Feb. 19, 1963 J. BATROW ETAL 3,077,884

ELECTRO-PHYSIOTHERAPY APPARATUS

Filed June 13, 1957 4 Sheets-Sheet 1

FIG. 1.

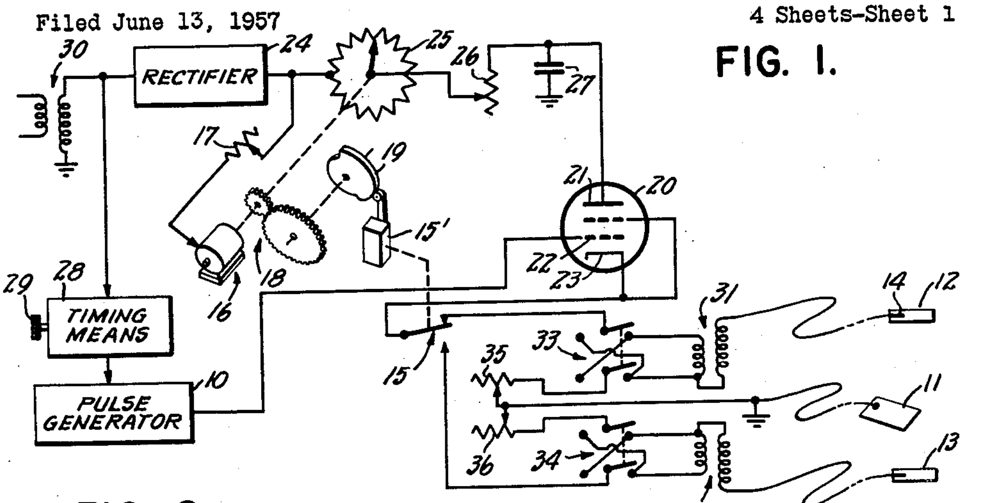

FIG. 2.

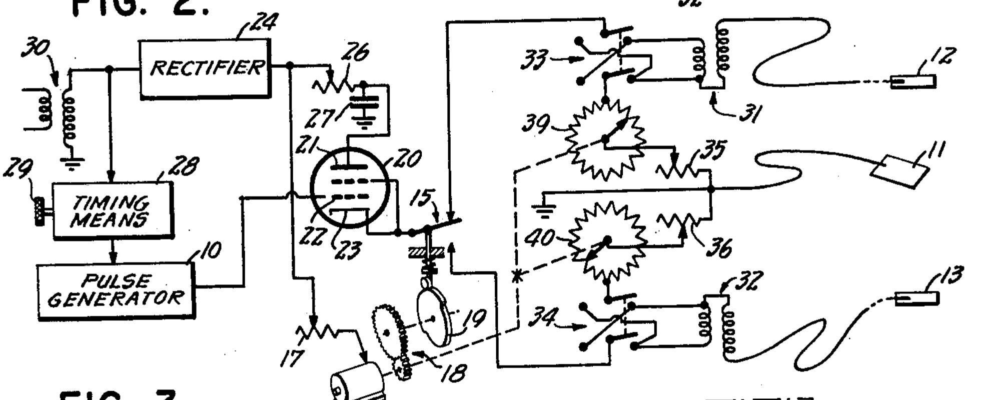

FIG. 3.

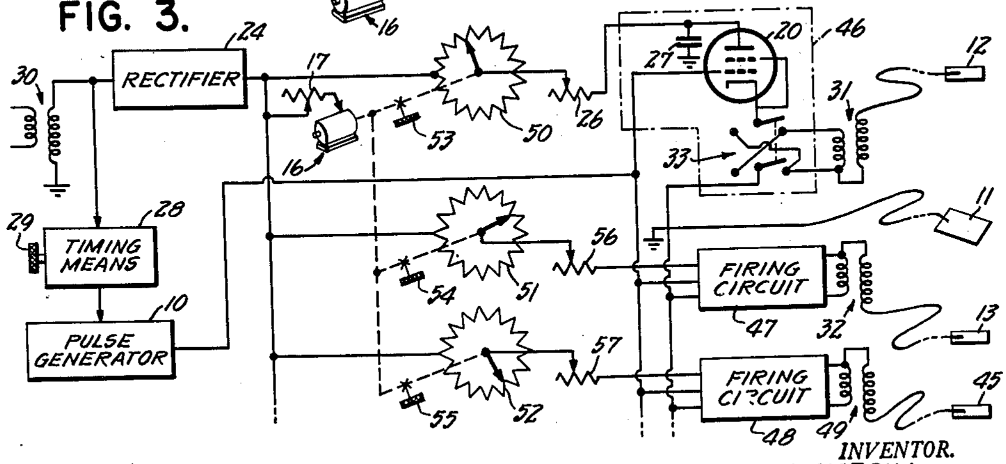

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FIG. 4.

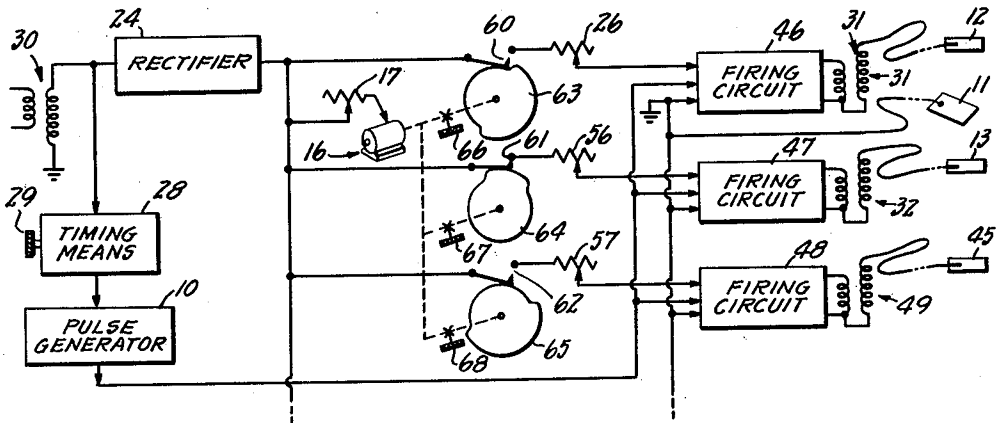

FIG. 5.

