Aug. 1, 1967 E. W. ROBINSON ET AL 3,333,581

PULMONARY RESUSCITATOR WITH ELECTRICAL CONTROL SYSTEM

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Fig. 1

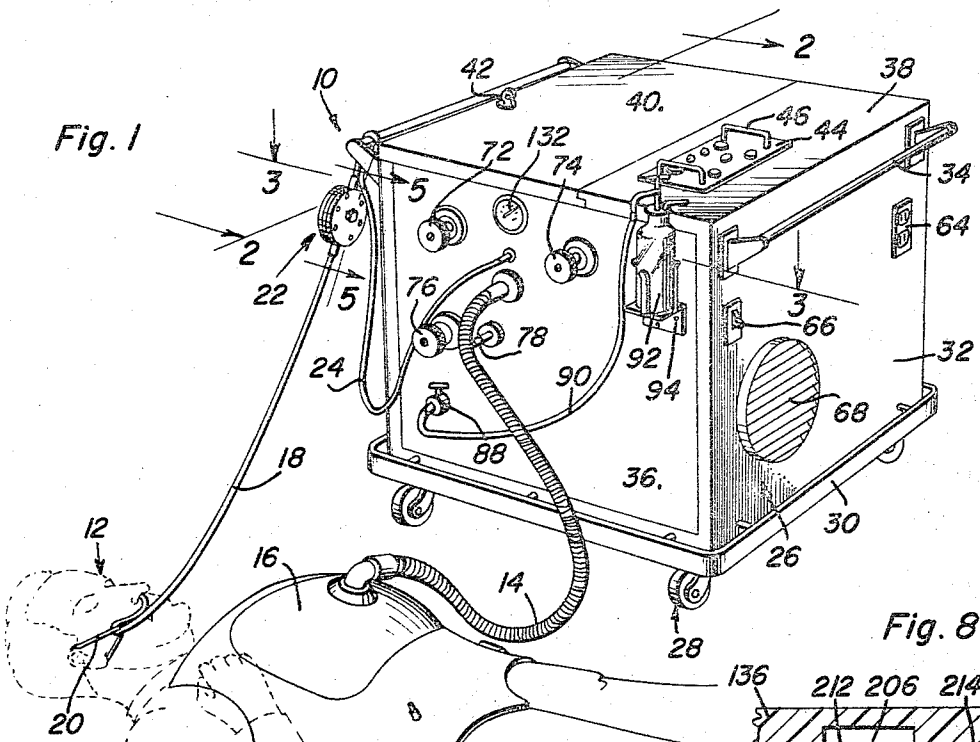


Fig. 2

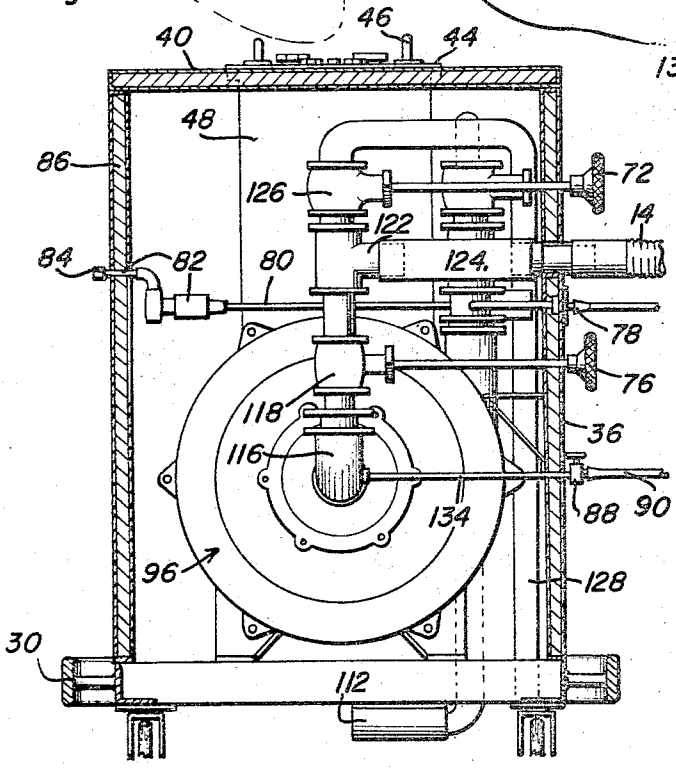


Fig. 8

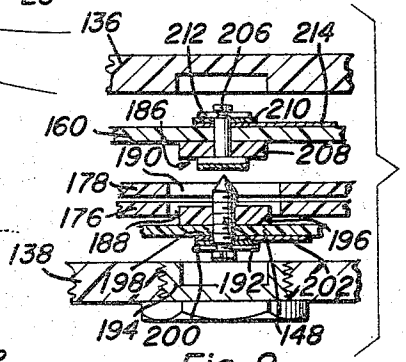
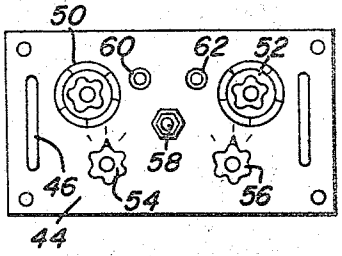


