 161 in FIG. 1 or an equivalent orifice body in FIG. 2B. Thus, when the valve 162 is opened, there is a gradually increasing pressure on the diaphragm 155, so that the stem 159 tends to close the valve 94 gradually. This affords a decreasing taper to the inspiratory flow rate during each cycle. The amount of decrease or taper depends upon the manual adjustment of the valve 144 and is usually set between zero and ninety percent of the full closure of the valve 94.

In addition to the atmospheric air supply, there is provision also for utilizing oxygen in varying proportions to atmospheric air. Oxygen from an external supply 83 (FIG. 2A) is led through a line 84 and through a pressure regulator 86 into a line 87 controlled by an oxygen flow valve 88 having an electrical operator 89. Outflow from the oxygen valve is through a duct 90 joining the duct 59.

In order to control the various instrumentalities described, the volume or position transducer 75 which translates the axial position of the diaphragm 71 and so the volume of the chamber 61 into a corresponding electrical signal is operated by the output of an oscillator 188 supplied from a suitable voltage source through conductors 186 and 187, the output of the oscillator travelling through a conductor 189 to the transducer 75. This in turn affords an output through a conductor 191 into a demodulator 192 effective through a conductor 193 upon an air volume detector 194.

The detector 194 is also responsive to a signal from a tidal volume control 196 having a variable output 197 and effective through a switch 198 and a conductor 199 joined to the detector 194. Also effective through the switch 198 and a conductor 201 is the variable control 202 of a deep-breath increment control 203. The switch 198 is positioned to utilize either one of the controls by means of the operation of a deepbreath volume switch 204 joined by a conductor 205 to a terminal A 206, later described.

Parallel to the air volume detector 194 there is provided an oxygen volume detector 207 receptive to signals through a conductor 208 from an oxygen air ratio

control 209 having a variable output 211 and joined through a conductor 213 to a switch 214 also connectable through a conductor 216 to ground. Parallel with the switch 214 is a switch 217 connected to a voltage source through a conductor 218 and also joined by a conductor 219 and a switch 221 to an alarm terminal for oxygen B 222, later described. The switches 214 and 217 are preferably joined by a gang connector 223 responsive to an activating coil 224 receiving its signal through a conductor 226 from an oxygen pressure switch 227 joined to the supply conduit 84. Should the oxygen pressure drop due to exhaustion of the supply, there is an automatic switchover to normal air by coil operation of the switch 214, and the alarm is given by operation of the switch 217. Also for controlling the oxygen, there is in the conductor 213 a manual switch 228 which shunts the variable control 211 to afford 100 percent pure oxygen.

The air volume detector 194 is effective through a conductor 231 and an and-gate 232. Also effective on the and-gate 232 through a conductor 233 is a signal from a terminal C 234, later described. When the and-gate 232 is appropriately provided with a pair of signals, the output is through a conductor 236 to an exclusive or-gate 237 effective through a conductor 238 and an amplifier 239 on the operator 58, so that the air valve 57 is correspondingly opened and closed.

Quite similarly, the oxygen volume detector 207 is effective upon an and-gate 242 through a conductor 243. The and-gate is likewise supplied with a signal through a conductor 244 from the terminal C 234. When both signals are present at the and-gate 242 there is a corresponding output signal through a conductor 247 to the exclusive or-gate 237 and likewise to an amplifier 248 effective upon the operator 89 of the oxygen valve 88. The oxygen valve is thus opened and closed in accordance with the received signals.

Also in parallel with the detectors 194 and 207 is a chamber-empty detector 251 receiving one signal from a variable controller 252 on a resistor 253, as well as from the conductor 193. The detector 251 is connected by a conductor 255 to a signal terminal 0 256, later described, and also to an inflation hold timer 257 connected to a signal terminal D 261, later described.

In the operation of the structure, when the chamber 61 is full and provides a corresponding signal in the conductor 231, that signal is also transmitted through a conductor 262 to a terminal E 263 (FIGS. 2A and 3A) and through a conductor 266 (FIG. 3A) to an and-gate 267. The companion enabling signal to the gate 267 is transmitted through a conductor 268 from a terminal F 269 (FIGS. 3A and 3B) and later described. Upon appropriate signals at the and-gate 267, an inhalation gate 273 is enabled and is ultimately actuated by a respiration rate timer 274 having a variable control 276 and effective through a conductor 279 upon the trigger of the inhalation gate 273. The conductor 279 also has an extension 282 leading to a terminal G 283 appearing also in FIG. 3B, to activate an alarm, later described.