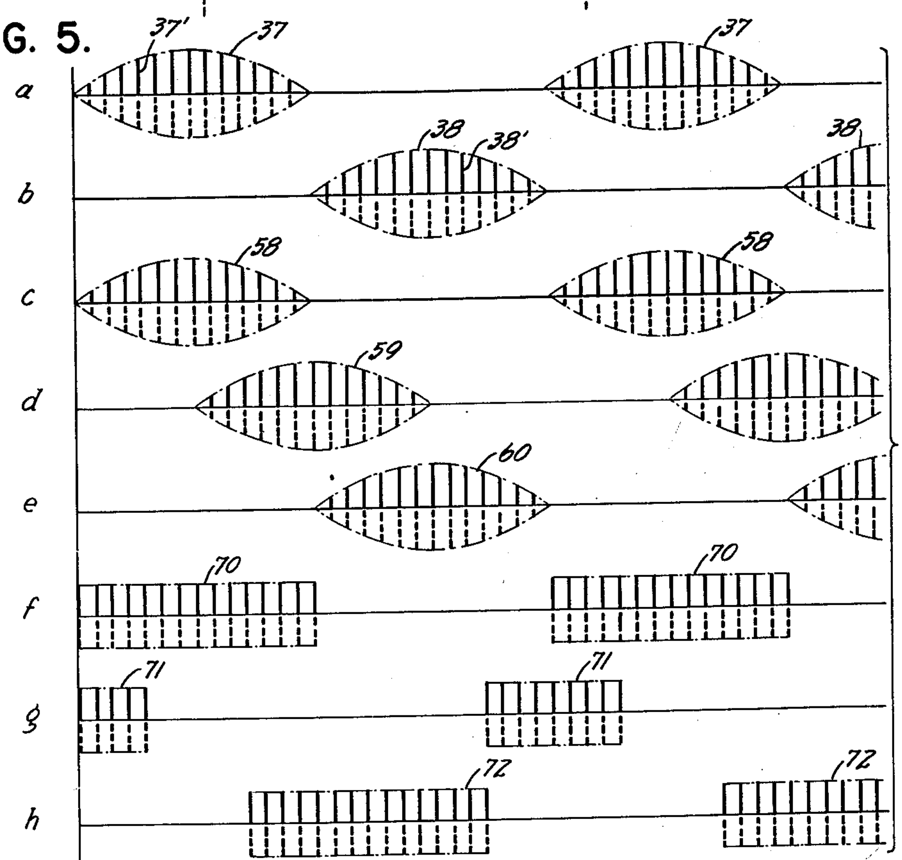

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FIG. 6.

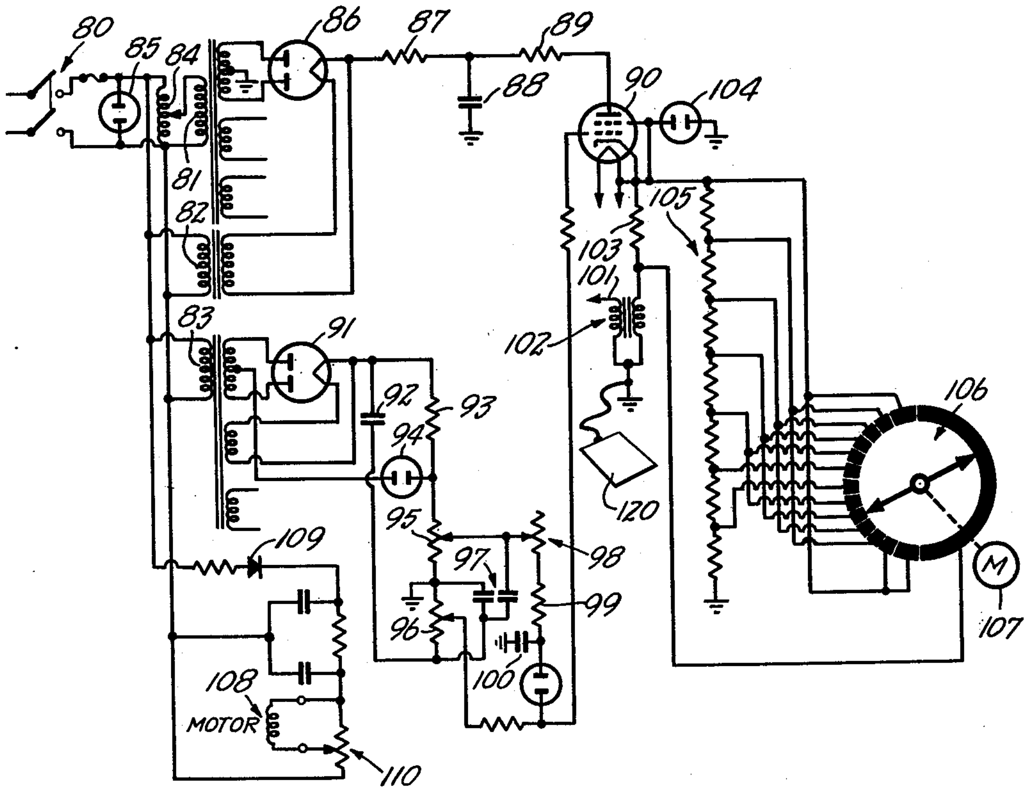

FIG. 7.

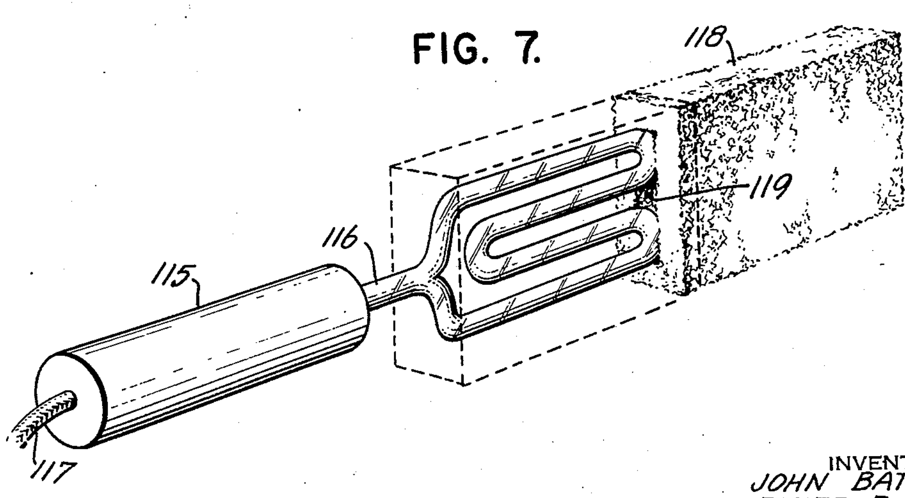

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FIG. 8.