Fig. 9



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PULMONARY RESUSCITATOR WITH ELECTRICAL CONTROL SYSTEM

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Fig. 3

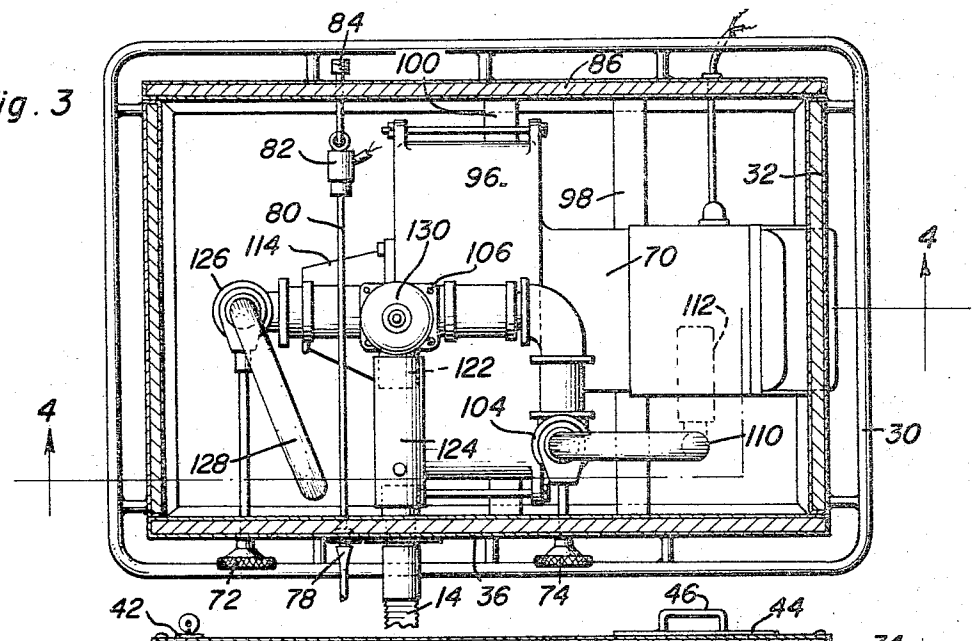

Fig. 4

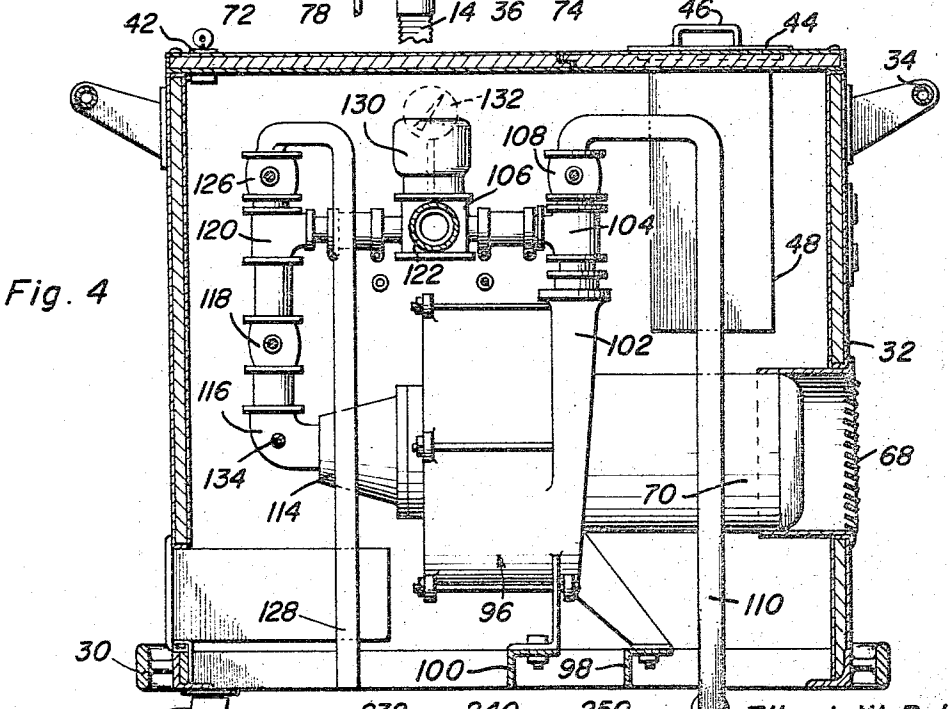

Fig. 11

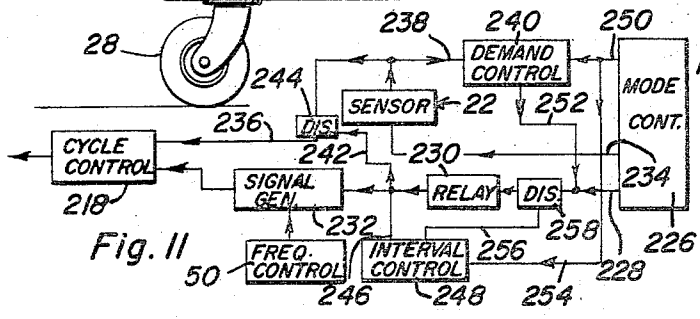

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Fig. 5

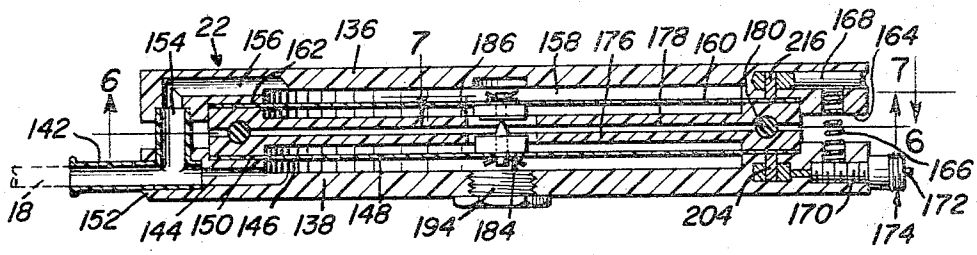


Fig. 10

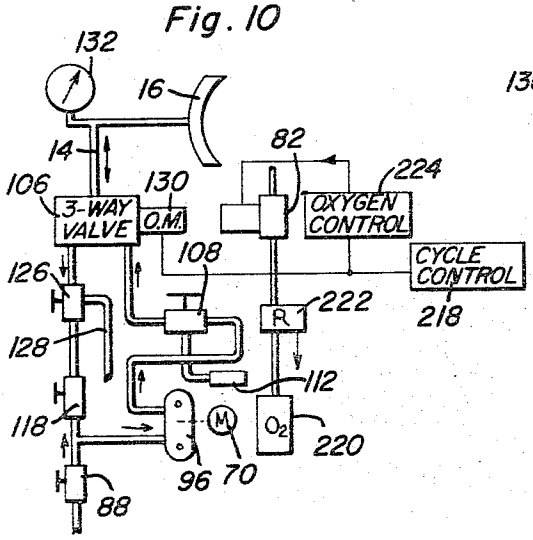


Fig. 6

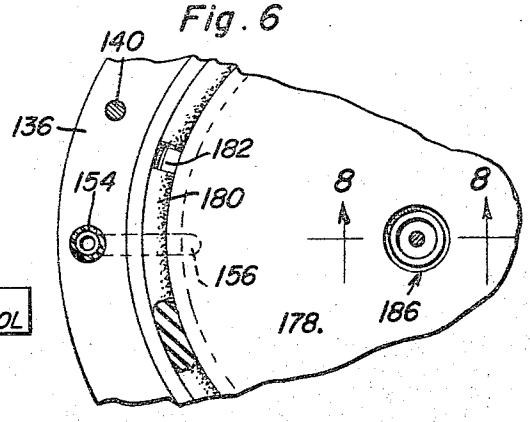


Fig. 7

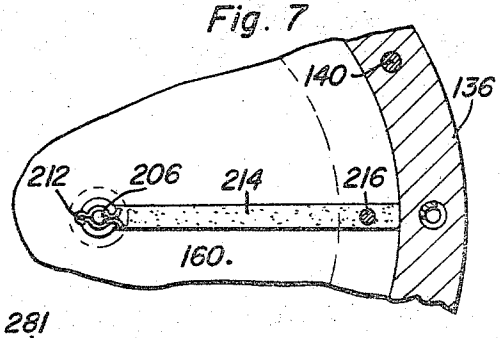
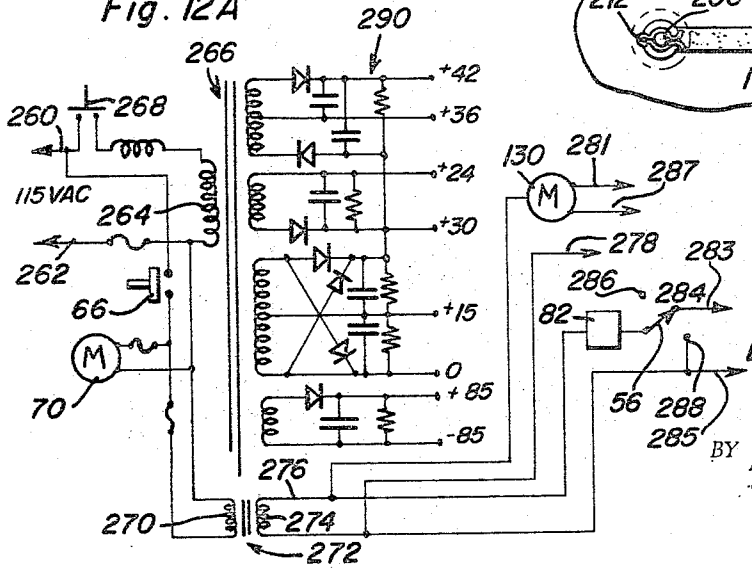


Fig. 12A



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PULMONARY RESUSCITATOR WITH ELECTRICAL CONTROL SYSTEM

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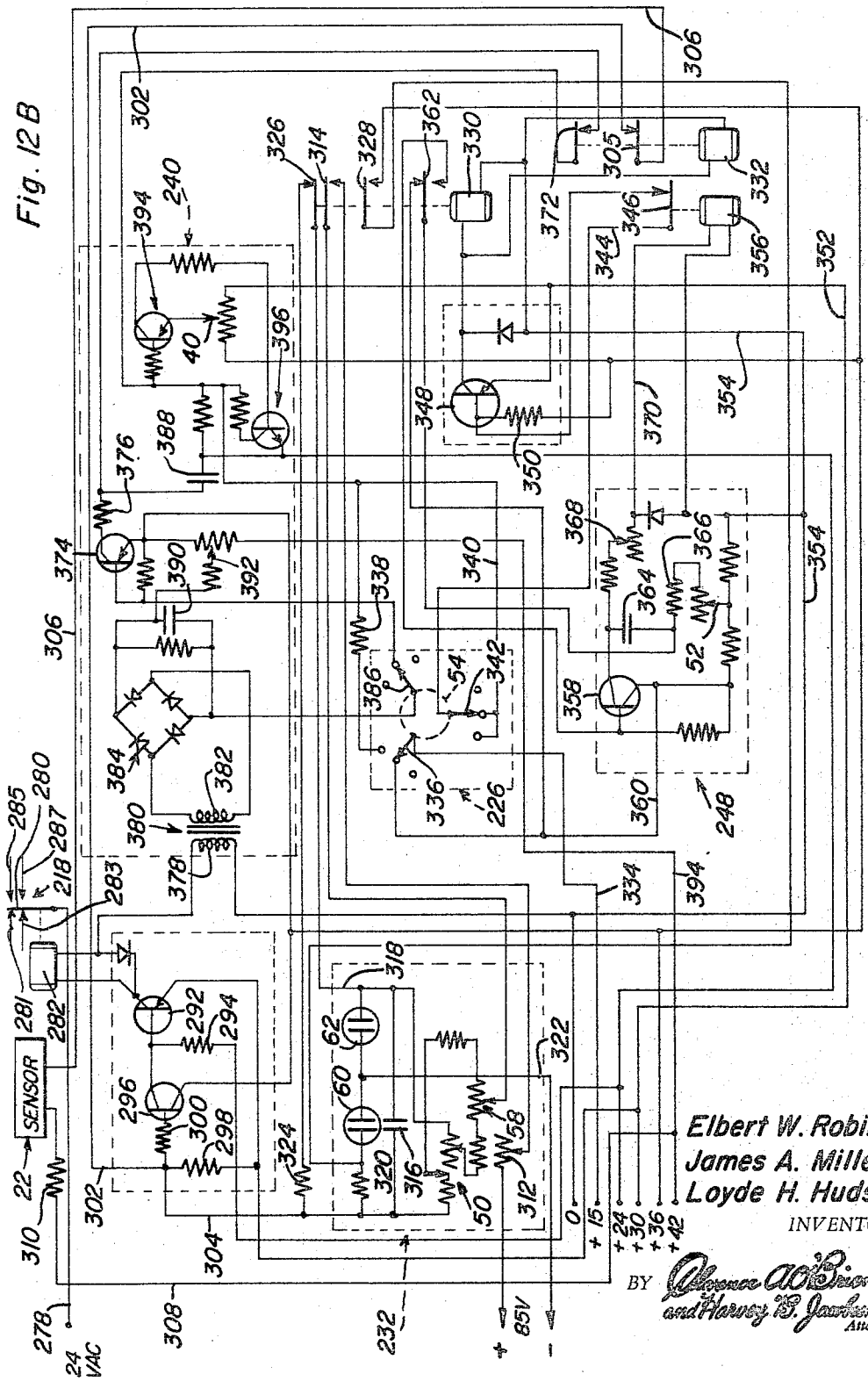
Fig. 12B



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3,333,581

PULMONARY RESUSCITATOR WITH ELECTRICAL CONTROL SYSTEM

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Filed Mar. 27, 1964, Ser. No. 355,177
12 Claims. (Cl. 128—30.2)

This invention relates to apparatus for resuscitating a patient by either assisting breathing or inducing breathing artificially.

A primary object of the present invention is to provide apparatus capable of being regulated in accordance with different requirements and situations for the resuscitation of patients exhibiting breathing difficulties.

An additional object of the present invention in accordance with the foregoing object, is to provide a control system for a resuscitator whereby its operational mode may be regulated and changed in accordance with different needs.

A still further object of the present invention is to provide a resuscitator having facilities for sensing the breathing action of a patient so that the resuscitator may be regulated in accordance with the patient's demand to assist breathing.

Another object of the present invention is to provide a resuscitator control system which may automatically induce breathing of a patient at a preselected rate and respond to any attempt on the part of the patient to resume natural breathing by converting operation of the resuscitator to regulation by patient demand.

