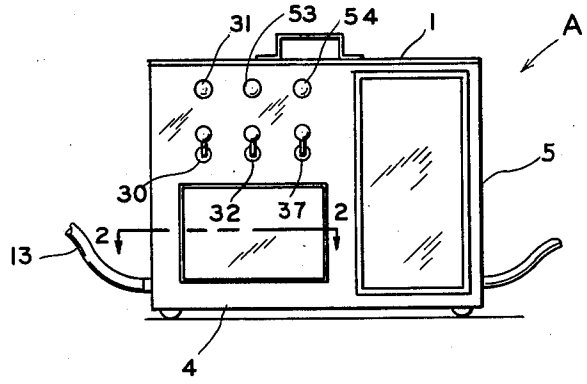
June 5, 1962 W. H. SMITH 3,037,498

CONTROL SYSTEMS FOR MECHANICAL RESPIRATORS

Filed Aug. 29, 1957 2 Sheets-Sheet 1

FIG. 1



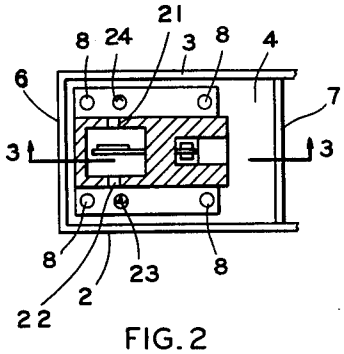


FIG. 2

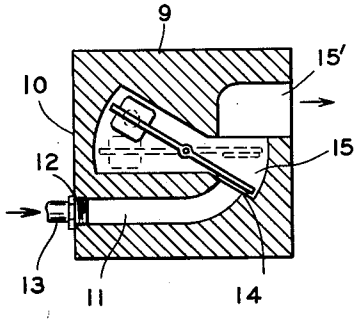


FIG. 3

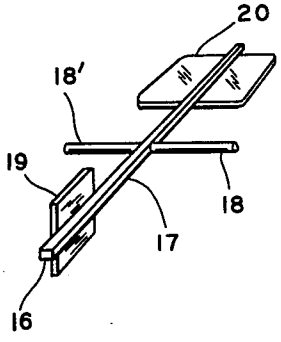


FIG. 4

INVENTOR.
WILLIAM HAROLD SMITH
BY
Alfred W. Petcheff

June 5, 1962 W. H. SMITH 3,037,498

CONTROL SYSTEMS FOR MECHANICAL RESPIRATORS

Filed Aug. 29, 1957 2 Sheets-Sheet 2

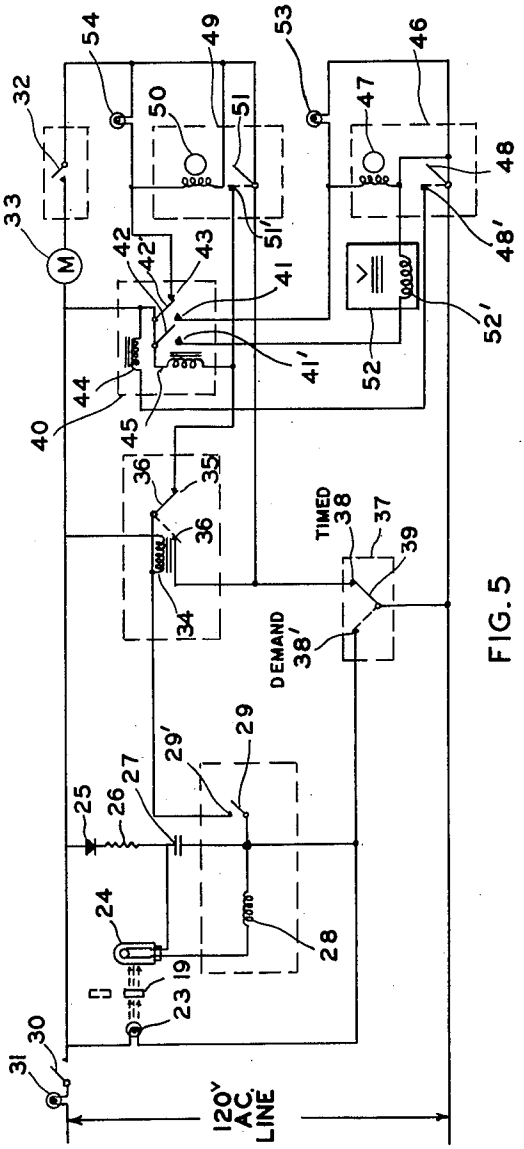


FIG. 5

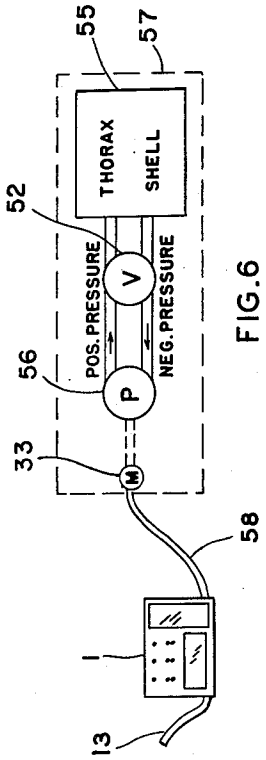


FIG. 6

INVENTOR.

WILLIAM HAROLD SMITH

BY

Alfred W. Petcraft

United States Patent Office

3,037,498

Patented June 5, 1962

3,037,498

CONTROL SYSTEMS FOR MECHANICAL RESPIRATORS

William Harold Smith, Norwalk, Conn., assignor, by mesne assignments, to Shampaine Industries Inc., St. Louis, Mo., a corporation of Missouri

Filed Aug. 29, 1957, Ser. No. 681,115
15 Claims. (Cl. 128—30)

This invention relates in general to medico-electronic devices and, more particularly, to a control system for mechanical respirators, such as iron lungs and the like.

In the care of patients suffering from poliomyelitis affecting the thoracic muscles, normal breathing is usually impossible. Such patients can be sustained, however, through resort to artificial breathing devices, such as the so-called "iron lung" or similar equipment in which motor driven pumps alternately apply increasing and decreasing pressure within the chamber surrounding the patient's body or chest. When the pressure is slightly above atmospheric pressure, it is usually referred to by physicians as "positive" pressure and, under such pressure condition, the patient exhales. Similarly, when the pressure is slightly below atmospheric, it is usually referred to as "negative" pressure and the patient inhales. If a patient had a complete muscular deficiency in the chest and had no ability whatsoever to breathe, the iron