

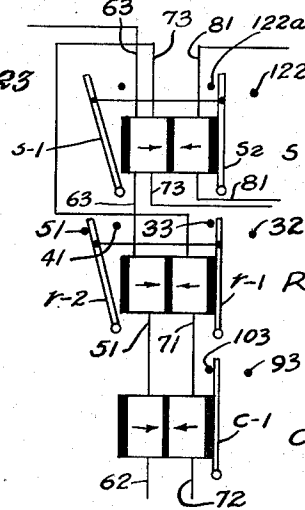
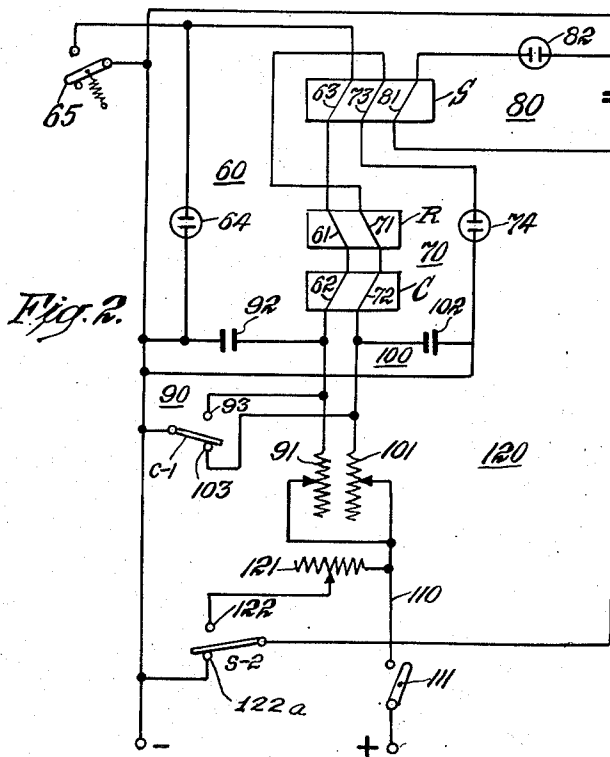
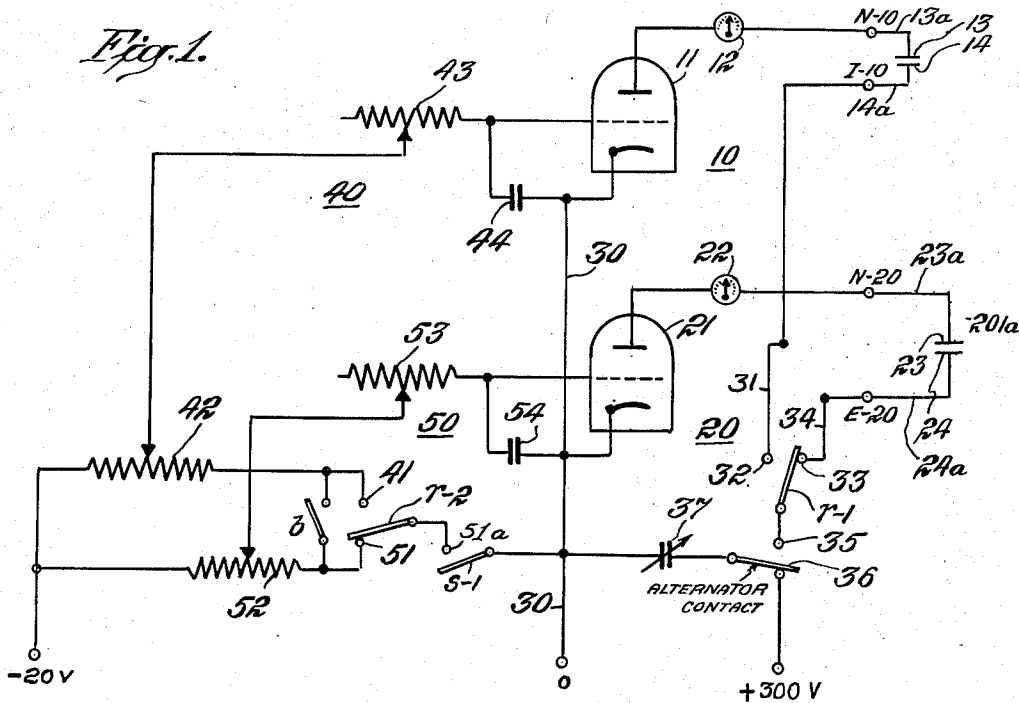
June 28, 1955