Yet another object of the present invention is to provide a novel low pressure sensing device for rendering the resuscitator operative to regulate breathing in accordance with the natural breathing rate of the patient.

These together with other objects and advantages which will become subsequently apparent reside in the details of construction and operation as more fully hereinafter described and claimed, reference being had to the accompanying drawings forming a part hereof, wherein like numerals refer to like parts throughout, and in which:

FIGURE 1 is a perspective view of the apparatus of the present invention being used.

FIGURE 2 is a sectional view taken substantially through a plane indicated by section line 2—2 in FIGURE 1.

FIGURE 3 is a sectional view taken substantially through a plane indicated by section line 3—3 in FIGURE 1.

FIGURE 4 is a sectional view taken substantially through a plane indicated by section line 4—4 in FIGURE 3.

FIGURE 5 is a sectional view through the sensor device.

FIGURE 6 is a sectional view taken substantially a plane indicated by section line 6—6 in FIGURE 5.

FIGURE 7 is a partial sectional view taken substantially through a plane indicated by section line 7—7 in FIGURE 5.

FIGURE 8 is an enlarged partial sectional view taken substantially through a plane indicated by section line 8—8 in FIGURE 6.

FIGURE 9 is a top plan view of the control panel associated with the resuscitator apparatus.

FIGURE 10 is a schematic control circuit diagram corresponding to the apparatus of the present invention.

FIGURE 11 is a work flow diagram diagrammatically illustrating the control system associated with the present invention.

FIGURES 12A and 12B are electrical circuit diagrams illustrating one form of control system associated with the present invention.

Referring now to the drawings in detail, and initially to FIGURE 1, it will be observed that the resuscitator apparatus generally referred to by reference numeral **10** when in use may assist or induce breathing of a patient **12** by alternatively applying pressure and vacuum through a flexible outlet conduit **14** to a chest shell device **16** placed about the patient so as to expand and collapse the patient's chest cavity in order to induce or assist inhalation and exhalation. Accordingly, pressure applied to the chest shell through the outlet conduit **14** will cause collapse of the chest cavity in order to produce exhalation while vacuum pressure in the conduit will expand the chest cavity in order to induce or assist inhalation, pressure and vacuum being established in the outlet conduit cyclically in accordance with the breathing rate. The breathing rate may be preselected or may be regulated in accordance with the natural breathing rate of the patient through the use of a nasal canula or tube **18**, one end of which is inserted into a nostril of the patient and held in position by any suitable means as for example the string **20** hooked about the ear of the patient. Any inhalation by the patient producing a very small vacuum pressure signal will therefore be communicated by the tube **18** to a sensor device **22** electrically connected to the resuscitator apparatus by the electrical cable **24** so as to regulate operation thereof in accordance with the natural breathing rate of the patient.

The resuscitator apparatus is mounted within a housing generally referred to by reference numeral **26** supported by caster wheels **28** so as to facilitate movement thereof. A guardrail **30** is mounted adjacent the bottom of the housing in encircling relation thereto while opposite side walls **32** of the housing are provided with push rod handles **34** for movement of the apparatus. The housing **26** is also provided with a front wall **36** and a top wall **38** having a removable closure panel **40** providing access to the interior of the housing. A key operated lock device **42** may therefore be provided to hold the panel **40** in place.

Mounted on the top wall **38** is a control panel **44** provided with a pair of handles **46**. As more clearly seen in FIGURES 1, 2, 4 and 9, the control panel **44** is connected to an enclosure **48** for the electrical control components to be hereafter described. The control panel therefore mounts the various adjustable control devices associated with the control system including a breathing rate selector **50** by means of which the number of strokes or breathing cycles per minutes may be preselected for one mode of operation of the resuscitator apparatus. A test interval selector **52** is also mounted on the control panel by means of which operation of the resuscitator under the selected breathing rate control may be interrupted after a time interval selected for a predetermined period (5 seconds) during which the sensor device **22** may convert operation of the resuscitator to a natural breathing rate if any breathing action of the patient is sensed. The operational mode of the resuscitator is selected by the mode selection control **54** while the administration of oxygen may be controlled in accordance with the setting of the oxygen control knob **56**. Facilities are also provided for varying the duration of the inhalation period of the resuscitator apparatus when regulated at a rate set by the rate selector **50**. Accordingly, a tool operated spacer control **58** is provided on the control panel **44** for such purpose. Finally, a pair of neon indicator lamps **60** and **62** are mounted by the control panel providing a visual indication of resuscitator operation. Electrical power for operating auxiliary equipment such as a heater for an atomizer, etc., may also be supplied through an electrical power cable plugged

into the electrical receptacle device **64** mounted on the side wall **32**. The side wall also mounts a motor switch **66** adjacent to an exhaust vent **68** through which heat may be dissipated from a pump motor **70** mounted within the housing **26** as more clearly seen in FIGURE 4.

Referring now to FIGURES 1, 2, 3 and 4, it will be observed that the front wall **36** of the housing mounts various valve control devices including a vacuum control knob **72**, a pressure control knob **74** and a flow rate control knob **76**. Also mounted on the front wall **26** is a tracheal tube connection **78** by means of which oxygen may be administered through a tracheal tube to the nostril or trachea of the patient. The tracheal tube connection **78** is therefore connected to a conduit **80** located within the housing and connected to the outlet of a solenoid control valve **82** having an inlet connection **84** projecting from the rear wall **86** of the housing. A pressure regulated source of oxygen (not shown) may therefore be connected to the connection **84** when oxygen is to be administered. The front wall **36** of the housing also mounts a restrictive suction valve **88** adapted to be connected by the tube **90** to a liquid trap **92** supported on the front wall by the bracket **94** by means of which fluids may be extracted from the patient when deemed advisable.

