

[54] **BREATHING ASSIST APPARATUS**

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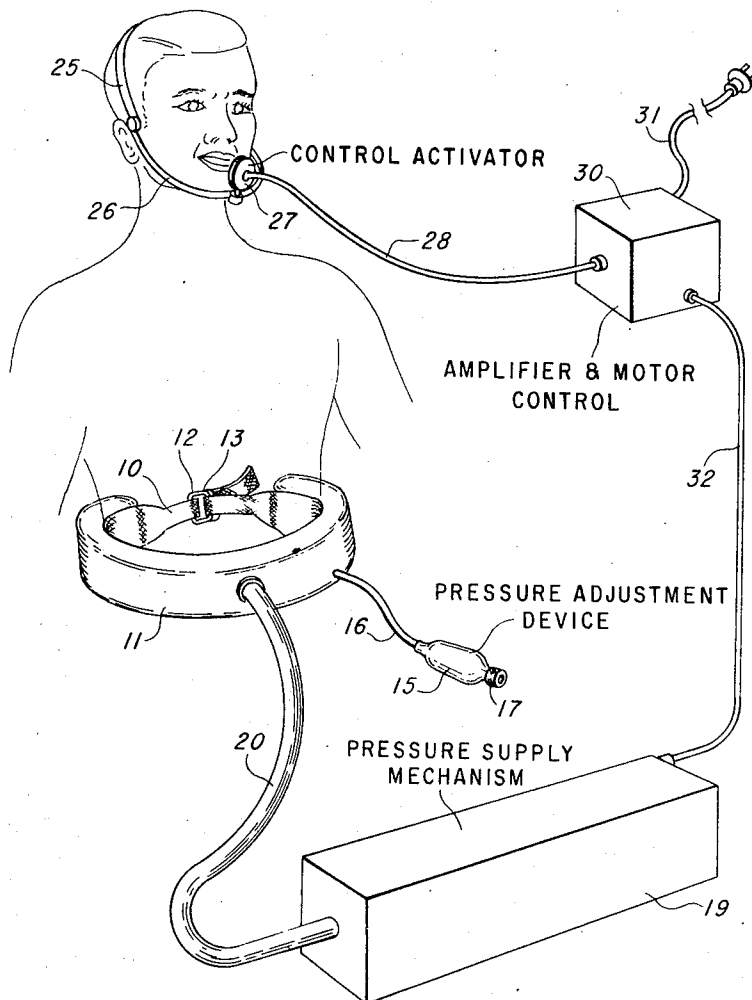