lung would be substantially satisfactory. However, most patients have some residual breathing power and it is highly desirable to stimulate the recovery, so far as possible, of more and more independent breathing power on the part of the patient. Moreover, where a patient with some residual breathing power is placed in a respirator of any type, the operational cycle of the machine must be adjusted closely to the patient's breathing cycle, but the patient also must learn to synchronize his breathing with the cycle of the machine. Unless the timing of both machine and patient are closely observed and held in synchronized relation, the patient will soon be trying to exhale when the machine is applying negative pressure and inhale when the machine is applying positive pressure, thereby, in extreme cases, producing suffocation and death.

Even where the situation is not severe, many polio patients are "over ventilated," that is to say, forced to breath too deeply and too often, thereby causing a dangerous CO_2 level and blood pH. Another serious defect in mechanical respirators is the creation of an excessive and constant negative pressure on inhalation, which eventually leads to emphysema. It, therefore, would be extremely desirable to operate mechanical breathing devices on patient demand.

Hence, it is the primary object of the present invention to provide means and methods for synchronizing the operational cycle of mechanical respirators with the patent's breathing cycle and maintaining such synchronism during any and all variations in patient-demand.

It is another object of the present invention to provide a sensing element which responds to the flow of breath from the nose of a patient.

It is a further object of the present invention to provide a device of the type stated which is simple and yet highly accurate.

It is also an object of the present invention to provide a device of the type stated which can be comfortably applied to the patient.