Mounted within the housing **26**, is an air pump mechanism **96** supported in fixed position by being bolted to the cross angle frame members **98** and **100**, the pump mechanism being driven by the motor **70** aforementioned which is connected to the pump mechanism housing and projects laterally from one side of the pump mechanism. The pump mechanism has a discharge portion **102** connected by the T-coupling **104** to one of the inlet ports of a three-way valve device **106**. The T-coupling **104** is also connected to a pressure control valve **108** through which the discharge pressure of the pump mechanism may be regulated by controllable venting through a downwardly extending exhaust conduit **110** having an outlet end extending below the housing and connected to a restrictive outlet muffler **112**. Thus, the pressure control knob **74** connected to the pressure control valve **108** may restrictively open or close the pressure control valve **108** in order to regulate the discharge pressure from the pump mechanism. The pump mechanism is also provided with an inlet connection **114** connected by the elbow **116** to the flow rate control valve **118** to which the control knob **76** is connected for controlling the opening of the valve **118** in order to regulate the volumetric flow rate of air. The flow rate control valve **118** is connected to the T-coupling **120** through which suction pressure is applied to an inlet port of the three-way valve device **106**. Accordingly, the valve device **106** is provided with two inlet ports for respective connection to the regulated pressure discharge of the pump mechanism **96** and the suction inlet of the pump mechanism. The valve device **106** is provided therefore with a common outlet **122** connected by the coupling **124** to the outlet conduit **14**. Accordingly, regulated discharge pressure from the pump mechanism **96** and inlet suction pressure are alternatively applied to the outlet conduit **14**. The inlet suction or vacuum pressure is regulated by the vacuum control valve **126** connected to the T-coupling **120** and restrictively open under control of the control knob **72** for drawing a fresh supply of air through the intake conduit **128** extending downwardly from the vacuum control valve **126** to the bottom of the housing. The valve device **106** is therefore actuated so as to establish fluid communication between the common outlet **122** and the two inlet ports respectively exposed to regulated discharge pressure and regulated vacuum pressure. Movement of the valve device **106** between its operative positions is effected in a cyclic manner by means of an oscillating motor **130** mounted on top of the valve device. The pressure in the common outlet of the valve device is indicated by the pressure gauge **132** mounted on the front wall **36** of the resuscitator housing. The restrictive suction valve **88** is also connected by the suction line **134** to the elbow **116** so as to supply suction pressure to the liquid trap **92** when the valve **88** is open.

Successful operation of the resuscitator depends in large measure upon the ability of the sensor device **22** to sense a relatively small pressure variation occurring as a result of inhalation by the patient. Referring therefore to FIGURES 5, 6, 7 and 8, it will be observed that the sensor device includes a pair of parallel spaced housing sections **136** and **138** interconnected in spaced relation by a plurality of fastener assemblies **140**. An inlet tube connector **142** is received within the housing section **138** so as to establish fluid communication between the tube **18** and a passage **144** which opens into a pressure sensing chamber **146** formed by the housing section **138** on one side of a flexible diaphragm **148**. The diaphragm **148** is secured at a circumferentially outer portion to a stepped annular shoulder **150** formed on the housing section **138** between the chamber **146** and the radially outer annular surface **152** through which the fastener assemblies **140** extend. The inlet connector **142** is also provided with a connecting portion **154** received within the housing section **136** for communication with the passage **156** formed therein. The passage **156** communicates with a pressure sensing chamber **158** formed on one side of the diaphragm **160** secured to the annular shoulder portion **162** of the housing section **136**. The housing section **136** is therefore also provided with a radially outer annular portion **164** through which the fastener assemblies **140** extend. Also extending between the radially outer portions **164** and **152** of the housing sections, opposite the inlet connector **142**, is a spring element **166** reacting between brass terminal pin **168** and an externally threaded sleeve **170** through which a brass pin **172** extends. An electrical connector **174** is mounted about the brass terminal pin **172** so as to establish electrical connections between the terminal pins **168** and **172** through the electrical cable **24** extending from the sensor device to the resuscitator apparatus.

The diaphragms **148** and **160** are maintained in spaced relation to each other by a pair of spacer members **176** and **178** separated by an annular O-ring **180** having a gap **182** so as to maintain the space between the spacer members under atmospheric pressure. Vacuum pressure applied to the pressure sensing chambers **146** and **158** will accordingly cause displacement of the diaphragms away from each other opening the electrical contact otherwise established between contact assemblies **184** and **186** respectively mounted centrally of the diaphragms **148** and **160**, the contact assemblies being movable through alined openings **188** and **190** in the spacer members. The contact assembly **184** includes an externally threaded conductive screw member **192** having a slotted adjustment end for receiving a screw driver inserted through a central opening in the housing section **138** when the nut **194** is removed. The contact screw **192** is therefore threadedly received within a nonconductive button **196** on one side of the diaphragm **148**, a washer **198** being provided on the other side and held in assembled position by a clip **200**. A gold leaf foil strip **202** is mounted on the diaphragm **148** establishing a current carrying path from the conductive screw element **192** to a silver pin **204** electrically connected to the terminal pin **172**. The conductive screw element **192** is therefore adapted to engage and establish electrical contact with the gold plated silver pin **206** in the contact assembly **186**. A light-weight button **208** holds the pin **206** on one side of the diaphragm **160**, the pin **206** extending through a washer **210** on the other side of the diaphragm **160** and held assembled thereon by the clip **212**. A gold leaf foil strip **214** is mounted on the diaphragm **160** and establishes a current carrying path from the pin **206** to a silver pin **216** connected to the brass terminal pin **168**. It will therefore be apparent, that the contact assemblies **184** and **186** will establish an electrical connection which is opened in response to the sensing of inhalation or a relatively low vacuum pressure

in the pressure sensing chambers **146** and **158** communicating with the nostril of the patient through the tube **18**.

Operation of the resuscitator apparatus may be reviewed with reference to FIG. 10. It will therefore be recalled, that regulated discharge pressure from the pump **96** and regulated vacuum pressure from the vacuum control valve **126** is alternatively applied to the outlet conduit **14** through the three-way valve **106** in a cyclic manner by operation of the oscillating motor **130**. Operation of the oscillating motor **130** is therefore regulated by a cycle control component **218**. Also, energization of the solenoid valve **82** for administering oxygen from any source **220** at a pressure regulated by the regulator valve **222** may be effected through the oxygen control component **224** as a result of which oxygen may be supplied to the patient either continuously or during the inhalation portion of each cycle as regulated by the cycle control **218**. Referring therefore initially to FIGURE 11, the control system through which the cycle control **218** is operative to regulate the cycling of the oscillating motor **130**, is diagrammatically illustrated. The control system is therefore provided with a mode control component **226** the setting of which is selected by manipulation of the mode selector **54** aforementioned in order to establish one of three different operational modes for the resuscitator apparatus. When the mode control is set for continuous operation, as indicated by line **228**, the relay **230** is operated so as to energize a signal generator **232** dispatching cycling control signals to the cycle control **218** by means of which the frequency of the oscillating motor **130** is regulated in order to induce breathing at a preselected rate. Thus, the output frequency of the signal generator **232** is selected by the frequency control **50**. The resuscitator apparatus in this mode of operation will therefore be regulated at a preselected frequency to the exclusion of any other regulation. When however, the mode selector **54** is set to a controlled position as depicted by line **234**, the sensor device **122** is rendered operative so as to regulate the cycling signal dispatched by the cycle control **218**. The output signal from the sensor **22** is supplied to the cycle control **218** by the line **236**. When the sensor **22** is operative to regulate the cycling frequency, the signal generator **232** will be inoperative inasmuch as the relay **230** will not be energized. Thus, the operational modes represented by lines **228** and **234** respectively effect cycling at a preselected rate through the signal generator **232** and at a natural rate as sensed by the sensor **22** to the exclusion of any other regulation. Automatic operation is effected when the mode selector **54** is set to an automatic position as depicted by the line **250** in FIGURE 11. Under automatic operation, the loss of a signal output from the sensor **22** is operative on the demand control **240** to supply an operating signal by line **252** to the relay **230** through which operation of the signal generator is initiated and the sensor disabled. However, a signal is also supplied through line **254** to the interval control component **248** which then periodically dispatches of a signal through line **256** to the disabling switch **258** interrupting energization of the relay **230** and regulation under control of the signal generator **232**. Accordingly, the disabling signal in line **242** is also removed so as to permit the sensor **22** to regulate cycling if any inhalation of the patient is sensed during the interruption period effected by the interval control **248**. If inhalation is sensed by the sensor **22**, the signal in line **238** applied to the demand control **240** will prevent cycling regulation by the signal generator **232**. Should however, natural breathing cease, no signal will be dispatched by the sensor **22** to the line **238** so that the demand control **240** will once again supply a signal in line **252** in order to resume operation under control of the signal generator **232**.