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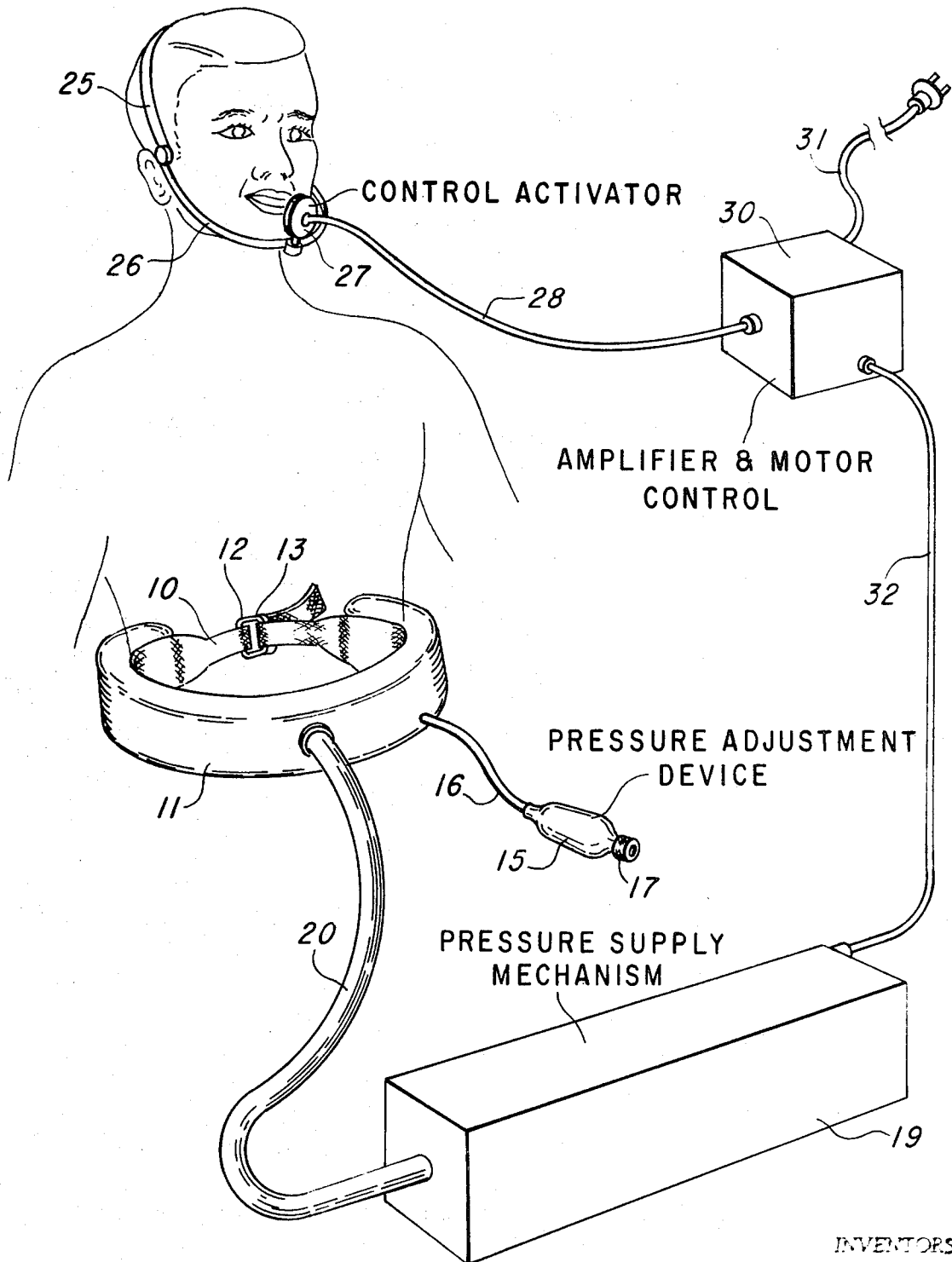
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ABSTRACT