With the above and other objects in view, my invention resides in the novel features of form, construction, arrangement, and combination of parts presently described and pointed out in the claims.

In the accompanying drawings

FIG. 1 is a front elevational view of the respirator control constructed in accordance with and embodying the present invention;

FIG. 2 is a vertical sectional view taken along line 2—2 of FIG. 1;

FIG. 3 is a fragmentary sectional view taken along line 3—3 of FIG. 2;

FIG. 4 is a perspective view of the nasal sensing vane and shutter forming a part of the present invention;

FIG. 5 is a schematic wiring diagram of the control system; and

FIG. 6 is a block diagram showing the control unit and its connection to a thorax shell.

Referring now in more detail and by reference characters to the drawings, which illustrate a preferred embodiment of the present invention, A designates a control system for mechanical respirators including a housing **1** comprising front and rear walls **2**, **3**, a bottom wall **4**, end walls **5**, **6**, and a partition **7** intermediate the end walls **5**, **6**. Rigidly secured to the bottom wall **4** by means of bolts **8** and between the partition **7** and end wall **6** is a nasal sensory device **9** including a base member **10** having a horizontal inlet conduit **11** tapped at one end for reception of a fitting **12** secured to one end of a flexible tube **13**. At its other end, the conduit **11** curves upwardly and terminates in a shoulder **14** which is presented toward a chamber **15**. The base member **10** is also provided with an outlet conduit **15'** which terminates at its inner end in the chamber **15** in upwardly spaced relation to the shoulder **14**. Positioned within the base member **10** and within the chamber **15** is a very light weight sensing element **16** including an elongated rod **17** integrally provided intermediate its ends with a pair of opposed shafts **18**, **18'**, each being rockably journaled in the base member **10**. At its forward end, the rod **17** is provided with a thin flat shutter **19** and at its rear end the rod **17** is provided with a flat vane **20** lying in a plane at right angles to, and being slightly heavier than, the shutter **19** so as to normally bear against the shoulder **14** closurewise across the conduit **11**. Bored through the base member **10** are spaced aligned apertures **21**, **22**, each of which communicates with the chamber **15**. Also mounted within the housing **1** adjacent the aperture **21** is an illumination source **23** and similarly mounted adjacent the aperture **22** is a photoelectric cell **24**. The photoelectric cell **24** is of the cadmium sulphide type and is photo-resistive so that as the light intensity on the photo-sensitive area of the cell **24** increases, the resistance of the cell **24** decreases. It will be apparent that when the sensing element **16** is in the position shown in full lines in FIG. 3, the shutter **19** will prevent the light from the illumination source **23** from impinging upon the photoelectric cell **24**, but when the sensing element **16** is in the position shown in dotted lines, the light will be directed through the apertures **20**, **21**, so as to strike the photoelectric cell **24**.

The control circuit for the device A includes a selenium rectifier **25**, a fixed resistor **26**, an electrolytic capacitor **27**, a S.P.S.T. relay **28** having contacts **29**, **29'**, a power on-off switch **30**, power on-off pilot light **31**, and a switch **32** for starting a motor **33**. Also included in the circuit is a S.P.D.T. time delay relay **34** having contacts **35**, **35'**, **36**, a manually operable S.P.D.T. selector switch **37** having contacts **38**, **38'**, **39**, a D.P.D.T. latching relay **40** having contacts **41**, **41'**, **42**, **42'**, **43**, an inspiration coil **44** and an expiration coil **45**, an expiration timer **46** including a motor **47** adapted to open and close contacts **48**, **48'**, an inspiration timer **49** including a motor **50** adapted to open and close contacts **51**, **51'**, and a solenoid operated sequencing valve **52** having a solenoid **52'**. Preferably, the circuit is also provided with an expiration pilot light **53**

and an inspiration pilot light 54, each of which is illuminated when the timer associated therewith is in operation. The expiration timer 46 and inspiration timer 49 are of similar construction and each may be set to operate for a predetermined period of time, at the end of which the contacts therein will be momentarily closed and for purposes presently more fully appearing. The aforementioned circuit components are connected together in the manner shown in FIG. 5.