Referring now to both FIGURES 12A and 12B, one form of electrical circuitry corresponding to the control system depicted in FIGURE 11, is shown. The power supply shown in FIGURE 12A includes therefore, a pair of powerlines **260** and **262** connected to a 115 v. AC electrical source for energizing the primary **264** of a main power transformer **266** when the power switch **268** is closed. Also, upon closing of the motor switch **66**, the pump motor **70** is energized together with the parallel connected primary **270** of transformer **272** through which the oscillating motor **130** is energized. The secondary **274** of the transformer **272** is therefore connected by a line **276** to one terminal of the motor **130** and by line **278** to the cycling control switch **280** of the cycle control **218** as shown in FIGURE 12B in order to reverse energization of the motor **130**. The cycling control switch **280** is therefore oscillated between contacts **281**, **283** and **285**, **287** by pulsing of the power relay **282**. Contacts **281** and **283** are respectively connected to motor **130** and the automatic contact **284** of selector switch **56** so that the cycling switch **280** may switch the oscillating motor **130** and at the same time deenergize the solenoid valve **82** when the selector switch **56** is in an automatic position engaging contact **284**. Accordingly, during the inhalation period the solenoid valve **82** will be deenergized and open so as to supply oxygen to the patient, the valve being closed during the exhalation portion of the cycle by energization of the solenoid valve through the cycling control **218**. When however, the selector **56** is in the continuous position engaging the contact **286** no energizing circuit can be completed for the solenoid valve **82** so as to maintain a continuous supply of oxygen. One terminal of the solenoid valve **82** is therefore connected to line **276** from the secondary **274** of transformer **272**, and the other terminal connected to selector switch **56**. When the selector **56** engages the off contact **288** which is connected to line **278** of secondary **274**, the solenoid valve **82** will remain energized continuously so as to cut off the supply of oxygen. The transformer **266** is also provided with a plurality of rectifier circuits **290** associated with a plurality of secondary windings providing rectified voltages of different values as indicated in FIGURE 12A to the various components of the electrical circuitry depicted in FIGURE 12B.

It will be observed in FIGURE 12B, that the power relay coil **282** of the cycle control **218**, is pulsed by an amplifier output signal appearing at the collector of the second stage amplifier transistor **292**. The emitter of the transistor **292** is connected to the +30 volt source of the power supply **290** producing an energizing current in the power relay **282** when a signal is applied to the base of the transistor biased through bias resistor **294** connected to the +24 volt source of the power supply. The signal applied to the transistor **292** is derived from the collector of the first stage amplifier transistor **296** having an emitter connected to the +36 volt source of the power supply. The base of transistor **296** is biased through resistor **298** connected to the +30 volt source and the resistor **300**. The transistors **296** and **292** are therefore operative to amplify an input signal supplied to the base of the transistor **296** from either line **302** or line **304**.

The signal input line **302** is connected to the sensor **22** through the normally closed relay sensor switch **305** and line **306**. Accordingly, upon closing of the contact assemblies in the sensor **22**, an input voltage is established in line **302** derived from the 42 volt source connected to the sensor by line **308** and the voltage reducing resistor **310**. This voltage signal will therefore occur during the exhalation portion of the cycle sensed by the sensor device **22** in order to supply cycling pulses to the component **218** at the natural breathing rate. Alternatively, pulsing of the power relay **282** may be effected by signal voltage supplied by line **304** to the amplifier stages. The voltage signal appearing in the line **304** is however, regulated in accordance with a selected frequency output of the signal generator **232**.

The signal generator **232** is in the form of a flip-flop

circuit connected to the +85 volt source through potentiometer 312 when the normally open relay input switch 314 is closed. A reduced voltage is then supplied through the inhalation spacer potentiometer 58 to a resistance divider network and through the potentiometer setting of the frequency control 50 establishing reduced differential voltages of a regulated value on opposite sides of the storage capacitor 316 cousing it to charge and discharge at a regulated rate as the neon lamps are triggered on and off. Accordingly, the storage capacitor 316 is connected between the signal output line 304 and line 318 to establish a conductive path either through the neon lamp 62 or the neon lamp 60 in series with resistor 320, the neon lamps being interconnected with a common return line 322 connected to the −85 volt source. The capacitor 316 is charging and discharging at a controlled rate with alternatively supply voltage signals in output line 304 as aforementioned. The shunt connection through resistor 324 is closed by the normally closed relay rate switch 326 so as to maintain capacitor 316 in a completely discharged state. It will therefore be apparent, that when the relay coil 330 is de-energized, the normally open relay switches 314 and 328 and normally closed relay switch 326 will maintain the signal generator 232 inoperative. As long as the relay coil 332 is de-energized at the same time, the normally closed relay switch 305 will maintain the sensor 22 operative to regulate the cycling pulses applied to the component 218.

When the mode selector 54 is displaced to the position for continuous mode of operation, clockwise from the position illustrated in FIGURE 12B, an electrical connection is established from the +15 volt source through line 334, switch 336, resistance 338, line 340, switch 342, line 344 and normally closed energizing relay switch 346 to the base of transistor 348. The base of the transistor is biased through bias resistor 350 by the +36 volt source so that the voltage signal applied thereto will render the transistor conductive in order to establish a conductive path from the +30 volt source through line 352, the emitter and collector of the transistor 348, to the relay coil 330 connected to the zero voltage line 354. Also connected in parallel with relay coil 330 to the collector of transistor 348, is the relay coil 332 also connected in common with the zero voltage line 354. It will therefore be apparent, that relay coils 330 and 332 will be simultaneously energized so as to open the sensor relay switch 305 disabling regulation by the sensor and actuating the realy switches 314, 326 and 328 in order to place the signal generator 232 into operation. Cycling of the resuscitator apparatus will then be effected at a selected rate determined by the setting of the potentiometers associated with the frequency controlling control knob 50. The setting of the spacer potentiometer 58 on the other hand, is made infrequently in order to vary the duration of the inhalation portion of the breathing cycle.