When an impulse comes from the inhalation gate 273, it is conducted through a lead 286 to an inhalation control 288 having a time limit control 289 and when activated affording a signal through a conductor 292 to a terminal H 293 (FIGS. 3A and 2B) and later described. In FIG. 2B the terminal H 293 leads through an amplifier 296 to the inhalation pilot operator valve 106 (FIG. 1) through the operator 107 thereof. More particularly, a branch conductor 298 (FIG. 2B) extends to

the operator 163 of the valve 162, which controls the occurrence of the taper on the inspiratory flow rate, as previously described. Also, from the conductor 297 there is a branch 299 effective through a switch 131 on the operator 128 of the humidifier valve 127, as previously described.

Another output from the inhalation control 288 (FIG. 3A) is through a conductor 302 to an exhalation control 304 having a limit timer 306. The output of the control 304 is effective upon a conductor 308 (FIGS. 3A and 3B) joined to the terminal C 234 (FIGS. 3B and 2A) so that the exhalation signal is afforded the and-gates 232 and 242 as previously mentioned.

The conductor 308 (FIG. 3B) has a branch conductor 316 extending to a terminal J 317 (FIGS. 3B and 2B) and is consequently effective through an amplifier 319 and a conductor 321 on the operator 181 for the exhalation pilot valve 179 as previously noted. The conductor 308 continues (FIG. 3B) to one of the alarms, in this instance a timed airway disconnect alarm 324 having a timer 326 usually set at about one-tenth of a second and joined by a conductor 328 to an and-gate 329, the other signal to which is supplied through a terminal K 332 (FIGS. 3B and 2B) from an airway disconnect detector 336, as will later be described in connection with various of the alarm structures. When the and-gate 329 is energized, a signal is sent to a control board 339 and has the effect of illuminating an alarm light 343.

Means are provided for affording a deep breath from time to time. From a suitable source of voltage available in a conductor 351 (FIG. 3A) power may be supplied under control of a manual switch 352 to a conductor 353 leading to a control 356 in a synchronizing logic element 357. A deep-breath timer 358 with a variable control 359 is joined through a conductor 361 to the conductor 353, so that either manually or at set times the synchronizing logic can be energized. Output from the control 356 is to a synchronizing and-gate 364 and through a conductor 372 to a control board 374, the output of which is effective upon one side of an and-gate 369, the other side of which is connected to a signal divider 367 also supplying a signal through a conductor 371 to the and-gate 364. The signal divider 367 receives its impulse through a conductor 366 joined to the conductor 292. Thus, when the and-gate 369 is energized, its output is sent through a conductor 377 to a multiple deep-breath generator 378 having a switch 379 connecting in circuit any selected one of a group 380 of resistors.

The output pulse from the deep-breath generator 378 is effective through a conductor 381 on the reset mechanisms of both the control 356 and the control 374. There is consequently, as set and as selected, an output signal from the synchronizing logic board 357 in a conductor 386 leading directly to the deep-breath volume terminal A 206 in FIG. 3B and in FIG. 2A. This is effective to control the operation of the switch 198 between the tidal volume control 196 and the deep-breath increment control 203.

Joined to the conductor 386 (FIG. 3A) is a conductor 391 extending to a resistor 392 in parallel with a resistor 394 itself connected to the conductor 292. The resistors are joined by a conductor 395 to an integrator 396 (FIG. 3B). The output of the integrator goes to one side of an amplifier 397 connected to an or-gate 399 leading to a terminal F 269 (FIGS. 3B and 3A) so as to be effective upon the inhalation gate 273. The or-gate

399 is also connected to the conductor 391 extending from the synchronizing logic 357 for the deep-breath mechanism by a conductor 400.

The amplifier 397 and the conductor 400 are respectively connected through inverters 404 and 406 into an and-gate 409 also receiving a signal through a conductor 411 from a terminal G 283 FIGS. 3B and 3A) so that the respiration rate control signal is available at the and-gate 409, which furnishes an output through a conductor 412 into an alarm board 414 effective when the inhalation quantity exceeds the exhalation quantity and acting through a conductor 417 to illuminate a light 418 as an alarm.

The inflation hold timer 257 (FIG. 2A) affords a signal to the terminal D 261 (FIGS. 2A and 3A) from which the signal is carried through a conductor 421 to an or-gate 422, the output of which travels through a conductor 423 to the inhalation control 288 to terminate its output.

As shown in FIG. 2A, the chamber-empty detector 251 affords a signal to the terminal O 256, likewise shown in FIG. 3B, so that the signal is then transmitted through a conductor 424 to a control board 425 having an output carried through a conductor 426 to the other side of the or-gate 422 (FIG. 3A) and having a branch 427 extending to a terminal P 428 (FIGS. 2B and 3B) connected through a conductor 429 (FIG. 2B) to the actuator 430 of a dump valve 431 effective to connect the conduit 91 to atmosphere and thus immediately drop the pressure in the chamber 61 to atmospheric pressure.