The solenoid sequencing valve 52 is interposed between a conventional pneumatic thorax shell 55 and pump 56, which is, in turn, operatively connected to the motor 33, as shown in FIG. 6, so that the valve 52 can control the application of either positive or negative pressure in the thorax shell 55. Thus, when the solenoid 52' is energized, the valve 52 opens, applying positive pressure to the thorax shell 55, and, when the solenoid 52' is de-energized, the valve 52 will permit the application of negative pressure in the thorax shell 55. The motor 33, pump 56, solenoid operated valve 52, and thorax shell 55 are all normally mounted on a mechanical respirator diagrammatically indicated at 57, the details of which are conventional and are, therefore, not shown or described. With the exception of the motor 33 and solenoid operated valve 52, the components of the circuit shown in FIG. 5 are all mounted in the housing 1 and an electrical cable 58 is provided for connection between the housing 1 and the respirator 57. For convenience, the switches 30, 32, 37, and the pilot lights 31, 53, 54, are mounted on the front wall 2 of the housing 1, as shown in FIG. 1.

In use, the free end of the tube 13 is preferably taped or otherwise secured adjacent the patient's nostrils and the switch 30 is closed, illuminating the pilot light 31. If it is desired to provide timed respiration, the switch 39 is manually moved to the "Timed" position to close the contacts 38, 39, as shown in full lines in FIG. 5. The switch 32 is then closed to start the operation of the motor 33. Initially, the contacts 42', 43, of the latching relay 40 are closed, as shown in full lines, allowing current to flow through the inspiration pilot light 54 and also through the inspiration timer motor 50. The solenoid 52' is de-energized so that the valve 52 will cause negative pressure to be applied to the patient through the thorax shell 55. The inspiration timer motor 50 will operate for its pre-selected period of time, at the end of which time there will be a momentary closing of contacts 51, 51', allowing current to flow through the expiration coil 45 of the latching relay 40, causing the contacts 41', 42, and the contacts 41, 42', in the latching relay 40 to close and lock. At the same time, current will also flow through the expiration pilot light 53, the expiration timer motor 47, and through the solenoid 52', energizing same and opening the valve 52 so as to apply positive pressure from the pump 56 to the thorax shell 55. The expiration timer motor 47 will operate throughout its pre-selected time, at the end of which time there will be a momentary closing of the contacts 48, 48', permitting current to flow through the inspiration coil 44 of the latching relay 40, opening the contacts 41', 42, and the contacts 41, 42', and closing the contacts 42', 43. When the contacts 41', 42, open, the solenoid 52' is de-energized, closing the valve 52, thereby applying negative pressure to the thorax shell 55, completing the cycle. It should be noted that when the selector switch 39 is set to the "Timed" position, there will be no current flowing through the lamp 23 or photoelectric cell 24 and the breathing of the patient is completely controlled by the operational cycle of the control circuit.