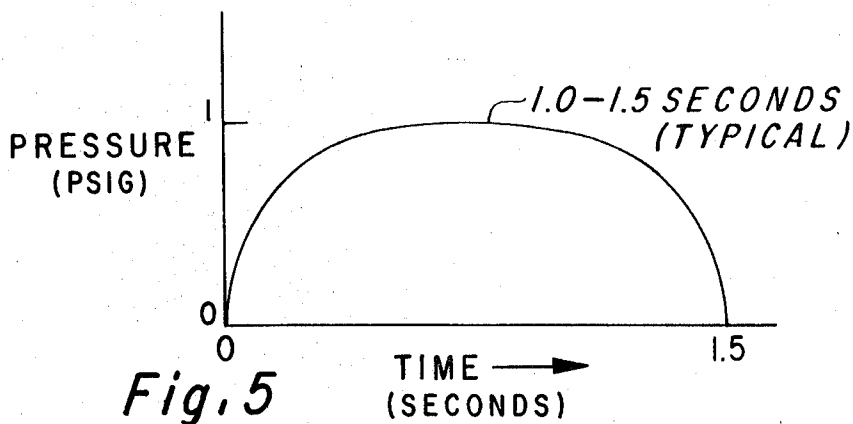
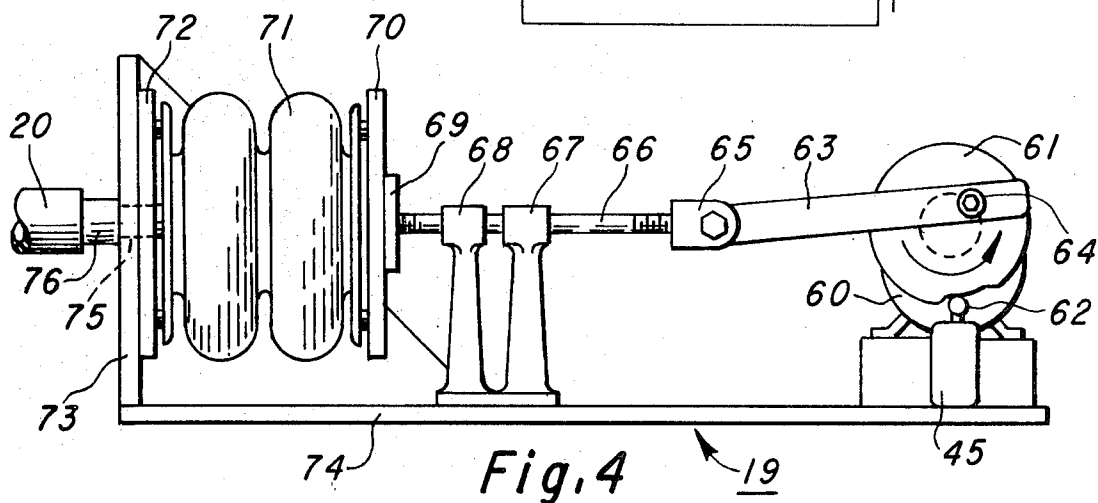
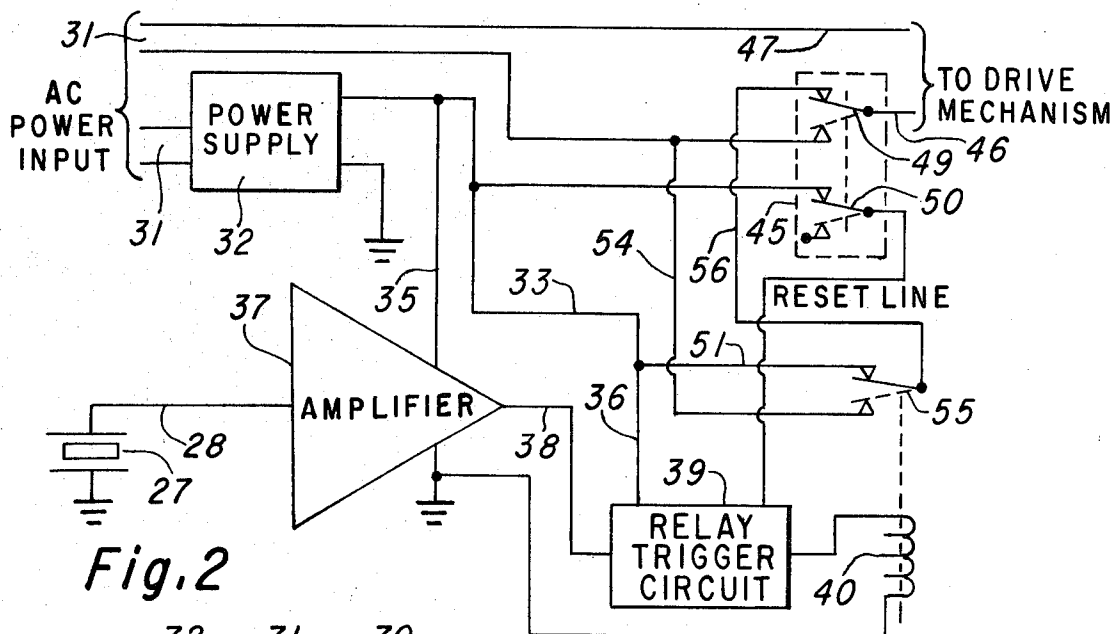
A device for providing assistance to persons with emphysema and problems relating to breathing. Essentially the invention provides means for applying pressure to the abdominal and lower rib region which assists in forcing air from a person's lung. The pressure is applied during the exhalation phase of the breathing cycle and the pressure applying means is activated by the person's efforts to exhale. The pressure is released upon completion of the exhalation phase avoiding interference with the inhalation phase.