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APPARATUS FOR THE STIMULATION OF RESPIRATION
AND ELECTRORESPIRATOR

2,711,729

Filed June 13, 1951

2 Sheets-Sheet 1



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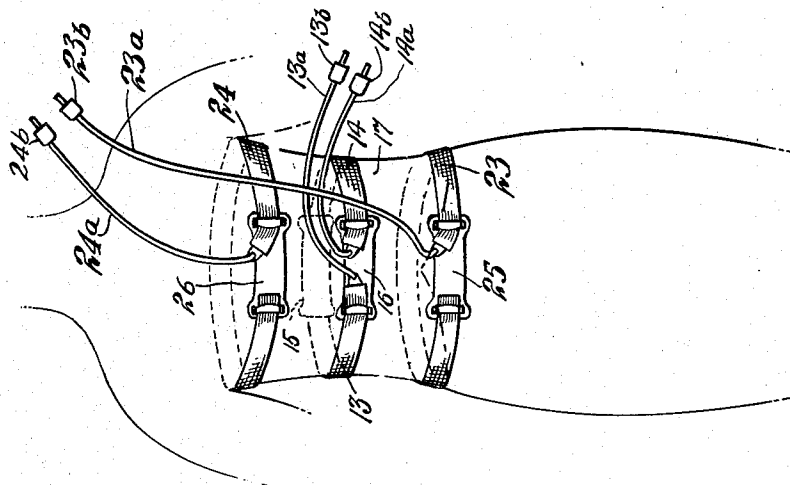


Fig. 3.

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APPARATUS FOR THE STIMULATION OF RESPIRATION AND ELECTRORESPIRATOR

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8 Claims. (Cl. 128—28)

The present invention relates to a method for the electric stimulation of respiration and to an electro-respirator.

One object of the present invention is to provide a method whereby human respiration can be successfully stimulated in cases where it has become feeble or even ceased due to disease or accidental interference with the breathing mechanism, for instance, in the case of poisoning or drowning.

Another object of the present invention is to provide a method of electrically stimulating respiration which is easy to apply, efficient and free of undesirable by or after effects and which causes a minimum of pain and discomfort to the patient.

A still further object of the invention is to provide a method of electrically stimulating human respiration by the application of current pulses to respiratory muscle groups through the skin overlying such muscle groups.

Still another object of the invention is to stimulate both inspiration and expiration by the application of current pulses alternately in breathing rhythm to inspiratory and expiratory muscle groups through skin areas overlying such muscle groups.

A further object of the invention is to provide an electro-respirator which permits the application of electric pulses alternately to inspiratory and expiratory muscle groups through skin areas overlying such muscle groups and the proper and automatic timing of such electric pulses in breathing rhythm.

A further object of the invention is to provide an electro-respirator which can be used to apply stimulating current pulses either alternately in the proper breathing rhythm to at least one muscle group controlling respiration and to at least one muscle group controlling expiration or simultaneously to several muscle groups controlling inspiration or to several muscle groups controlling expiration.

A specific object of the invention is to provide a device in which the character, duration and magnitude of each stimulating pulse can be easily and accurately adjusted to the physiological requirements of the case, and in which the breathing rate as well as the duration of each inspiration and expiration phase can be controlled and adjusted as desired.