When it is desired to adjust the operation of the thorax shell 55 in accordance with the residual breathing power of the patient, the selector switch 39 is manually moved to the "Demand" position, closing contacts 38', 39; whereupon, the inspiration timer motor 50 is cut out of the circuit and current is supplied to the illumination source 23 and photoelectric cell 24. The solenoid 52' in the valve 52 will be de-energized and negative pressure will be present in the thorax shell 55. The contacts 42', 43, of the latching relay 40 will be closed and current will flow through the inspiration pilot light 54, and as long as the patient is inhaling, the circuit will remain locked in this position. When the patient exhales, a slight amount of pressure is built up in the tube 13 and inlet conduit 11, which is impressed upon the vane 20, causing the sensing element 16 to swing to the position shown in dotted lines in FIG. 3 and move the shutter 19 out from between the apertures 21, 22. Light from the illumination source 23 will then impinge upon the photoelectric cell 24, decreasing its resistance and allowing current to flow therethrough and through the relay 28, closing its contacts 29, 29'. As soon as the contacts 29, 29', of the relay 28 are closed, current will flow through the time delay relay 34, the contacts 35, 36, of which are normally closed as shown in full lines. Current also will flow through the expiration coil 45, closing the contacts 41', 42, and 41, 42', through the expiration timer motor 50, and through the solenoid 52', which opens the valve 52, causing positive pressure to be applied from the pump 56 to the thorax shell 55. The expiration timer motor 50 will operate throughout its pre-selected period of time, at the end of which time there will be a momentary closing of the contacts 48, 48', allowing current to flow through the inspiration coil 44, causing the contacts 41', 42, and 41, 42', to open, and causing the contacts 42', 43, to close. When the patient has finished exhaling, the sensing element 16 returns to the position shown in full lines in FIG. 3, causing the shutter 19 to prevent light from striking the photoelectric cell 24; whereupon, the contacts 29, 29', in the relay 28 will open, stopping current flow through the relay 34 and closing the contacts 35, 36, therein. At the moment the relay 28 closed, allowing current to flow through the time delay relay 34, the contacts 35, 36, remained closed for a delay period of about one second, at the end of which time the contacts 35, 36, were opened and the contacts 35', 36, were closed, causing the contacts 51, 51', of the inspiration timer motor 49 to be closed. Therefore, if, for some reason or another, the sensing element 16 should become stuck in the position shown in dotted lines in FIG. 3, allowing light to continuously impinge upon the photoelectric cell 24, the relay 34 acts as a safety device preventing the thorax shell 55 from being continuously held in the expiratory position, since failure of the contacts 35', 36, of the relay 34 to open will cause the circuit to be locked into timed respiration.

It will be apparent that by setting the selector switch 39 to operate on demand respiration, the device A can synchronize the operation of the respirator 57 in accordance with the patient's need to exhale, although the length of time through which the thorax shell 55 operates to apply positive pressure is timed.

It should be understood that changes and modifications in the form, construction, arrangement, and combination of the several parts of the control systems for mechanical respirators may be made and substituted for those herein shown and described without departing from the nature and principle of my invention.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. An apparatus for use with patients who are unable to sustain normal breathing but have some residual breathing power, said apparatus comprising thorax-constricting means for alternately increasing and decreasing the pressure on the chest of the patient, current-transmitting means operatively associated with said thorax-constricting means, and a nasal sensing device including a sensing element movably secured therein, said sensing element being provided with a pressure-responsive element the actuation of which will move said sensing element, said sensing element being operatively associated with and adapted to actuate said current-transmitting means so that movement of said sensing element will determine the

point in time at which the applied pressure on the chest of the patient increases and decreases.

2. An apparatus for use with patients who are unable to sustain normal breathing but have some residual breathing power, said apparatus comprising means for alternately increasing and decreasing the pressure on the chest of the patient, current transmitting means operatively associated with said last-mentioned means, said current transmitting means being adapted to control the point in time at which the applied pressure on the chest of the patient increases, a nasal sensing element operatively associated with and adapted to actuate said current transmitting means, and means by which the nasal sensing element can be operatively connected to the nostrils of the patient so as to be responsive to the residual breathing cycle of the patient.

3. An apparatus for use with patients who are unable to sustain normal breathing but have some residual breathing power, said apparatus comprising means for alternately increasing and decreasing the pressure on the chest of the patient, a photo-electric cell, an illumination source adapted to direct light onto said photo-electric cell, said aforementioned means being operatively associated with and responsive to the current flow through the photo-electric cell, the current flow through said photo-electric cell being adapted to control the point in time at which the applied pressure on the chest of the patient increases and decreases, a movable sensing element having a shutter for optional disposition across the beam of light from the illumination source, whereby to control the current flow through the photo-electric cell, and means by which the sensing element can be operatively connected to the nostrils of the patient so as to be movable responsive to the residual breathing cycle of the patient.