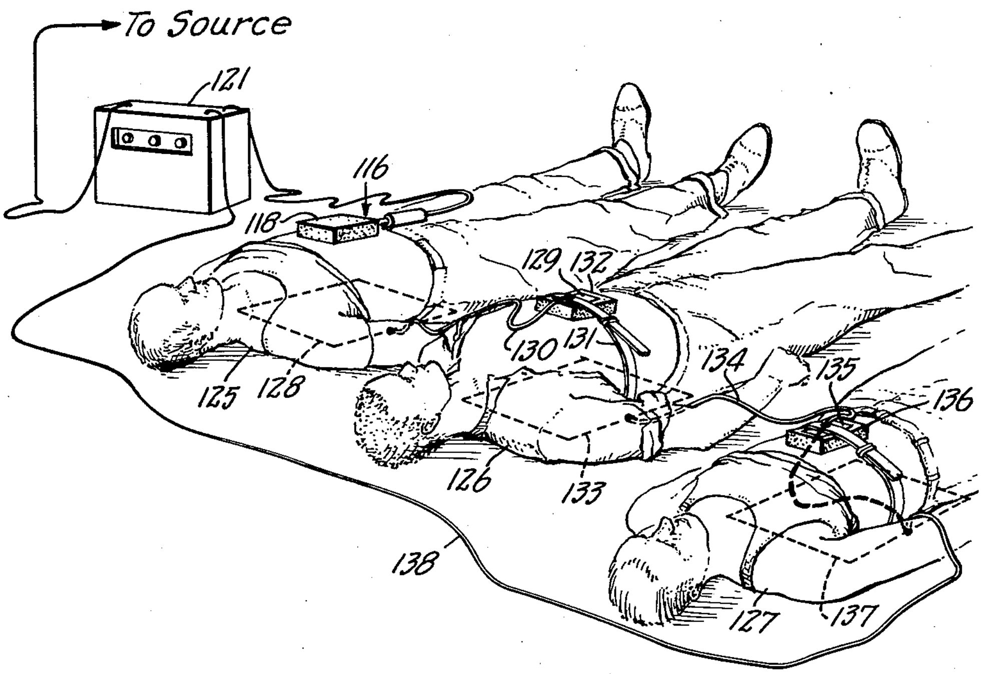
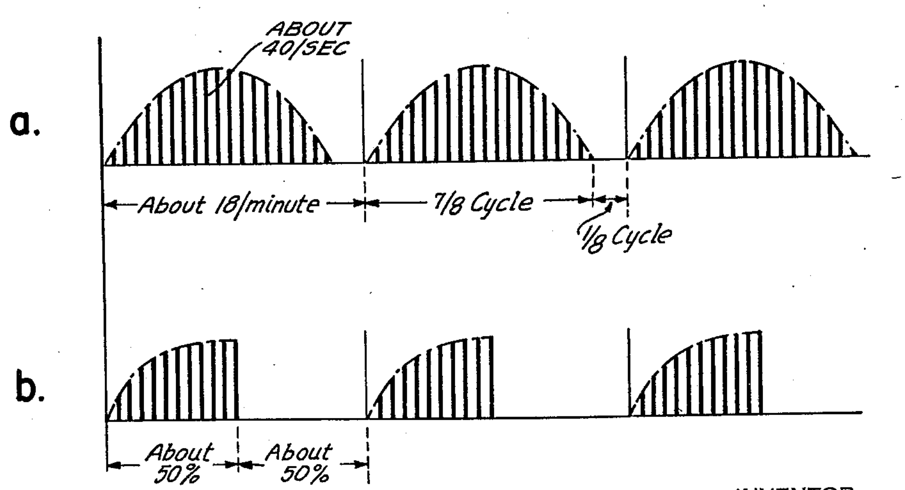


FIG. 9.



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ELECTRO-PHYSIOTHERAPY APPARATUS

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Filed June 13, 1957, Ser. No. 665,424
28 Claims. (Cl. 128—423)

This invention relates to electro-physiotherapy, and is particularly concerned with devices for neuromuscular stimulation. The present application is related to U.S. Patent No. 2,641,259, issued June 9, 1953, and discloses certain improvements not disclosed in said application. This application is a continuation-in-part of pending application Serial No. 357,962, filed May 28, 1953 and now abandoned.

It is an object of our invention to provide an improved device of the character indicated.

It is another object to provide an improved therapeutic tool, whereby a plurality of muscles in the body may be selectively stimulated in a desired pattern of stimulation.

It is a specific object to meet the above objects with a device which may independently stimulate each of a plurality of muscles in one body, with different characteristic stimulation patterns.

It is another specific object to provide a stimulator for automatically alternating the stimulation of one muscle, as distinguished from that of another muscle in the same body, in a given pattern of alternation.

It is a further specific object to provide an improved means for inducing artificial respiration, involuntarily and without need for special provision of oxygen.

It is an object to meet the above objects with means effective to stimulate one or a plurality of patients concurrently.

It is a general object to meet the above objects with an improved electro-therapy apparatus which may utilize relatively high voltages in application to the body and which may, nevertheless, be applied with complete safety to the human body, more or less regardless of the area of close contact with the skin, and also more or less regardless of the sweat condition of the skin.

Other objects and various further features of the invention will be pointed out or will occur to those skilled in the art from a reading of the following specification in conjunction with the accompanying drawings. In said drawings, which show, for illustrative purposes only, preferred forms of the invention:

FIG. 1 is an electrical diagram schematically showing a neuromuscular stimulator embodying principles of the invention;

FIGS. 2, 3 and 4 are similar diagrams illustrating modifications;

FIG. 5 is a graphical representation in simplified form, illustrating the functioning of various of the forms of FIGS. 1 to 4;

FIG. 6 is a circuit diagram of a further embodiment, specifically designed for artificial respiration of human beings and animals;

FIG. 7 is a perspective view of an applicator for use with the circuit of FIG. 6, two parts of the applicator being partially separated, to reveal their relationship;

FIG. 8 is a simplified view illustrating multiple resuscitation with a single equipment of FIG 6; and

FIG. 9 is a diagram illustrating preferred and alternative excitation patterns with the apparatus of FIG. 6.