7 Claims, 5 Drawing Figures





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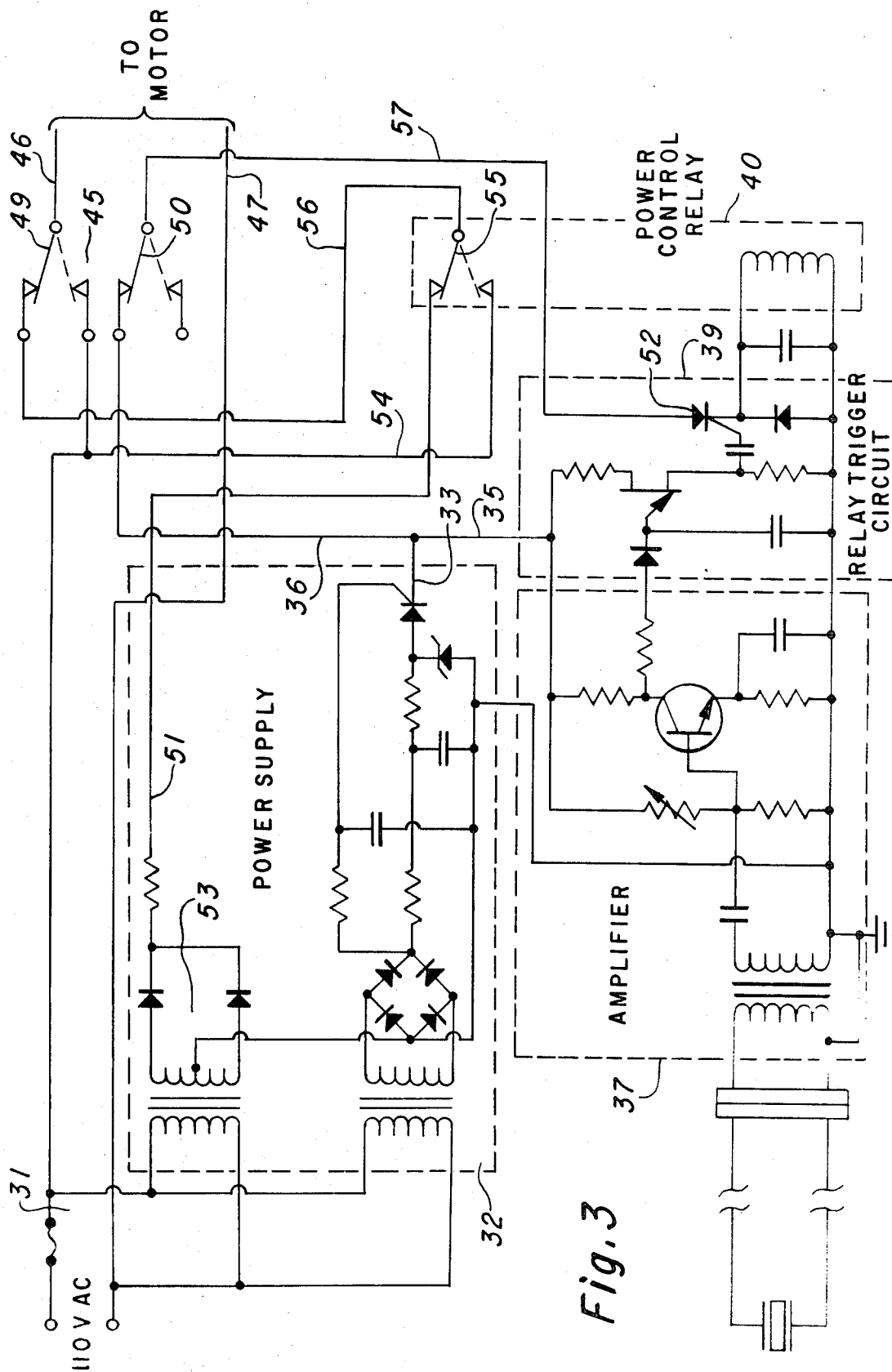