Specific objects of the invention are the provision of an electro-respirator of this type in which duration of the actual electric pulses supplied to the several muscle groups during each inspiration and expiration phase may be varied independently of the duration of the inspiration or expiration phase itself, and in which an inspiration phase may be started immediately by the physician, or by the patient himself, at any stage of the automatic operation of the device.

These and other objects which will appear more clearly as the specification proceeds are accomplished by the method and apparatus described hereinafter in detail and defined in the appended claims.

The present invention is based on the discovery that a

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satisfactory stimulation of the respiratory mechanism can be obtained by the application of rhythmically controlled electric pulses each composed of low frequency current impulses alternately to inspiratory and expiratory muscle groups through skin areas overlying such muscle groups.

A preferred method according to the present invention comprises broadly the steps of applying electric pulses each composed of low frequency current impulses alternately to inspiratory and expiratory respiratory muscle groups through skin areas overlying such muscle groups and to regulate the electric pulses automatically in accordance with a desired breathing rhythm.

According to one embodiment of the invention, electric pulses are alternately applied to at least one inspiratory muscle group, and to at least one expiratory muscle group, and the alternate stimulation of the inspiratory and expiratory muscle groups by means of electric pulses is regulated in accordance with a predetermined breathing rhythm.

Apparatus for the execution of the method according to the present invention is illustratively exemplified in the appended drawings, in which:

Fig. 1 is a diagram of the electrode circuits and the control circuits in one embodiment of an apparatus according to the invention;

Fig. 2 is a circuit diagram of a timing device which may be used in combination with the electrode and control circuits according to Fig. 1;

Fig. 3 shows electrodes arranged on the body of a patient in position for alternate stimulation of inspiration and expiration phases;

Fig. 4 shows a wiring diagram using conventional symbols to illustrate the operation of relays S, R and C.

Referring now to the drawings, and first to Figs. 1 to 3, the electro-respirator comprises two electrode circuits 10 and 20, each containing a triode valve 11 and 21, respectively. In each circuit 10 and 20, a negative contact terminal N-10 and N-20 is connected permanently to the anode of the associated triode through an indicator 12, 22. The cathodes of the two valves are connected in parallel to the zero potential of a source of current over a common conductor 30. The electrode circuits 10 and 20 contain further an inspiration contact terminal I-10 and an expiration contact terminal E-20, respectively. The inspiration contact terminal I-10 is connected through a conductor 31 to one fixed contact 32 of a reversible switch r-1, the other fixed contact 33 of the switch r-1 being connected by a conductor 34 to the expiration terminal contact E-20. The movable contact of switch r-1 connects contact 32 and 33 alternatively to a common contact 35 of an alternator switch 36 which is moved back and forth between its two positions by driving means, not shown, at a frequency of between about 10 and 150 times per second. The frequency of the alternator switch movements may be adjustable in known manner. During each of its cycles, the alternator switch alternately connects one side of a variable condenser 37 to the positive pole of a source of current which, in the example shown, provides a voltage of +300. The opposite side of the condenser 37 is connected to the zero terminal of the source of current.

The two electrode circuits are completed by two pairs of electrodes 13, 14, and 23, 24 which can be attached to the body of a patient, for instance, in the manner illustrated in Fig. 3. In this figure the electrodes 13 and 14 are illustrated by way of example only, as conducting belt portions connected in front and in back by insulating members 15 and 16 and having each a lead 13a, 14a terminating in plugs 13b, 14b, respectively. The electrodes 13 and 14 may be attached to the body of a patient, for instance, directly above the diaphragm, in the manner shown so that, upon connection of the plugs 13b and 14b

to the opposite terminals of an electrode circuit, current pulses will flow through the diaphragm-controlling muscles in a direction substantially transversely of the body of the patient. As will be seen in Fig. 1, the lead 13a is connected to the terminal N-10 and the lead 14a is connected to the terminal I-10.