As in the case of said patent, the present improved equipment is designed to excite the muscles of the body by stimulating or modulating upon the nervous system of the body. While the complete physical process of such stimulation and modulation has not yet been established to the satisfaction of all, it has been definitely established

that, through methods described in greater detail in said application, various parts of the muscular system may be selectively stimulated through the nerves associated therewith; thus, depending upon the selected nerve ending for application of the excitation, particular muscles may be excited—all with complete safety to the patient.

While, as indicated, the exact mechanism within the body is not fully understood, it is known that with such a stimulator, as described in greater detail in said application, relatively steep-walled pulses of predominant initial polarity are produced and that such pulses are effective in producing stimulation. If the rate of repetition of such pulses is of the order of 10 to 20 per second, then it is known that the nerve will have full opportunity to recover between successive excitations, so that each excitation may produce maximum muscle-stimulating effect. It is further known that by increasing the pulse rate beyond 20 per second (this will, of course, vary between individuals), as, for example, to 40 or 50 per second, the nerve is unable to recover between successive excitations; temporary paralysis results and is characterized by tetanic contraction of the muscle thereby affected. Tetanic contraction can be caused to take place in selected visceral as well as skeletal muscles by applying this type of pulse excitation at the nerve endings corresponding to such muscles.

Briefly stated, the invention in one general form contemplates improvement of the stimulator of said patent, by providing the same with a plurality of body-applicator outlets, and by providing modulating or surging means for the automatic independent excitation of said outlets in accordance with a desired programming cycle. By this means it is possible to excite, through one outlet and one body-applicator electrode, a first muscle or set of muscles in the body, and independently, through another outlet and a separate body-applicator electrode, a totally different muscle or group of muscles. In one simplified form to be described, the modulating means for effecting the desired relation between excitation or surge patterns for the respective electrodes is merely a switch with means for alternating the stimulator-output connection between the respective body-applicator electrodes in a desired pattern or sequence. In other forms, the modulating envelope for each of the modulations or surges to the respective electrodes may be varied, as may also the phase relation between these envelopes.

In another general form to be described, the invention is applicable primarily to artificial resuscitation by electronic means. In such case, the apparatus is as generally described above, except that only one predetermined surge pattern or modulation is employed for the intensity of groups of successive pulses. The modulation rate is such as to achieve a normal breathing rate, completely involuntary, as far as the patient is concerned. The body-applicator electrode is so designed as to enable placement over the solar plexus area, and thereby to achieve coupling to nerve endings, including the phrenic nerve, as well as to nerve endings governing the intercostal muscles; there results true tetanic contraction and full diaphragm opening in a controlled pattern, thereby inducing the body itself to inhale so that if the body is able to accept oxygen in the innermost recesses of the lung, this will be achieved, without any need for special provision of pure oxygen or of an oxygen-rich atmosphere.

Referring to FIG. 1 of the drawings, the invention is shown in application to a neuromuscular stimulator, comprising pulse-generator means **10**, body-grounding means **11**, and two body-applicator electrodes **12**—**13**, said electrodes being independent of the grounding connection **11** and constituting elements of two independent output circuits. Each of the electrodes **12**—**13** is preferably of the type more particularly described in the said copending application, for reasons of extreme comfort and safety. The electrodes 12—13 may thus be gas-filled dielectric envelopes, each containing a single electrode lead, as at 14, passing through the envelope to the interior so as to establish electrical continuity with the conductive gas therein. In use, the other end of the electrode is applied directly to the skin, or otherwise to the body, so that the conductive gas is placed in series with the body, and so that the electrical coupling to the body includes the capacitance of the dielectric, as well as that of the skin.

In accordance with the invention, modulating means including a phase-splitter are provided for producing at least two phase-displaced outputs characterized by the envelope of the output of pulse generator 10. In the form of FIG. 1, the phase-splitting means comprises switching means 15 with drive means which may include an electric motor 16, with selectively variable means 17 to control the speed and, therefore, the alternating rate of switching means 15. The drive for switching means 15 may include a gear train 18 and a cam 19, providing a desired on-off sharing of the modulating cycle. Cam 19 happens to be shown for equal on-off sharing, but it will be understood that the on-off proportion may be one-third to two-thirds, or any other desired relationship. For clarity in the drawings, the electrical connections of the switching means 15 are identified by the reference numeral 15, while the mechanical operation of the switching means 15 is separately identified by the reference numeral 15′.

High-voltage pulses for application to the respective electrodes 12—13 may be derived from a power amplifier 20, which is shown to include a plate circuit 21, a control-grid circuit 22, and a cathode circuit 23. The output may be taken from the cathode circuit 23 and is, therefore, connected directly to the switching means 15. Basic control is derived from the pulse generator 10 connected to the control-grid circuit 22, and the power is available from a supply, including rectifier means 24, variable potentiometers 25—26, and a charging capacitor 27. Timing means 28 may control the rate of operation of pulse generator 10, and it is schematically indicated by means of knob 29 that the rate of operation of timing means 28 may be selectively varied, as, for example, from a repetition rate of the order of 10 to 20 per second, in order to produce discrete successive muscular excitations and relaxations, to a rate of 40 to 50 per second, in order to produce tetanic muscular contraction in the selected muscle or muscle group. We have shown common supply means 30 for both the rectifier 24 and the timing and generator means 28—10, and the motor 16 is shown to operate from the output of the rectifier 24.

The described circuit will be seen to provide for continuous charging of capacitor 27, as long as amplifier 20 is not conductive, that is, in the absence of a control pulse from generator 10. Upon the application of a control pulse from the generator 10, tube 20 conducts to discharge the energy of capacitor 27 into the cathode circuit 23, and, depending upon the particular connection or position of switching means 15, the resulting pulse output is relayed to one or to the other of the body-applicator electrodes 12—13, completing the circuit in each case through the grounding means or plate 11; satisfactory grounding may be achieved by having the patient stand on plate 11, or by clamping or otherwise attaching plate 11 to the body.

In the form shown, a preference is indicated that the output circuit 23 be coupled to the respective electrodes 12—13 through independent step-up transformers 31—32, and, for a purpose which will later be clear, we have provided polarity-reversing means 33—34 in each of these circuit connections. Thus, for pulses relayed to the output when switching means 15 is in the position shown in FIG. 1, the primary of transformer 31 will be excited in one or the other polarity with respect to ground, depending upon the setting of means 33, and the output pulses appearing between electrodes 11—12 will be characterized by initial wave fronts reflecting the polarity setting. A similar situation will prevail for the polarity of pulses appearing between electrodes 11—13 when switching means 15 is in its other possible position. Potentiometers 35—36 illustrate that independent control may be had of the magnitude of pulse trains applied between electrodes 11—12 for one condition of switching means 15, as compared with the magnitude of pulse trains applied between electrodes 11—13 for the other condition of switching means 15.