When the mode selector 54 is in the automatic position illustrated in FIGURE 12B, no voltage is directly available from the +15 volt source for supply to the line 340 in order to trigger the transistor 348 into a conductive state for energizing the relay coils 330 and 332 as aforementioned in connection with the continuous mode of operation. Instead, signal voltage for triggering the transistor 348 into its conductive state is supplied to line 340 from the demand control circuit 240 and periodically interrupted by the test interval timer 248 at periods determined by the setting of the potentiometer control 52 by energization of the relay coil 356 opening the normally closed relay switch 346 in order to remove the signal voltage from the base of transistor 348 switching it to its nonconductive state. The interval control component 248 is rendered operative to function under the automatic mode of operation inasmuch as the switch 336 then connects the +15 volt line 334 to the emitter of transistor 358 through line 360. With relay coil 330 energized, the interval relay switch 362 is actuated so as to remove the 15 volts applied to one side of the capacitor 364 while at the same time connecting the base of transistor 358 thereto. The voltage supplied to the base of transistor 358 will therefore be applied through a resistance divider network and the potentiometer 368 from the capacitor 364 through the resistor 366 in series therewith in order to control the discharge rate of capacitor 364 and the operation of relay 356. The capacitor 364 when discharging does so at a rate regulated by the interval control potentiometer 52. Accordingly, the charge on capacitor 364 will decrease until a trigger voltage value appears on the base of transistor 358. When triggered, the transistor 358 will conduct energizing current to the relay coil 356 through line 370, the relay coil 356 being connected to the zero voltage line 354. Accordingly, the relay coil 356 will actuate relay switch 346 to deenergize the relay coils 330 and 332. Upon deenergization of the relay coils 330 and 332, operation of the system will change from regulation by the signal generator 232 to regulation by the sensor 22 if it is sensing inhalation of the patient. Also, relay switch 362 will reset the test interval control 248.

When operating in automatic mode either from signal generator 232 or sensor 22, transformer 380 connected by its primary 378 to the relay 282, supplies a pulse to the charge capacitor 390 and thereby triggers transistor 374 into conduction. The secondary 382 of transformer 380 is therefore connected by the full wave rectifier 384 across the charge capacitor 390. The base of transistor 374 during the automatic mode of operation is therefore connected to one side of the full wave rectifier through switch 386 in the mode control while the emitter is connected through the voltage driving resistor 391 to the 42 volt source. The output of the transistor 374 is conducted from the collector through the load resistor 376. The base and emitter are also maintained at a predetermined potential difference by the resistor 393 so that the trigger pulse from the capacitor 390 applied through the potentiometer 392 may trigger the transistor 374 into conduction.

When the signal generator 232 is operating, relay switch 372 is open and transistor 394 conducts because of the voltage established on its base by the 24-volt source through resistors 395 and 389 in series. The emitter of transistor 394 is therefore biased by a voltage established through potentiometer 400 interconnected between the 30 and 36 volt sources. A voltage is thereby established on the base of transistor 396 through resistor 396 which causes it to conduct and maintain a signal in line 340. The signal in line 340 holds transistor 348 conductive and relays 330 and 332 energized so that the signal generator 232 is in an operating condition. When the test interval control 248 operates as previously described, relay switch 346 is opened removing the signal in line 340 from transistor 348. Operation is thereby returned to control by sensor 22. As a result thereof, relay switch 372 is closed so that a charge accumulated on capacitor 388 drives transistors 394 and 396 into a non-conducting state, removing any control signal from line 340. The timing capacitor 388 is charged each time relay 282 operates because of a pulse transferred thereto through the transistor 374 rendered conductive as hereinbefore indicated. If the relay 282 continues to operate indicating that the patient is attempting to control the resuscitator through the sensor 22, the timing capacitor 388 will be maintained in the charged condition and no signal will be developed by transistors 394 and 396. However, if the relay 282 fails to operate for as long as five seconds, the charge on the timing capacitor 388 will be drained off through resistor 389 thereby driving transistors 394 and 396 into a conducting state and establishing a signal on line 340 to operate transistor 348 and transfer control of the resus-

citator back to the signal generator **232**. The foregoing cycle will repeat itself.

From the foregoing description, the construction, operation and utility of the resuscitator apparatus and control system associated therewith will be apparent. It will therefore be appreciated that the resuscitator is capable of being regulated to provide the proper pressure and vacuum levels for the chest shell **16** in order to induce or assist the patient with breathing. The operational mode of the resuscitator may also be varied for continuous operation at a controlled breathing rate or at a natural breathing rate by use of the low pressure sensor device **22**. Automatic operation of the resuscitator may also be effected so that the breathing rate may be controlled and periodically during a test interval of preselected duration, the signal generator regulating the cycling rate, is temporarily disabled to permit the sensor to take over regulation at the natural breathing rate if the patient is breathing. Should the sensor device fail to detect any breathing on the part of the patient, after the test interval has elapsed, operation is resumed under regulation of the signal geneerator.

The foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly all suitable modifications and equivalents may be resorted to, falling within the scope of the invention as claimed.

What is claimed as new is as follows:

1. In combination with a resuscitator for alternatively applying pressure and vacuum to the chest cavity of a patient, a control system comprising, pressure sensing means for detecting inhalation by the patient, signal generating means operatively connected to the cycling control means for regulating inhalation and exhalation of the patient at a preselected frequency, demand control means responsive to detection of inhalation by the pressure sensing means for replacing regulation of the cycling means by the signal generating means with patient demand when sensed by the pressure sensing means during a test interval, interval control means operatively connected to the demand control means and the signal generating means for periodically interrupting operation of the signal generating means to permit regulation of the cycling means by the pressure sensing means during said test interval, and mode control means operatively connected to the demand control means and the interval control means for selectively disabling operation of the signal generating means and the interval control means for exclusive regulation of the cycling means by the pressure sensing means or the signal generating means.