The electrodes 23 and 24 may be, for instance, continuous belt elements reaching almost around the body of the patient and being secured in front each by a single insulating member, 25 and 26, respectively. The electrode 23 has a lead 23a terminating in a plug 23b and the electrode 24 has a lead 24a terminating in a plug 24b. As shown by way of example only, in Fig. 3, the electrode 24 is mounted around the upper part of the chest directly under the armpits while the electrode 23 encircles the body of the patient in the region of the navel. When the electrodes 23 and 24 are connected to opposite terminals of an electrode circuit, current will flow between these two electrodes through expiration controlling muscle groups in a direction substantially lengthwise of the patient's body.

As indicated in Fig. 1, the lead 23a of electrode 23 is connected to the terminal N-20 of electrode circuit 20 while the lead 24a of electrode 24 is connected to the contact terminal E-20 of electrode circuit 20.

The flow of current in each of the electrode circuits 10 and 20 is determined by the charge on the grids of valves 11 and 21, which in turn is controlled by two separate grid control circuits 40 and 50. Each grid control circuit has an input terminal 41, 51, respectively, these input terminals being alternate fixed contacts of a reversible switch r-2. Each grid control circuit further comprises a rheostat 42, 52 having its opposite ends connected respectively to the associated input terminal 41, 51 of its circuit and to a common negative potential, which in the example shown is indicated as being -20 volts. The adjustable contacts of the rheostats 42 and 52 are connected in parallel to the common zero conductor 30 each over a second adjustable rheostat 43, 53 and a condenser 44, 54. The adjustable rheostats 43, 53 form with the associated condensers 44, 54 time constant elements which permit an adjustment of the surge rate of the current pulses passed through the valves 11 and 21. The grids of the valves are connected to the control circuits 40 and 50 between the adjustable rheostats 43, 53 and the condensers 44, 54, respectively.

The movable contact of the reversible switch r-2 is connected to the zero conductor 30 over a make and break switch s-1 operating over contact 51a. A manually operated bridging switch b, shown in Fig. 1 in open position, makes it possible to interconnect grid control circuits 40 and 50 for simultaneous operation.

The timing of the pulses supplied to the electrode circuits 10 and 20 is controlled by a timing device, the circuits of which are illustrated diagrammatically in Figs. 2 and 4. This timing device comprises an inspiration control circuit 60, an expiration control circuit 70, and three two-position relays S, R, C. Relay S controls the contact s-1 in the grid control circuit and a contact s-2 of the timing device. Relay R controls contact r-1 of the reversible switch for the electrode circuits and contact r-2 of the grid control circuits, and relay C controls contact c-1 of the timing device. The relays R and C have each one winding 61 and 62, respectively, in series with the inspiration control circuit 60, and one winding 71 and 72, respectively, in series with the expiration control circuit 70. The relays R and C thus operate to shift their associated contacts to one position when current flows in the inspiration control circuit 60 and to the opposite position when current flows in the expiration control circuit 70. The relay S also has one winding 63 in series with the inspiration circuit 60 and one winding 73 in series with the expiration circuit 70, but this relay shifts its associated contacts to the same position whenever current flows in either the

inspiration circuit or the expiration circuit. In order to shift the contacts associated with relay S to their opposite positions, this relay is provided with a third winding 81 in a pulse terminating circuit 80. Each of the circuits 60, 70 and 80 contains further a glow lamp, 64, 74 and 82, respectively.

Associated with the inspiration and expiration control circuits 60 and 70, respectively, are inspiration and expiration starting circuits 90 and 100, respectively, each including an adjustable rheostat 91, 101. The rheostats 91, 101 have movable contacts connected in parallel over a common lead 110 and a master switch 111 to the positive terminal of a source of current. The winding of each adjustable rheostat 91, 101 is connected to one side of a condenser 92, 102, respectively, the other side of which is connected to the negative terminal of the source of current. Each condenser can be short circuited over a contact 93, 103, respectively, by means of the change-over switch c-1 which is controlled by the relay C. The switch c-1 acts as a reversing switch to direct the current alternately to the windings 63, 61, 62 and 73, 71, 72 controlling the relays S, R and C. Referring to Fig. 1, it will be seen that in one position the relay R throws switches r-1 and r-2 to the expiratory electrodes 23, 24 and then inspiratory electrodes 13, 14. Associated with the pulse-terminating circuit 80 is a starting circuit 120 which comprises an adjustable rheostat 121, contacts 122 and 122a of the two-position switch s-2 controlled by the relay S and a condenser 123, one side of which is connected in one position of the movable contact of switch s-2 over rheostat 121 to conductor 110 while its other side is connected to the negative terminal of the source of current.