Fig. 3

BREATHING ASSIST APPARATUS

Emphysema is a disease affecting a person's lungs and the muscles used in exhaling air from the lungs. During the inhalation phase of breathing, the normal lung capability of persons suffering from emphysema seems to be a relatively little affected and breathing is almost normal. In a normal person, air is exhaled by elastic recoil without muscular effort whereas the act of expiration in persons with emphysema is accomplished by active muscular work. Furthermore, with emphysema, there is atrophy of the diaphragm which becomes markedly depressed so that it no longer serves as a functional respiratory muscle. Thus, a characteristic of emphysema is difficulty in exhalation or expiration. The principle upon which this invention is based is that of providing compression of the abdomen and lower ribs during the exhalation phase of breathing and initiating the compression coincident, as closely as possible, with the beginning of exhalation, in replacement of the elastic recoil or of active muscular exhalation. As an added benefit, in applying a pressure to the diaphragm and pushing it upward, there is the probability of returning the muscle to a partial functional state.

Accordingly, it is an object of this invention to provide assistance during the portion of the breathing cycle when assistance is required and, thereafter, to release the assisting means so as not to interfere with otherwise normal breathing.

Another object of this invention is to provide sensitive means for detecting effort to exhale and, upon detection, activating the breathing assist means.

Still another object is to detect efforts to exhale without impeding or hindering the exhalation of air from a person's lungs.

A still further object of this invention is to provide breathing assistance which is foolproof in operation and does not expose the user to hazards or danger especially while sleeping or in a semiconscious condition.

Another object is to apply pressure over the time period of the exhalation phase of breathing which pressure increases to a maximum and then decreases corresponding to the normal movement of a person's diaphragm.

Another object of this invention is to provide a structure which is compact for ease of location, use and storage and, as well, simple in construction and with relatively few moving parts for long life and maintenance free operation.

Other objects and advantages reside in the details of construction and operation as more fully described and claimed hereinafter and as shown in the accompanying drawings.

The drawings are as follows:

FIG. 1 is a representation of the preferred embodiment of the breathing assist apparatus.

FIG. 2 is a block diagram of the breath signal amplifier and control circuit for activating the pressure supply apparatus of FIG. 4.

FIG. 3 is a detailed circuit diagram of the block diagram of FIG. 2.

FIG. 4 shows a side elevation view of a mechanism and air supply reservoir for applying pressure to the abdomen and lower rib region.

FIG. 5 is a curve of the pressure provided by the mechanism and air supply reservoir of FIG. 4 over the time period of the exhalation phase of breathing.

Describing now the breathing assist apparatus, FIG. 1 shows in representative form a preferred embodiment of the apparatus. In this embodiment, the means for applying pressure to the abdomen and lower rib region is by an expandible sack 11 which can be strapped in place by means of a belt 10. The belt 10 extends lengthwise of the sack 11 and is maintained in place by loops, tabs or a separate cloth cover enclosing the sack. Sack 11 is elongated, double walled, expandible, sealed at either end and leakproof. Suitable construction materials for the sack are rubber and plastics. Two openings are provided in sack 11, one of which connects with tube 16 and the other with air supply hose 20. At either end of belt 10 are clasps 12 and 13 suitable for joining together and holding belt 10 and sack 11 in place. The exact construction of the clasps 12 and 13 is not material to this invention and could be replaced by, for example, a buckle arrangement. However, it is preferred that the clasp arrangement allow the wearer to adjust the belt 10 to the most effective position and degree of tightness and permit easy and quick release in the manner of standard safety, or seat, belts.

The tube 16 communicates with a hand operated bulb pump 15 controlled by screw closure 17. The purpose of the hand operated bulb pump is to inflate sack 11 initially and, thereafter, to adjust the pressure inside the sack and, also, bellows 71 (described as part of FIG. 4 hereinafter). With screw 17 closed, squeezing bulb pump 15 increases the air supply in the sack and thus the pressure. When screw 17 is loosened, air escapes and the pressure within the sack is reduced.

With belt 10 in position, the wearer next positions on his head the headset support 25 to which is attached strap 26 supporting microphone 27. Headset 25 may be of any convenient construction and, instead of fitting over the head and down by the side of the person's ears as shown, may consist of a strap encircling the head. In any event, the purpose of the headset is to provide support for microphone 27 so that it may be positioned in front of the wearer's mouth and nose. Microphone 27 is of the piezoelectric crystal type and, when the wearer begins to exhale, no matter how slight, the breath impinges directly on the microphone and causes an electrical signal to be produced. The electrical signal is fed by leads 28 to the amplifier and motor control 30.