The discussion thus far has concerned itself with operation which presumes that the only function of the modulator is to switch a given intensity of pulses from one to the other of the two available output circuits. However, by synchronizing the operation of potentiometer 25 with that of the drive means 16 and with switching means 15, a further repeated modulation may be introduced on the envelope of the pulse-wave trains. This further modulation is preferably such as to provide progressive growth of the envelope of pulses (in any given wave train) up to a maximum and with a continuous decay, so as to produce a gentle surge of limiting applied voltage in first one, and then the other, of the two output circuits. This type of action is best illustrated in curves *a* and *b* of FIG. 5, wherein the envelope 37 may be seen to characterize the growth and decay of amplitudes of successive pulses 37′ appearing in, say, the first output across electrodes 11—12, while the envelope 38 characterizes the amplitude of successive pulses 38′ appearing in the second output between electrodes 11—13. By proper choice of threshold as, for example, depending upon the setting of potentiometer 26, the actual curvature and duration of the envelopes 37—38 may be selectively varied. If desired, the winding of potentiometer 25 may be of the so-called non-linear type, so as to produce wave envelopes of specialized character. In each case, the dashed images of the heavy pulses 37′—38′ will be understood to indicate the polarity change resulting in the case of curve *a* when switch 33 is thrown, and in curve *b* when switch 34 is thrown.

FIG. 2 illustrates a stimulator embodying the features of FIG. 1, with the exception that the potentiometer means employed for modulating the envelope of successive wave trains is connected in a different part of the circuit. For this reason, those parts of FIG. 2 which correspond to parts of FIG. 1 have been given the same reference numerals and will not be reidentified. The modulating potentiometer may be connected between the cathode circuit 23 and the switching means 15, but in FIG. 2 two potentiometers 39—40 are connected in the circuits to ground of the respective transformer inputs. Dashed lines indicate synchronism of the two potentiometers 39—40 with each other and with operation of switching means 15. It will be seen that functioning in the circuit of FIG. 2 is basically the same as that described for FIG. 1, except that by adjusting the angular placement of the contact arm for one of the potentiometers (39) with respect to the other (40) one may provide selective availability of different envelope wave forms to characterize the pulse trains for the two alternating positions of switching means 15; also, potentiometers 39—40 may be non-linear and may have different non-linear characteristics, depending upon the need for different envelope patterns best suited to the stimulation of the particular nerve-muscle systems served thereby.

FIG. 3 illustrates a further modified multiple-output stimulator, lending itself to the employment of a plurality of independent outputs as, for example, the three outputs shown. These outputs in each case will be realized as employing the grounding means 11 in common, and the applicator electrodes 12—13—45 as and where needed on the body, depending upon muscle or muscle systems to be served thereby.

The basic difference between the stimulator of FIG. 3 and those already discussed resides in the selective availability of phase control for the surges to be applied to the several output circuits. This implies that two or more output circuits may be functioning for overlapping periods of time; therefore, an independent firing circuit 46—47—48 has been provided for each of the output circuits. The firing circuit in every case may include elements already identified, as, for example, variable potentiometer 26, charging capacitor 27, amplifier 20, and polarity-reversing means 33. Since each firing circuit incorporates its own energy-storing and discharge means, all triggered by the same pulse generator 10, there is never any question as to the fidelity of operation, even during overlapping periods of operation for two or more output circuits.

Independent selective pulse control for the arrangement of FIG. 3 may be achieved through the employment of separate modulating potentiometers 50—51—52, all of which are preferably driven in synchronism, as by motor means 16.

It is suggested at 53 that by a simple manual knob or other control means acting through differential gearing, the phase of the contact arm for potentiometer 50 may be selectively varied with respect to similar arms for potentiometers 51—52; and, to provide complete flexibility of phase control, further differential controls are illustrated, all independent of each other, at 54—55, for the drives to the potentiometers 51—52 served thereby.

In operation, the circuit of FIG. 3 will provide independent modulations on the wave trains appearing in each of the several output circuits. These modulations may, in one or more cases, extend for the full cyclic period of the basic modulator drive; however, potentiometers 26—56—57 suggest that independent control may be provided in each of the several output circuits of the threshold at which the varying circuits become operative so that at least for part of the modulating cycle for each of potentiometers 50—51—52, as the case may be, no output discharge is created in one or more of the several output circuits. A simplified illustration of such operation is given in curves *c*, *d*, and *e*, of FIG. 5, wherein a modulated envelope 58 may be interpreted as characterizing the output of a first circuit between electrodes 11—12, and wherein the envelopes 59—60 may be characteristic of the wave trains appearing in the other two output circuits 11—13 and 11—45. It will be understood that by the simple expedient of adjusting one of the differential control knobs as, for example, the knob 54, the occurrence or phase of the envelope 59 may be displaced with respect to the other two envelopes 58—60 in order to produce a desired pathological result.

FIG. 4 illustrates a further modification which may resemble that shown in FIG. 3, except for a change in the modulating means employed. The modulating in FIG. 4 may involve separate on-off keying or switching means 60—61—62, for governing the operation of the respective firing circuits 46—47—48, and all keying means may be run by a common drive 16. The keying means is shown controlled by separate cams 63—64—65, which may have different on-off programs, depending upon the desired pathological result. In the form shown, the cam 64 is indicated as having a substantially shorter "on" period than is characteristic of the other two cams 63—65. For selective phase control, independent manually operated differential means 66—67—68 may be connected in the several drives to cams 63—64—65.

The operation of the circuit of FIG. 4 is schematically illustrated in curves *f*, *g*, and *h*, of FIG. 5, wherein the envelope 70 characterizes a first wave train controlled by switching means 63—60 and appearing in the output 11—12. The shorter wave trains 71 are controlled by switching means 64—61, and appear in the second output 11—13, and the remaining wave trains 72 appear in the output 11—45. As in the case of FIG. 3, the relative phase of the described wave trains 70—71—72 may be selectively varied by adjustment of one or more knobs 66—67—68, and the relative amplitudes of these wave trains is also subject to independent control, as by adjustment of potentiometers 26—56—57.