It should be noted that the inspiration control circuit 60 is connected across the condenser 92, the expiration control circuit 70 is connected across the condenser 102, and the pulse-terminating circuit is connected across the condenser 123.

A manually operable switch 65 permits temporary closing of the inspiration circuit at will.

With the electrodes 13, 14 and 23, 24 attached to the body of the patient, for instance, as shown in Fig. 3 and connected to the terminals of the electrode circuits, as shown in solid lines in Fig. 1, and switch b open, the apparatus operates in the following manner:

When the master switch 111 is closed, a charge is placed on the condenser 92 of the inspiration starting circuit 90 over the adjustable rheostat 91. After a time interval, which depends on the position of the movable contact of the rheostat 91, and which may vary from between about $\frac{1}{40}$ to about $\frac{1}{60}$ of a minute, the charge of the condenser becomes sufficient to cause its discharge through glow lamp 64 and windings 63, 61 and 62 of relays S, R and C. This causes closing of switch s-1 and shifting of the movable contact of switch r-2 to the input terminal 41 of the grid control circuit 40. Simultaneously, the movable contact of switch r-1 is switched over to contact 32 to prepare a circuit through terminal I-10. Closing of switch s-1 and shifting of switch r-2 to input terminal 41 lowers the negative bias from the grid of tube 11 and induces a current surge through the plate circuit of said tube and the electrode circuit 10. The alternator contact 36 in its lower position places a charge on condenser 37 and in its upper position, in which it touches contact 35, permits a discharge of condenser 37 and the delivery of a short current impulse into the electrode circuit 10 through the valve 11, the indicator 12, the terminal N-10, lead 13a, electrode 13 transversely through the diaphragm muscles of the patient, electrode 14, lead 14a, terminal I-10, movable contact of switch r-1 and alternator contact 36. By adjustment of the alternator frequency, the frequency of the impulses thus delivered can be varied from about 10 to about 150 times per second. An impulse frequency of about 50 to 60 per second has been found to be most favorable for

many cases and a nonadjustable alternator operating in this range of frequencies may be used instead of the adjustable alternator shown. The alternator 35, 36 constitutes a source of low frequency current.

The duration of the individual impulses, on the other hand, can be changed independently of the frequency by adjustment of the variable condenser 37. The proper selection of the duration of the individual short impulses is of considerable importance. The shorter the impulses are the smaller is the mean value of the current passing through the body with a corresponding diminution of possible undesirable side effects, such as a skin irritation and pain sensations. Generally, excellent results can be obtained with very short impulses of less than 1 msec. duration, which obviate skin irritations and pain sensations completely. In some cases, however, an effective muscle contraction can be obtained only with impulses of greater duration. In these cases, however, the sensitivity is usually reduced to such an extent that even relatively long impulses do not create any painful sensations.

The amplitude of the current impulses depends on the adjustment of rheostat 42. Adjustment of the rheostat 43 which forms part of the time-constant element 43, 44 makes it possible to effect a gradual increase in the amplitude of the successive current impulses of which each individual pulse is composed so that the current flowing through the electrodes and the muscles of the patient can be given the desired surge characteristics.

When current is supplied to the inspiration control circuit, change-over switch *c*-1 is switched from contact 103 to contact 93. This connects both sides of condenser 92 to the negative terminal of the source of current to insure a complete discharge of this condenser and to render recharging thereof impossible as long as switch *c*-1 retains its upper position.