It can be seen that, if microphone 27 is positioned in front of the wearer's mouth and nose, there is no impediment to breathing such as might be occasioned by a mask or sensor operating on a pressure drop principle at the beginning of the exhalation cycle. This is not to say that a mask fitting over the wearer's nose and mouth might not be required at times, for example, in a hospital in conjunction with other equipment and medication for the wearer. If a pressure drop principle is employed, the change in pressure may be used to close a switch and generate the electrical signal to the amplifier and motor control. In addition, other kinds of sensors than microphone 27 may be used such as hot wire anemometers and thermistors which produce electrical signals by changing resistance to current flow as the exhaled air passes the sensor. Whatever device is used, however, the requirement is for high sensitivity to

small movements of air and rapid response so as to initiate timely activation of the pressure supply mechanism.

The amplifier and motor control is shown in block diagram in FIG. 2 and in detail circuit diagram in FIG. 3. Describing the block diagram of FIG. 2, AC power is fed into the control by line 31 whose plug end may be connected into any suitable source of 110-120 volt AC power such as is standard in homes, offices and hospitals. Within the control, power supply 32 generates a B+ voltage and this voltage is supplied through lead 33 to leads 35 and 36. Lead 35 is connected to amplifier 37 and lead 36 to the relay trigger circuit 39. The signal from microphone 27 is fed through lead 28 to amplifier 37. The amplifier 37 amplifies the signal and feeds the signal through lead 38 to the relay trigger circuit 39. The coincidence of a signal from amplifier 37 and the B+ voltage supplied through line 36 permits a silicon controlled rectifier in the trigger circuit to turn on and provide an output to activate power control relay 40 and move its armature. Movement of the armature of relay 40 moves switch contact 55 to the position shown in dashed lines and the AC power from line 31 then feeds directly through leads 54 and 56, leaf spring 49 of switch 45, and lead 46 to a motor in the pressure supply mechanism. Lead 47 is the return line from the motor. The pressure supply mechanism will be described subsequently in connection with FIG. 4. However, for clarity of description at this point, it should be noted that a cam is carried on the motor and has a contact surface such that switch contacts 49 and 50 of switch 45 remain in their closed position until the motor is energized. As the motor begins to turn, the cam surface and a cam follower then cause the switch contacts 49 and 50 to move to the position as shown in dashed lines and, thereupon, to connect the motor directly to the source of AC power by way of switch contact 49. The momentary lapse of power to the motor in switching from one line to another has been found not to interfere with its continued operation. Movement of switch contact 50 to the position shown in dashed lines interrupts the B+ voltage supply to relay trigger circuit 39 through reset line 57 and the armature of power control relay 40 and switch contact 55 return to their normal position. As the motor and cam rotate through a complete revolution, the cam surface and follower permit switch contacts 49 and 50 to return to their normal position and the AC power to the motor is disconnected. A back EMF for dynamic braking of the motor is provided by a circuit which includes power supply 32, line 51, switch contact 55, lead 56, switch contact 49 in its normally closed position, and lead 46 to the motor. In this state, the control is in condition to receive the next signal from microphone 27 and repeat the sequence of steps described above.

FIG. 3 shows the block diagram of FIG. 2 in detailed circuit form. In FIG. 3, the corresponding portions of the circuit diagram have been outlined with dashed lines to indicate the portion of the circuit providing the various functions described above such as the power supply, amplifier, relay trigger circuit, etc. The silicon controlled rectifier mentioned in the description of FIG. 2 is shown as at 52. Similarly, the dynamic braking voltage is supplied by means of the transformer and

diode combination shown generally as at 53 and the voltage is fed to the motor by means of lead 51 through the normally closed leaf switch 55, lead 56, switch contact 49 and lead 46. Since the operation of the circuit of FIG. 3 has been described in general terms in connection with FIG. 2 and the circuit operates in a straight forward fashion to provide the control desired in accordance with this invention, it is not deemed necessary to describe in detail here all the circuit elements of the circuit diagram. It should be understood that other circuits can be provided that will provide the equivalent function to that of FIG. 3.