In FIG. 6, the invention is shown in application to a special-purpose instrument designed for operation by non-technical personnel and for use specifically as an artificial resuscitator. To this end, the device is adjustable by the operator only (1) for maximum intensity of applied voltage and (2) for on-off selection, these controls being available at 98—80, respectively, and being the only controls on the exterior or front panel of the instrument.

The on-off switch 80 is of the single-throw double-pole variety connecting the supply line directly to a series of transformer primaries 81—82—83, by way of a preset voltage pick-off at 84. A neon lamp 85 is also mounted on the front panel and indicates the set condition of the switch 80. Transformers 81—82 form part of a regulated power supply comprising a double-diode rectifier 86 and filtering or smoothing elements 87—88—89, for development of regulated B-plus voltage for the firing tube 90.

The charging circuit is supplied by the transformer 83 and is shown to comprise a double diode 91, filtering and smoothing elements 93, and a voltage regulator, such as a neon tube 94 (mounted within the instrument, not on the front panel thereof). A regulated voltage appears across resistors 95—96, an intermediate point of which is grounded. Further filtering and smoothing is accomplished by 97—98—99, and the level of instantaneous charging at the charging capacitor 100 is determined by the setting of potentiometer 98; as indicated above, the control for the potentiometer 98 is one of the few controls presented on the front panel of the instrument.

The output circuit to the body applicator (FIG. 7) is derived at connection 101 to the secondary of output transformer 102; transformer 102 is shown supplied in series with a resistor 103, in a cathode-follower circuit of tube 90. To provide an indication that the circuit is functioning, a panel-mounted neon lamp 104 is shown connected from a second grid of the tube 90 to ground.

Controlled level of output pulses as a function of time is in the form shown determined by a programmed sequence of variably shunting the resistor 103, as by employment of a multi-tap resistor line 105 and commutation means 106 for applying variously tapped shunts from line 105 across the cathode-follower circuit. A continuously running motor 107 drives the commutator 106, the windings for which are schematically indicated at 108 to be driven by a D.-C. power supply developed by rectifier 109. Motor speed is selected by potentiometer 110; and this control function is preferably behind the panel of the instrument and is therefore not available for adjustment, once set at the factory.

The modulation pattern effected by the commutator 106 is preferably of the form graphically indicated in FIG. 9*a*, wherein it will be seen that the steady rate of motor 107 develops a full cycle of commutator action at 106 at substantially a normal breathing rate, namely, about eighteen full cycles per minute. Each of these cycles is preferably characterized by a somewhat sinusoidal ascendancy to and decay from maximum intensity, with a dwell to allow the body to relax for exhalation; preferred proportions and rates are indicated by legend in FIG. 9*a*. FIG. 9*b* shows an alternative surging pattern for situations in which it is desired to effect the most rapid relief from stimulation, during each surge cycle. The pulse-repetition rate remains of the order of 40 per second, but commutator connections are rearranged in order that surge build-up can be gradual, followed by a dwell of about 50 percent of the surge cycle.

In another embodiment of this invention the electrophysical neuromuscular stimulator has two pulse generators each including charging means. There are provided means for rapidly discharging the means at controlled intervals and means timing successive discharges at a repetition rate sufficient to produce tetanic contraction. There are also provided separate output electrode means for each of the generators and separate modulating means for separately intensity modulating the outputs of the generators. Also, means are provided for controlling the modulators in differently phased relation in a program cycle of a repetition rate which is substantially less than the repetition rate at which the discharges are timed.

FIG. 7 shows a preferred applicator for the resuscitator of FIG. 6. The applicator preferably comprises an insulated handle **115** from which an elongated tube **116** of high-strength dielectric material, such as Pyrex glass, projects at one end. The said tube **116** is preferably folded several times in essentially a single plane, providing a single envelope. The tube **116** is evacuated and filled with a conductive gas, such as argon or neon, at very reduced pressure. At a portion of tube **116** near or within the handle **115** is a single electrode element (not shown), cable connections to which are suggested at **117**.

As indicated generally above, resuscitation with the device of FIG. 6 is achieved by operating upon the large collection of nerve endings in the solar plexus region. Possible contact with such plurality of nerve endings is achieved by applying conductive material, such as a damp cloth, over the entire folded region of the tube **116**. For this purpose, it has been found most convenient to employ a viscose or the like sponge **118**, cored out as suggested at **119**, so as to permit slidable insertion of the folded part of the tube **116**. Insertion is facilitated by first dampening and wringing out the sponge **118**.

In use, the intensity control at **98** is first set to zero, and the applicator, including sponge **118**, applied directly to the skin over the solar plexus area. For resuscitation purposes, the patient will ordinarily be lying on the ground, and the ground-return plate **120** may therefore be placed directly under the patient. The intensity control **98** is then increased until patient reaction is noted. For a patient who is unable to breathe, but whose nerves still conduct, this will ordinarily mean advancing the intensity control to a fairly high setting; once the instrument is able to operate on the nerves, the patient will be observed to breathe in complete rhythm with the commutated modulations, and as he recovers, the depth (or extent) of his response (for a given setting at **98**) will increase. The intensity setting at **98** may then be backed off, as long as the operator observes that the machine is still controlling the patient's breathing. When it is apparent that the patient is attempting to do his own breathing independent of that controlled by the instrument, it becomes possible to remove the instrument from the patient; this may be done by first reducing the intensity setting at **98** to zero and then removing the applicator.

FIG. 8 shows further utility for the apparatus of FIGS. 6 and 7 for situations in which a number of patients are to be revived at the same time, all by the same single resuscitator **121** described in connection with FIG. 6. In the arrangement shown, the applicator **116** (fitted with sponge **118**) is applied directly to the solar plexus of a first patient **125**. The next patients **126—127** are connected in series with patient **125** by means of similar adapter-connection assemblies.

The first such connection assembly comprises a body plate **128** placed under the first patient **125** and an applicator plate **129**, interconnected by flexible insulated conductor means **130**. The plate **129** may be riveted to a part of a strap **131** of sufficient length to wrap around the body of patient **126** and to be clamped in place over the solar plexus region. Again, extensive contact with the nerve endings in question is facilitated by means of a dampened viscose or the like sponge **132**. For convenience, the connections of short cable **130** to plates **128** and **129** may be made with removable snap fittings of conventional design.