Simultaneously, the short circuit across condenser 102 over contact 103 is broken and a charge is placed on condenser 102 over adjustable rheostat 101. The condenser 102 is now charged for a predetermined time interval determined by the position of the adjustable contact of rheostat 101.

Furthermore, when switch *s*-1 is closed, the movable contact of switch *s*-2 is shifted from its lower position to its upper position (see Fig. 2) to close the circuit 120 thereby placing a charge on the condenser 123 over master switch 111, adjustable rheostat 121 and contact 122. By adjustment of the rheostat 121, charging of the condenser 123 may be completed in a time period which is less than that required for charging of the condenser 102, in order to cause termination of the current pulse stimulating the inspiration-controlling muscles prior to the beginning of the expiration phase.

When condenser 123 has received a sufficient charge, it discharges over the pulse terminating circuit 80 through glow lamp 82 and winding 81 of relay S. This causes opening of switch *s*-1 with termination of the inspiration pulse and return of switch *s*-2 to its lower position to insure complete discharge of condenser 123. Thus it is possible to slow down the breathing rhythm to increase, for instance, the time interval between the beginning of each inspiration phase and the beginning of the next following expiration phase, by adjustment of condenser 101, without increase in the duration of the inspiration current pulse which might cause undesirably long muscle contractions. The charging of condenser 102 is meanwhile continued, and when this condenser has attained its full charge, it discharges through the expiration control circuit 70, including glow lamp 74 and windings 71, 72 and 73 of relays R, C and S, respectively. As a result, switch *s*-1 is closed again and switch *s*-2 is returned to its upper position to close the charging circuit 120 for condenser 123. Switches *r*-1, *r*-2 and *c*-1 are reversed, thus closing the grid circuit 50 for the grid of tube 21 over rheostat 52 and time-constant element 53,

54, and also the electrode circuit 20 from one side of the condenser 37 over valve 21, indicator 22, contact N-20, lead 23a, anode 23, vertically extending expiratory muscle groups of the patient, electrode 24, lead 24a, terminal E-20, contact 33, movable contact of switch *r*-1 in its right-hand position, contact 35 and alternator contact 36 to the other side of condenser 37. A current pulse of desired duration and characteristics is thus supplied to the expiratory muscles.

Due to the return of switch *c*-1 to its lower position, the inspiration starting circuit 90 across condenser 92 is now again rendered operative and a new breathing cycle is initiated in the manner described before.

If it is desired to interfere momentarily with the automatic operation of the timer in order to start immediately a new inspiration phase, the physician or the patient himself may close switch 65, for instance, by operation of a push button, to short circuit glow lamp 64 and to obtain a flow of current in the inspiration control circuit through rheostat 91 and windings 61, 62 and 63 of relays R, C and S. This shifts all the switches to their position for the start of an inspiration phase and causes the immediate passing of a current pulse through the inspiration controlling muscle group. When the push button is released, switch 65 opens and the timer resumes its automatic operation.

It should be understood that the invention is not meant to be limited to the embodiments illustrated and described herein. The electrodes and the means for attaching them to the body of a patient may obviously be varied as desired, and they may be suitably attached in various positions to the body of a patient to effect alternating stimulation of inspiratory and expiratory muscle groups, including others than those specifically mentioned in the preceding specification, as may be desired. Other modifications and variations of the method and the apparatus of the present invention will occur readily to those skilled in the art without deviation from the principles and from the scope of the present invention, as defined in the following claims.

I claim:

1. An electro-respirator comprising two pairs of positive and negative electrodes, said electrodes including belt sections of substantial surface area adapted to be positioned on the trunk of the body over inspiratory controlling muscles and belt sections of substantial surface area adapted to be positioned on the trunk of the body over expiratory controlling muscles, an inspiratory electrode feeding circuit, means connecting said inspiratory electrode feeding circuit with said positive and negative inspiratory controlling electrodes, an expiratory electrode feeding circuit, means connecting said expiratory electrode feeding circuit to said positive and negative expiratory controlling electrodes, switching means adapted to be connected to a source of pulsating current and arranged to connect the inspiratory and expiratory electrode feeding circuits alternately to said source, said switching means being adapted to control the rate of switching such that it will change the flow of current back and forth between the inspiratory and expiratory feeding circuits in normal breathing rhythm.