Turning now to the pressure supply mechanism 19, FIG. 4 shows in a side elevation view the mechanism for providing an air pressure supply to sack 11. The motor and cam discussed above in connection with FIG. 2 is shown in FIG. 4 as 60 and 61 respectively. The centerline of cam 61 is mounted on the output rotor of motor 60. Motor 60 may be a variable speed or a constant speed motor with the proviso that, either by a slow motor speed or by suitable reduction gearing, the output rotor rotates desirably at approximately 30 revolutions per minute which is adequate to provide assistance for a breathing rate of 20 complete cycles per minute. It is understood, of course, that motor 60 may be set to the speed which corresponds to the desired breathing rate.

Switch 45, described above, is shown mounted on the base of motor 60 so that cam follower 62 may control the movement of switch contacts 49 and 50 according to the surface provided for cam 61. The action of the cam, cam follower, leaf springs and control of power has been described above with respect to the operation of the control of FIG. 2.

Arm 63 is movably mounted by bolt 64 located eccentrically on cam 61. Arm 63 terminates in clevis 65 which is connected to one end of rod 66. Rod 66 extends through two linear bushings 67 and 68 and is connected at its other end to connector plate 69. Connector plate 69 is attached at the center of a circular plate 70. A bellows 71 is in position between circular plate 70 and a like circular plate 72. In turn, circular plate 72 is connected to an end support member 73. The base of motor 60, bearings 67 and 68, and the end support plate 73 are all supported from a base member 74. An opening 75 is shown in dashed lines through circular plate 72 and the support member 73 and communicates with pipe 76. The end of hose 20 (see FIG. 1) is then fitted over the end of pipe 76.

In operation, as the motor rotates, arm 63 is moved in an oscillating back and forth motion by its eccentric mounting to cam 61. The oscillating back and forth motion of arm 63 is translated by clevis 65 to a straight back and forth motion of rod 66. As rod 66 moves back and forth, bellows 71 is compressed from or permitted to return to its normal position, as the case may be, and the air contained within bellows 71 is transmitted through hose 20 to sack 11 and back to bellows 71.

The mechanism of FIG. 4 for compressing bellows 71 is only one of the many possible such mechanisms. For example, bellows 71 may be rotated 90° and moved up and down by the force of a rod pressing near its midpoint on plate 69 with the rod being pivoted at one end and moved at its other end by a crank and slider rotated by motor 60. As another means, motor 60 and cam 61

may be mounted to bear against plate 69 with bellows 71 being compressed and released as a function of the surface of cam. It is even possible for motor 60 and cam 61 to be positioned internally of bellows 71 with push and pull being exerted by arm 63 suitably attached to plate 69. Still another means for moving bellows 71 is by a motor with a centrally rotated helical screw which is advanced or retracted by the direction of rotation of the motor. The advance of the screw bearing against plate 69 compresses the bellows and retraction of the screw permits the bellows to assume its normal position. In all these embodiments, suitable modifications would be made to carry out the required electrical connection to and operation of the motor control circuit and switches. Furthermore, although perhaps not as feasible for the purposes of this invention as a source of air pressure, bellows 71 and its associated mechanisms could be replaced by an air compressor and a valve arrangement controlled by the signal from microphone 27. It is also conceivable that the pressure to the abdomen and lower ribs could be applied by a plate movable by electromotive force or other mechanism.

As previously indicated, the motor rotor is set to rotate at approximately 30 revolutions per minute because the breathing cycle for inhalation and exhalation for persons with emphysema may be faster than normal and as short a time period as 3 seconds. FIG. 5 shows a curve of pressure against time for the pressure created by the pressure supply mechanism. According to the curve, pressure builds up gradually from zero to a maximum, dwells momentarily and then diminishes gain to zero. The maximum pressure coincides in the exhalation phase with the need for greatest movement of the person's diaphragm. Actually, during part of the motor rotation cycle, a negative pressure is created which assists in pulling air from sack 11.