Series connection of patients **126—127** may be exactly the same as that described for patients **125—126**. Thus, body plate **133** (under patient **126**) may be connected by flexible cable **134** to an applicator plate **135** strapped over a dampened viscose or the like sponge **136**, at the solar plexus region of patient **127**. Finally, and assuming that patients **125—126—127** are the only ones requiring resuscitation, the last patient **127** may lie on a body or grounding plate **137** having flexible connection **138** to the resuscitator equipment **121**, this connection corresponding to that described at **120** in FIG. 6.

It is a phenomenon which we have not been able thus far to fully explain, but when plural patients **125—126—127** are connected to a single equipment **121**, the intensity setting at **98** (to produce a given stimulation response) need not be as great as that which would be required to produce the same stimulation response in a single patient. The single gas-filled dielectric tube **116** serves all patients, and it has been found that if one patient responds or recovers more rapidly than another patient, he may be effectively removed from the stimulation circuit merely by applying a shorting connection, as suggested by heavy dashed lines **140** between the applicator plate **135** and the ground plate **137**. Such a connection in no way affects the pattern of stimulation for the remaining two patients **125—126** because, of course, the rhythm for all patients is basically determined from commutating action at **106**.

It will be seen that an improved stimulator has been provided for automatically coordinating the stimulation of independent nerve-muscle systems within any one body. Not only is selective control provided for the rate of alternation or, rather, for the cycle of the basic modulation, but, in addition, selective control is provided for polarity and intensity, as well as phasing of output pulses and wave trains (FIGS. 1–4). Stimulation is painless and is unaffected by the sweat condition of the skin.

In use, the circuits of FIGS. 1 and 2 have been found helpful in artificial-respiration applications, the circuit of FIG. 6 being preferred for non-professional use. In employing the circuits of FIGS. 1 and 2 for artificial respiration, the grounding means **11** may be clamped to a foot or leg of the patient (or may be placed under the body, as in FIG. 8) while one of the electrodes **12** is applied to the skin, near nerve endings controlling muscles causing contraction of the lungs (e.g. over the abdomen, below the umbilicus), while the other electrode **13** is also applied to the skin, but near the nerve ending controlling muscles causing expansion of the lungs (e.g. solar plexus region, above the umbilicus); moistened sponges, as at **118**, are preferred in the use of both electrodes **12—13**. It will be seen that by adjusting the timing means at **29** to provide a rapid repetition rate for tetanic contraction, as, for example, 40 to 50 per second, and by adjusting the modulation speed at **16** to correspond with the desired breathing rate of the patient (e.g. 18 full cycles per minute) the patient may be caused to inhale and exhale completely involuntarily and with strong muscular excitation for both phases of the breathering cycle.

While the invention has been described in detail for the preferred forms shown, it will be understood that modifications may be made within the scope of the invention as defined in the claims which follow.

We claim:

1. An electrophysical neuromuscular stimulator of the character indicated comprising

first and second gas-filled dielectric applicator electrode means,

separate return electrode means,

signal producing means to produce a series of relatively high voltage pulses at a predetermined frequency,

means repetitively coupling said signal producing means to said first applicator electrode means and said return electrode means during one interval of time and to said second applicator electrode means and said return electrode means during a second interval of time,

said first applicator electrode means and said second applicator electrode means being coupled in alternation to said signal producing means, whereby said high voltage pulses may be applied from said first dielectric applicator electrode means to the body and then from said second dielectric applicator electrode means to the body in repeating alternating sequences, whereby the conductive path from each applicator through the body includes the dielectric of the respective applicator and said high voltage pulses thereby produce relative small currents in the body for activation of one or more muscles through one or more nerve paths.

2. A stimulator according to claim 1 in which said signal producing means produces high voltage pulses at a frequency sufficient to produce tetanic contraction.

3. A stimulator according to claim 1, and including modulating means for modulating the intensity of pulses supplied to first and second applicator electrode means of said electrodes.

4. In an electrophysical neuromuscular stimulator of the character indicated, pulse-generator means developing a train of voltage pulses having a steep-walled wave front of characteristic polarity, said pulses being at a repetition rate sufficient to produce tetanic contraction, two independent output circuits for independent application of potentials to a body, said output circuits including at least one dielectric body-applicator electrode in each of said circuits, amplitude-modulator means for modulating the intensity of the pulse output of said generator means, said modulator means including phase-splitting means, whereby said modulator means may provide two outputs of the same cyclic modulating period but of different phase, means separately connecting said independent outputs for supply by said respective phases in the output of said modulator means, and grounding means for the other side of each of said output circuits.

5. A stimulator according to claim 4, in which said grounding means includes a grounding plate common to both said independent output circuits.

6. In an electrophysical neuromuscular stimulator of the character indicated, pulse-generator means including a ground connection and developing a train of voltage pulses having polarized steep-walled wave fronts, said pulses being at a repetition rate sufficient to produce tetanic contraction, body-applicator means including two separate dielectric electrodes independent of said grounding means amplitude-modulator means including a balanced ground for modulating the intensity of pulse output of said generator means, said modulator means including phase-splitting means, whereby said modulator means may provide two outputs with respect to ground of the same cyclic modulting period but of different phase, means connecting one of said electrodes to one ungrounded output connection of said modulator means, and means connecting the other of said electrodes to the other ungrounded output connection of said modulating means.

7. In an electrophysical neuromuscular stimulator of the character indicated, pulse-generator means including an electrical capacitor, means connected to said capacitor for charging said capacitor, means including a timing means periodically discharging said capacitor at a rate capable of producing tetanic contraction, two separate transformers each including a primary winding and a secondary winding, first and second dielectric body-applicator electrodes connected respectively to the secondaries of said transformers, grounding means for the other poles of the secondaries of said transformers, and modulating means including phase-splitting means connected to the output of said pulse-generator means and including one output phase in exciting relation with one of said transformers and another output phase in exciting relation with the other of said transformers, the frequency of said modulating means being substantially less than the pulse-repetition frequency of said generator means.

8. A stimulator according to claim 7, in which polarity reversing means are included in one of the modulator-output connections to a transformer.

9. A stimulator according to claim 7, in which said phase-splitting means is a motor-driven switch alternately connecting said pulse-generator means to the respective transformer inputs.

10. A stimulator according to claim 9, in which said motor-driven switch includes a variable speed control, whereby the surge period characterizing modulation in the outputs of said electrodes may be selectively varied.

11. In an electrophysical neuromuscular stimulator of the character indicated, pulse-generator means, modulator means for intensity-modulating the level of pulse output from said generator means, two body-applicator electrodes, body-grounding means, and switching means including means for driving the same at a selectively variable alternating rate, said switching means connecting the modulated pulse output between said grounding means and one electrode in a first part of an alternating cycle, and between said grounding means and the other electrode in a second part of said alternating cycle, said alternating cycle having a period substantially greater than the pulse-repetition period of said pulse-generator means.