2. In combination with a resuscitator having cycling means for alternatively applying pressure and vacuum to the chest cavity of a patient to simulate or assist breathing action, a control system comprising, pressure sensing means for detecting inhalation by the patient, signal generating means operatively connected to the cycling control means for continuously regulating inhalation and exhalation of the patient at a preselected frequency, demand control means responsive to detection of inhalation by the pressure sensing means for replacing regulation of the cycling means by the signal generating means with patient demand as sensed by the pressure sensing means, interval control means operatively connected to the demand control means and the signal generating means for periodically interrupting operation of the signal generating means to permit regulation of the cycling means by the pressure sensing means during a test interval, and mode control means operatively connected to the demand control means and the interval control means for selectively restricting operation of the cycling means to exclusive regulation by the pressure sensing means or the signal generating means, said pressure sensing means comprising, a pair of diaphragms, spacer means mounting said diaphragms in fixed spaced relation to each other, contact means mounted on said diaphragms for relative movement through said spacer means, housing means enclosing the diaphragms and spacer means to form variable pressure sensing chambers on opposite sides of the diaphragms for inducing relative movement of the contact means, conductive terminal means mounted by the housing means in engagement with the diaphragms, and conductive coating strips mounted on said opposite sides of the diaphragms establishing current carrying paths between the contact means and the terminal means.

3. The combination of claim **2**, wherein the resuscitator comprises, a pump having an inlet and an outlet, discharge pressure regulating means connecting said outlet to the cycling means, suction pressure regulating means operatively connecting said inlet to the cycling means, and flow control means interconnecting the inlet to the suction pressure regulating means for volumetrically controlling contraction of the patient's chest cavity during inhalation.

4. The combination of claim **3** including restrictive valve means connected to the inlet to selectively provide suction pressure for fluid removal from the patient.

5. The combination of claim **4** including a regulated source of oxygen under pressure, valve control means connected to said cycling means for intermittent supply of oxygen to the patient simultaneously with the application of vacuum pressure to the chest cavity, and selector means operatively connected to the valve means for continuous supply of said oxygen.

6. The combination of claim **5** wherein said cycling means comprises, a three-way valve having a common outlet interconnected with said discharge pressure regulating means and said suction pressure regulating means, oscillating motor means connected to the three-way valve for alternatively connecting the common outlet to the discharge pressure regulating means and the suction pressure regulating means, and a chest shell connected to said common outlet adapted to be applied to the patient for expansion and contraction of the chest cavity of the patient.

7. In combination with a resuscitator having cycling means for alternatively applying pressure and vacuum to the chest cavity of a patient to simulate or assist breathing action, a control system comprising, pressure sensing means for detecting inhalation by the patient, signal generating means operatively connected to the cycling control means for continuously regulating inhalation and exhalation of the patient at a preselected frequency, demand control means responsive to detection of inhalation by the pressure sensing means for replacing regulation of the cycling means by the signal generating means with patient demand as sensed by the pressure sensing means, interval control means operatively connected to the demand control means and the signal generating means for periodically interrupting operation of the signal generating means to permit regulation of the cycling means by the pressure sensing means during a test interval, and said pressure sensing means comprising, a pair of diaphragms, spacer means mounting said diaphragms in fixed spaced relation to each other, contact means mounted on said diaphragms for relative movement through said spacer means, housing means enclosing the diaphragms and spacer means to form variable pressure sensing chambers on opposite sides of the diaphragms for inducing relative movement of the contact means, conductive terminal means mounted by the housing means in engagement with the diaphragms, and conductive coating strips mounted on said opposite sides of the diaphragms establishing current carrying paths between the contact means and the terminal means.

8. The combination of claim **7** including a regulated source of oxygen under pressure, valve control means connected to said cycling means for intermittent supply

of oxygen to the patient simultaneously with the application of vacuum pressure to the chest cavity, and selector means operatively connected to the valve means for continuous supply of said oxygen.

9. In combination with a resuscitator having a pump, cycling means for alternatively applying pressure and vacuum to the chest cavity of a patient to simulate or assist breathing action, discharge pressure regulating means connecting the pump to the cycling means and a control system comprising, pressure sensing means for detecting inhalation by the patient, signal generating means operatively connected to the cycling control means for continuously regulating inhalation and exhalation of the patient at a preselected frequency, demand control means responsive to detection of inhalation by the pressure sensing means for replacing regulation of the cycling means by the signal generating means with patient demand when sensed by the pressure sensing means, interval control means operatively connected to the demand control means and the signal generating means for periodically interrupting operation of the signal generating means to permit regulation of the cycling means by the pressure sensing means during a test interval, and said cyling means comprising, a three-way valve having a common outlet interconnected with said discharge pressure regulating means and said suction pressure regulating means, oscillating motor means connected to the three-way valve for alternatively connecting the common outlet to the discharge pressure regulating means and the suction pressure regulating means, and a chest shell connected to said common outlet adapted to be applied to the patient for expansion and contraction of the chest cavity of the patient.

10. In combination with means for producing pressure and vacuum and a resuscitator having cycling means for alternatively applying pressure and vacuum to the chest cavity of a patient to simulate or assist breathing action, a pressure sensing device comprising, a pair of diaphragms, spacer means mounting said diaphragms in fixed spaced relation to each other, contact means mounted on said diaphragms for relative movement through said spacer means, housing means enclosing the diaphragms and spacer means to form variable pressure sensing chambers on opposite sides of the diaphragms for inducing relative movement of the contact means, conductive terminal means mounted by the housing means in engagement with the diaphragms, conductive coating strips mounted on said opposite sides of the diaphragms establishing current carrying paths between the contact means and the terminal means, and an inlet tube connected to the chambers in the housing means adapted to be inserted in the nostrils of the patient.

11. A resuscitator comprising, a pump having an inlet and an outlet, discharge pressure regulating means connected to said outlet, suction pressure regulating means operatively connected to said inlet, flow control means interconnecting the inlet to the suction pressure regulating means, a three-way valve having a common outlet interconnected with said discharge pressure regulating means and said suction pressure regulating means, oscillating motor means connected to the three-way valve for alternatively connecting the common outlet to the discharge pressure regulating means and the suction pressure regulating means, a chest shell connected to said common outlet adapted to be applied to the patient for expansion and contraction of the chest cavity of the patient, a pressure sensing device for detecting inhalation by the patient, and control means operatively connecting the pressure sensing device to the oscillating motor for regulating operation thereof in accordance with the breathing rate of the patient.

12. The combination of claim **11** wherein said pressure sensing device comprising, a pair of diaphragms, spacer means mounting said diaphragms in fixed spaced relation to each other, contact means mounted on said diaphragms for relative movement through said spacer means, housing means enclosing the diaphragms and spacer means to form variable pressure sensing chambers on opposite sides of the diaphragms for inducing relative movement of the contact means, conductive terminal means mounted by the housing means in engagement with the diaphragms, conductive coating strips mounted on said opposite sides of the diaphragms establishing current carrying paths between the contact means and the terminal means, and an inlet tube connected to the chambers in the housing means adapted to be inserted in the nostrils of the patient.

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