Described briefly in its entirety, the person with a lung problem positions the sack around his abdomen and lower ribs and places the microphone support mechanism around his head so that the microphone is adjacent his mouth and nostrils. Upon exhalation, the microphone senses impingement of the wearer's breath at the beginning of exhalation and sends a signal to the control mechanism. The signal is amplified and used to trigger selective operation of switches which permit current to flow to and rotate an electric motor. A suitable mechanism translates the rotation of the motor to cause compression of a flexible air supply reservoir. Upon compression, air is transferred to the sack and belt around the wearer. The sack inflates and causes pressure against the abdomen and lower rib portion and, by compression thereof, assists the wearer in exhaling air from his lungs. The rotation time of the motor is approximately 2 seconds and during and at the end of each rotation cycle the switches are reset and the control mechanism is conditioned for the next signal from the microphone.

In experiments with victims of emphysema a marked degree of improvement in arterial oxygen, that is, reduction in arterial carbon dioxide, is found on use of the breathing assist apparatus of this invention. In measurements made with an intraesophageal balloon in patients wearing the breathing assist, the results indicate sufficient pressure increases within the chest to assist in expelling respired gas. Three patients were

tested two normal subjects and one with emphysema. The average increase in end-expiratory intrathoracic pressure produced by the device was approximately 5 cm. H₂O. Measurements were then made of the change in gaseous content of arterial blood produced by application of the breathing assist to two emphysema patients. These measurements indicated a reduction in partial pressure of CO₂ and an increase in partial pressure of O₂. Also one of these patients showed a change in arterial blood pH from 7.32 to 7.45 after only 10 minutes of use of the breathing assist. All of these responses indicate a significant change toward more normal values. No impediments to breathing were noticeable by the wearers and no health hazard, safety hazard or undue pressure was noted in any of the tests conducted over extensive periods thereby indicating suitability of the apparatus for the purpose intended.

A preferred embodiment of the apparatus has been described above. It should be noted that many variations and deviations in equipment are possible without departing from the scope of the invention. For example, various kinds of transducers have been mentioned above for use in place of microphone 27. As other examples, a variety of materials, arrangements and mechanisms have been mentioned as suitable for providing the pressure upon a person's abdomen and lower ribs. Thus, the invention hereof is suitable for being accomplished by a number of means and embodiments without departing from the scope of the invention as defined in the claims below.

What is claimed is:

1. Apparatus for assistance in breathing which comprises a self-contained fluid and actuating means for applying pressure to the abdomen and lower ribs over a time period equivalent to the exhalation phase in breathing, said means assisting in forcing air from a person's lungs and releasable at the end of the exhalation cycle, and sensing means minimizing impediments to breathing and operable upon detection of breath upon exhalation for actuating said means for applying pressure.

2. Apparatus for assistance in breathing which comprises a belt for attachment around the abdominal and lower rib region, said belt including expandable means, a reservoir connected to said expandable means and providing a self contained fluid supply, actuating means, and sensing means detecting the impingement of breath, said sensing means providing an output upon the beginning of exhalation to said actuation means whereby said actuating means is activated and causes fluid to flow from said reservoir to said expandable means during exhalation and to return to said reservoir at the end thereof.

3. The apparatus as defined in claim 2 which said sensing means comprises a microphone supported in non-breathing impediment manner adjacent a person's nose and mouth.

4. The apparatus as defined in claim 2 in which said expandable means comprises an elongated sack and said reservoir is compressible by said actuation means.

5. In a breathing assist apparatus, a pressure applying means for positioning around the abdomen and lower ribs, a reservoir of air connected to said pressure applying means in a self contained system, actuation means for alternately transferring air in said system to and

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from said reservoir and said pressure applying means, and breath signal detection means controlling said actuation means.

6. In a breathing assist apparatus as defined in claim 5, hand operated pump means for adjusting the pressure in said pressure applying means and in said reservoir.

7. Apparatus for assisting in breathing which comprises a self-contained fluid and actuating means for

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applying pressure to the abdomen and lower ribs over a time period equivalent to the exhalation phase in breathing, said means assisting in forcing air from a person's lungs and releasable at the end of the exhalation cycle, said means for applying pressure being actuated periodically corresponding to the breathing cycle of inhalation and exhalation.

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