2. An electro-respirator comprising two pairs of positive and negative electrodes, said electrodes including belt sections of substantial surface area adapted to be positioned on the trunk of the body over inspiratory controlling muscles and belt sections of substantial surface area adapted to be positioned on the trunk of the body over expiratory controlling muscles, an electrode feeding circuit connected with said positive and negative inspiratory controlling electrodes and an electrode feeding circuit connected with said positive and negative expiratory controlling electrodes, switch contacts in the said two electrode circuits and a reversing switch connected with a source of low frequency pulsating

current and movable between said switch contacts, and a breathing rhythm timing device in operative relation with said reversing switch for closing said reversing switch alternately in one of its positions and then the other to direct current through first one of said electrode feeding circuits to stimulate inspiration and then the other of said electrode feeding circuits to stimulate expiration in breathing rhythm.

3. The electro-respirator as claimed in claim 2, in which each of said electrode feeding circuits contains a triode valve having the anode connected with an electrode and the cathode connected with the current source.

4. An electro-respirator as set forth in claim 2, in which each of said electrode feeding circuits contains a valve having the anode connected with an electrode and the cathode connected with the current source, a separate grid control circuit for each valve and each grid control circuit having serially connected therein an adjustable resistance for varying the magnitude of the current pulses passed by the associated valve.

5. An electro-respirator as set forth in claim 1 wherein the source of pulsating current delivers alternately to said electrode feeding circuits current impulses of between 10 and 150 per second.

6. An electro-respirator as set forth in claim 1, in which said timing device includes an inspiration control circuit and an expiration control circuit, a two-position relay having its two windings arranged serially in said inspiration control circuit and said expiration control circuit, respectively, for the control of said reversing switch, a two-position change-over switch, an inspiration starting circuit operative when said change-over switch is in one position and including an adjustable time-constant element whereby the associated inspiration control circuit is rendered operative by said inspiration starting circuit after a predetermined time interval, an expiration starting circuit operative when said change-over switch is in its opposite position and including an adjustable time-constant element whereby the associated expiration control circuit is rendered operative by said inspiration starting circuit after a predetermined time interval, and means reversing said change-over switch simultaneously with

said reversing switch to actuate the expiration starting circuit upon operation of the inspiration starting circuit and shifting of the reversing switch to its inspiration position, and vice versa.

7. An electro-respirator as set forth in claim 6, in which said timing device contains a separate two-position control relay for the change-over switch, said last mentioned relay having two windings arranged in series with the two windings of the relay controlling the reversible switch.

8. An electro-respirator as set forth in claim 1, in which said reversing switch comprises a make and break contact and said timing device includes a two-position pulse control relay for controlling said contact, said pulse-control relay having two windings in series with the two windings of the relay controlling the reversible contact, said pulse-control relay being adapted to close the make and break contact when either of these two windings is traversed by current, a third pulse-terminating winding for said pulse-control relay to open said make and break contact when said pulse-terminating winding is traversed by current, a pulse-terminating circuit for said third winding, a separate starting circuit containing an adjustable time-constant element for rendering the pulse-terminating circuit operative after a certain time interval, and a switch for closing said separate starting circuit controlled by said pulse control relay to close said separating starting circuit when the make and break contact is closed and to open said separate starting circuit when the make and break contact is open.

References Cited in the file of this patent

UNITED STATES PATENTS

1,693,734	Waggoner	Dec. 4, 1928
1,752,632	De Beaumont	Apr. 1, 1930
2,295,585	Lindquist	Sept. 15, 1942
2,532,788	Sarnoff	Dec. 5, 1950

OTHER REFERENCES

Industrial and Engineering Chemistry for November 1937, p. 1316.