4. An apparatus for use with patients who are unable to sustain normal breathing but have some residual breathing power, said apparatus comprising means for alternately increasing and decreasing the pressure on the chest of the patient, a photo-electric cell, an illumination source adapted to direct light onto said photo-electric cell, said aforementioned means being operatively associated with and responsive to the current flow through the photo-electric cell, the current flow through said photo-electric cell being adapted to control the point in time at which the applied pressure on the chest of the patient increases and decreases, a movable sensing element having a shutter for optional disposition across the beam of light from the illumination source, whereby to control the current flow through the photo-electric cell, said sensing element also being provided with pressure-responsive means operatively connected to said shutter, and means by which the pressure-responsive means can be operatively connected to the nostrils of the patient so as to be actuable responsive to the residual breathing cycle of the patient.

5. An apparatus for use with patients who are unable to sustain normal breathing but have some residual breathing power, said apparatus comprising means for alternately increasing and decreasing the pressure on the chest of the patient, a photo-electric cell, an illumination source adapted to direct light onto said photo-electric cell, said aforementioned means being operatively associated with and responsive to the current flow through the photo-electric cell, the current flow through said photo-electric cell being adapted to control the point in time at which the applied pressure on the chest of the patient increases and decreases, a movable beam-like member provided with a shutter for optional disposition across the beam of light from said illumination source, whereby to control the current flow through the photo-electric cell, pressure-responsive means mounted on said beam-like element and being slightly heavier than said shutter, and means by which the pressure-responsive means can be operatively connected to the nostrils of the patient so as to be actuable responsive to the residual breathing cycle of the patient.

6. An apparatus for use with patients who are unable to sustain normal breathing but have some residual breathing power, said apparatus comprising means for alternately applying increasing and decreasing pressure on the chest of a patient in synchronized relation with the patient's breathing and control means including photoelectric cell means and a movable sensing element operatively connected to said photoelectric cell means, said control means operatively associated with said last-mentioned means and being operable to apply increasing pressure on the chest of the patient throughout a preselected time interval commencing upon exhalation by the patient.

7. A nasal sensory device comprising a base member having a conduit therein, said base member furthermore being provided with a chamber adapted to communicate with said conduit, means for connecting said chamber to the nose of a patient along a path which includes said conduit, an elongated beam-like member operatively mounted in said chamber and being provided with a vane adapted for normal disposition closurewise across said conduit, and a shutter operatively mounted on said elongated beam-like member, photoelectric cell means operatively associated with said base member, said vane being movable when pressure is created in said inlet conduit and thereby move said shutter so that said photoelectric cell means can be actuated.

8. A nasal sensory device including a base member having a chamber, inlet and outlet conduits each communicating with the chamber, means for connecting said chamber to the nose of a patient along a path which includes the inlet conduit, and a sensing element rockably mounted in said chamber and being provided with a vane adapted for normal disposition closurewise across said inlet conduit, said sensing element furthermore being provided with a shutter, photo-electric cell means operatively associated with said sensing element, said vane being movable when pressure is created in said inlet conduit and thereby move said shutter so that said photo-electric cell means can be actuated.

9. A nasal sensory device comprising a base member provided with a chamber, inlet and outlet conduits formed in said base member and communicating with said chamber, said base member also having apertures communicating with said chamber, an illumination source and photo-electric cell each operatively associated with said base member and being so arranged that a beam of light from said illumination source will pass through said apertures and chamber and impinge upon the photo-electric cell, and a sensing element operatively mounted in said chamber and being provided with a shutter adapted for optional disposition in said beam of light, said sensing element also being provided with means for normally closing off said inlet conduit when said shutter is away from said beam of light, said last-mentioned means also being actuable to open said inlet conduit and simultaneously move the shutter to a position in said beam of light.

10. Apparatus for use with patients who are unable to sustain normal breathing but have some residual breathing power, said apparatus comprising means for alternately applying increasing and decreasing pressure on the chest of the patient, control means operatively associated with said last-mentioned means for operating said last-mentioned means and thereby apply increasing pressure on the chest of the patient throughout a preselected time interval, and nasal sensing means adapted for operative connection to the nostrils of the patient and also operatively associated with said control means, said nasal sensing means being operable to actuate said control means and cause said increasing pressure to be applied to the chest of the patient throughout said preselected time interval commencing upon exhalation of the patient.