The set function for the board 425 (FIG. 3B) controlling the dump valve operator and the maximum inspiration pressure is derived ultimately from the airway 154 through an airway pressure transducer 432 (FIG. 2B) not only connected to the airway 154 but likewise connected to the outlet of the positive exhalation end pressure valve 169 through a pressure conduit 433. The electrical output of the transducer 432 is carried by a conductor 434 and through an amplifier 435 into a trunk conductor 436. This conductor extends to an amplifier 437 controlled by a variable input 438 and affording an output through a conductor 439 to a terminal L 440 (FIGS. 2B and 3B) joined to a conductor 441 (FIG. 3B) extending to the set portion of the board 425 and also to an alarm board 442 effective to illuminate a light 443 to indicate when a maximum inspiration pressure has been exceeded.

Also joined to the trunk conductor 436 (FIG. 2B) is a patient-effort detector 444 having a controllable input 446 and leading through a conductor 447 to a terminal M 458 (FIGS. 2B and 3A). A conductor 459 having a switch 461 therein leads from the terminal M 458 to an or-gate 460 also receiving a signal through the conductor 286 from the inhalation gate 273. In addition, the or-gate 460 receives a signal from a voltage source through a conductor 463 controlled by a manual inhalation switch 464.

The output of the or-gate 460 is into a reset conductor 471 (FIG. 3A) which extends to the reset portion of the respiration rate controller 274, to the terminate portion of the exhalation controller 304 and to the reset portion 473 (FIG. 3B) of a failure-to-cycle control 474 having a timer 476, usually set at about 15 seconds, so that in the event the mechanism does not function properly for that period of time there is a signal supplied through a conductor 478 to an alarm board 479 effective to illuminate an indicator light 484.

In addition, as shown in FIG. 3B, the signal in the conductor 471 is transmitted through a conductor 486 to an alarm board 487 having a timer 488 usually set for approximately three-hundredths of a second and then effective to afford an output to an and-gate 492 actuating an alarm for the end of the expiration pressure, but effective only when there is an end expiration pressure signal from a terminal N 494 (FIGS. 3B and 2B), the signal being from the trunk conductor 436 through an amplifier 495 having a variable control 496. When the and-gate 492 (FIG. 3B) is effective, it actuates an alarm board 503 and in turn illuminates an alarm light 507.

There is an additional alarm from the terminal B 222 (FIGS. 3B and 2A) to indicate low oxygen pressure. The signal at the terminal 222 is carried through a conductor 508 into an alarm board 511 and is effective to illuminate a signal light 514.

There is also afforded an alarm in the event the main 117-volt power supply should fail. From a low-voltage source there is power supplied through a conductor 516 (FIG. 3B) to a control switch 517 responsive to a power coil 521 connected in the main power line and normally holding the switch 517 open. When the main power fails, the switch 517 closes and serves through a manual disconnect switch 518 to energize a conductor 519 feeding an alarm board 523 to afford illumination of a proper signal light 526.

All of the various signal or alarm boards are connected to a conductor 529 extending to an alarm board 532 effective to energize an audible alarm 527. There is also a manual switch 537 connecting a suitable source of power through a conductor 542 to reset all of the alarm boards. In addition, the various alarm boards are connected through a conductor 543 to a short interval pulse generator 544 (FIG. 3B) extending through a conductor 546 to a chirp generator 547 and to an intermittent alarm light 548. The chirp generator and the

light may likewise be energized from a terminal Q 549 (FIGS. 3B and 2B) connected to the airway pressure transducer trunk conductor 436 through a conductor 551 and an amplifier 552 having a variable supply 553. Thus, if the alarms are not promptly reset, the chirp generator is effective to give audible alarms at short intervals, say, 10 seconds.

There has thus been provided a respirator having largely automatic but readily controllable functions to assist in or to maintain respiration and one that is usable under most all practical conditions encountered either at fixed locations, such as hospitals, or in transient locations, such as ambulances. The device, perhaps with changes in size, is useful with adults and also with pediatric cases.

What is claimed is:

1. A respirator comprising a displacement chamber having a wall movable toward and away from a predetermined location, means for urging said wall toward said location, means for supplying said chamber with gas at a pressure to urge said wall away from said location, means for detecting the position of said wall relative to said location, means for controlling said supplying means, means responsive to said detecting means for actuating said controlling means, a patient airway, means for connecting said chamber to said patient airway, a valve in said connecting means, means for operating said valve in accordance with pressure in said patient airway, and means additional to said operating means for urging said valve toward closed position.

2. A respirator as in claim 1 in which said additional means operates in time with the breathing pressure cycle in said airway.

3. A respirator as in claim 2 in which said additional means operates only during the inspiration portion of said cycle.

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