12. A stimulator according to claim 11, in which said modulating means includes a variable potentiometer, and means for driving said potentiometer in synchronism with the drive for said switching means.

13. A stimulator according to claim 12, in which said modulating means includes a vacuum tube including a plate circuit, a control-grid circuit, and a cathode output circuit, said pulse-generator means being connected to said control-grid circuit, said potentiometer being connected in said plate circuit, and said cathode circuit being connected through said switching means to said electrodes.

14. A stimulator according to claim 12, in which said modulator means includes a vacuum tube including a plate circuit, a control-grid circuit and a cathode output circuit, said pulse-generator means being connected to said control-grid circuit, a charging capacitor connected in said plate circuit, said cathode circuit including said potentiometer and being connected through said switching means in alternation to said respective body-applicator electrodes.

15. In an electrophysical neuromuscular stimulator of the character indicated, pulse-generator means, body-grounding means, a plurality of dielectric body-applicator electrodes independent of said grounding means, modulating means for intensity-modulating the output of said generator means, said modulating means including phase-splitting means with a selectively variable control for selectively adjusting the phase relation between a plurality of outputs of said modulator means, and means connecting each of the respective outputs of said plurality between said grounding means and separate of said body-applicator electrodes.

16. A stimulator according to claim 15, in which said modulating means includes for each phase of said plurality in said phase-splitting means a variable potentiometer and common drive means for said potentiometers.

17. A stimulator according to claim 16, in which said drive means includes for at least one of said phases a selectively variable differential connection, whereby said one phase may be shifted relatively to another of the split phases of said modulating means.

18. A stimulator according to claim 15, in which said modulating means includes for each of the split phases thereof separate on-off switching means, and common drive means for said switching means.

19. A stimulator according to claim 18, in which said drive means includes for at least one of said phases a

selectively variable differential connection, whereby the phase of operation of one switch may be selectively varied with respect to that of another switch.

20. A stimulator according to claim 18, in which said switches are cam-operated and are characterized by different on-off periods for the same overall cyclic period of said modulator means.

21. In an electrophysical neuromuscular stimulator of the character indicated, pulse-generator means including charging means and means for rapidly discharging the same at controlled intervals, means timing successive discharges at a repetition rate sufficient to produce tetanic contraction, three output electrodes including two gas-filled dielectric applicator electrodes, and control means functioning at a rate substantially lower than said repetition rate and connecting said generator means between one of said dielectric electrodes and said third electrode for a first fraction of a control cycle, said control means connecting said generator means between the other of said dielectric electrodes and said third electrode for a second fraction of said control cycle.

22. In an electrophysical neuromuscular stimulator of the character indicated, pulse-generator means, body-applicator means including three separate electrodes, modulator means for modulating the intensity of the pulse output of said generator means, said modulator means including phase-splitting means, whereby said modulator means may provide two outputs of the same cyclic modulating period but of different phase, means conecting one of said outputs only between a first two of said electrodes, and means connecting the other of said outputs only between the third of said electrodes and one of said first two electrodes.

23. Artificial-resuscitation means, comprising pulse-generator means developing a train of voltage pulses having a steep-walled wave front of characteristic polarity, said pulses being at a repetition rate sufficient to produce tetanic contraction, an output body-connection circuit including a dielectric body-applicator electrode and body-grounding means, amplitude-modulator means for modulating the intensity of the pulse output of said generator means, means driving said amplitude-modulator means through a recurrent cycle of surged intensity at a rate corresponding to normal breathing, said last-defined means being preset and unavailable for adjustment by an operator, and adjustable means for selectively varying the overall surge intensity of said trains of pulses.

24. Artificial-resuscitation means according to claim 23, in which said recurrent cycle is at a rate of approximately eighteen per minute.

25. Artificial-resuscitation means, comprising pulse-generator means developing a train of voltage pulses having a steep-walled wave front of characteristic polarity, said pulses being at a repetition rate sufficient to produce tetanic contraction, an output body-connection circuit comprising two separately unit-handling body-connection electrodes one of which includes a series-connected gas-filled high-strength dielectric element, whereby the capacitance of said element is necessarily in series with the body when said output circuit is connected thereto, amplitude-modulator means for modulating the intensity of the pulse output of said generator means, means programming said amplitude-modulator means through a recurrent cycle of surged intensity at a rate corresponding to normal breathing, and adjustable means for selectively varying the overall surge intensity of said trains of pulses.

26. Neuromuscular stimulator means, comprising pulse-generator means developing a train of voltage pulses at a repetition rate sufficient to produce tetanic contraction, an output body-connection circuit comprising two separately unit-handling body-connection electrodes one of which includes a series-connected gas-filled high-strength dielectric element and also includes a series-connected moistened sponge-like element for direct contact with the body at the area to be affected, and amplitude-modulating means connected to said output circuit and including a manual intensity control for selectively controlling the level of pulse-excitation of the body by said stimulator means.

27. The method of artificially resuscitating a plurality of patients with a single resuscitator having a pulse generator and a two-electrode output body-connection circuit, which comprises applying one of said electrodes to the solar plexus region of one patient and the other electrode to a part of another patient, electrically connecting another part of said one patient to the solar plexus region of said other patient, running said pulse-generator means at a rate sufficient to produce tetanic contraction, and surging the intensity of pulses in said output circuit in a recurrent pattern corresponding with a normal breathing rate.

28. The method of relieving a resuscitated patient from resuscitation that has been artificialy stimulated by the method of claim 27, which comprises electrically connecting the solar plexus region of the resuscitated patient to the patient's other area to which other electrical connection had been made, whereby the pattern of stimulation for an insufficiently resuscitated patient may continue uninterrupted when the resuscitated patient has been effectively removed from the output circuit of the resuscitator.

References Cited in the file of this patent

UNITED STATES PATENTS

1,338,269	Wappler	Apr. 27, 1920
1,645,215	Bauer	Oct. 11, 1927
1,752,632	De Beaumont et al.	Apr. 1, 1930
2,532,788	Sarnoff	Dec. 5, 1950
2,622,601	Nemec	Dec. 23, 1952
2,641,259	Batrow	June 9, 1953
2,651,304	Browner	Sept. 8, 1953
2,711,729	Hofmann	June 28, 1955