11. Apparatus for use with patients who are unable to sustain normal breathing but have some residual breathing power, said apparatus comprising means for alternately applying increasing and decreasing pressure on the chest of the patient, control means operatively associated with said last-mentioned means for operating said last-men-

tioned means and thereby apply increasing pressure on the chest of the patient throughout a preselected time interval, nasal sensing means adapted for operative connection to the nostrils of the patient and also operatively associated with said control means, said nasal sensing means being operable to actuate said control means and cause said increasing pressure to be applied to the chest of the patient throughout said preselected time interval commencing upon exhalation of the patient, said nasal sensing means also being operable to release said increased pressure at the end of said preselected time interval, and means for releasing said pressure upon failure of said nasal sensing means to cause release of said pressure.

12. Apparatus for use with patients who are unable to sustain normal breathing but have some residual breathing power, said apparatus comprising means for alternately applying increasing and decreasing pressure on the chest of the patient, current-transmitting means operatively associated with said last-mentioned means for operating said last-mentioned means and thereby applying increasing pressure on the chest of the patient throughout a preselected time interval, and nasal sensing means adapted for operative connection to the nostrils of the patient and also operatively associated with said current-transmitting means, said nasal sensing means being operable to actuate said current-transmitting means and cause said increasing pressure to be applied to the chest of the patient throughout said preselected time interval commencing upon exhalation of the patient.

13. Apparatus for use with patients who are unable to sustain normal breathing but have some residual breathing power, said apparatus comprising means for alternately applying increasing and decreasing pressure on the chest of the patient, control means operatively associated with said last-mentioned means for operating said last-mentioned means and thereby apply increasing pressure on the chest of the patient throughout a preselected time interval, nasal sensing means adapted for operative connection to the nostrils of the patient and also operatively associated with said control means, said nasal sensing means being operable to actuate said control means and cause said increasing pressure to be applied to the chest of the patient throughout said preselected time interval commencing upon exhalation of the patient, said nasal sensing means also being operable to release said increased pressure at the end of said preselected time interval, and relay means operatively interposed between the current-transmitting means and pressure-applying means for releasing said pressure upon failure of said nasal sensing means to cause release of said pressure.

14. An apparatus for use with patients who are unable to sustain normal breathing but have some residual breathing power, said apparatus comprising thorax-constricting means, electrically operated means for controlling the thorax-constricting means and causing said thorax-constricting means to apply increasing and decreasing pressure alternately on the patient, current-transmitting means for actuating said electrically operated means, switch means operatively connecting the current-transmitting means and electrically operated means, and nasal sensing means responsive to the residual breathing cycle of the patient and operatively associated with and adapted to actuate the current-transmitting means, thereby controlling the point in time at which the applied pressure on the patient increases, said switch means being operable to disconnect said current-transmitting means from the electrically operated means so that the electrically operated means can control the operation of the thorax-constricting means independently of the nasal sensing means.

15. An apparatus for use with patients who are unable to sustain normal breathing but have some residual breathing power, said apparatus comprising means for alternately applying increasing and decreasing pressure on the chest of the patient for predetermined time intervals, current-transmitting means connected to and operable to actuate said last-mentioned means, sensing means responsive to the residual breathing cycle of the patient and operatively associated with and adapted to actuate said current-transmitting means, thereby controlling the point in time at which applied pressure on the patient increases, and means operatively interposed between the current-transmitting means and pressure-applying means and being operable to break the connection between the current-transmitting means and pressure-applying means, whereby the latter can operate independently of the sensing means.

References Cited in the file of this patent

UNITED STATES PATENTS

2,067,744	Williams	Jan. 12, 1937
2,071,215	Peterson	Feb. 16, 1937
2,436,853	Coleman	Mar. 2, 1948
2,754,819	Kirschbaum	July 17, 1956

FOREIGN PATENTS

528,669	Great Britain	Nov. 4, 1940