

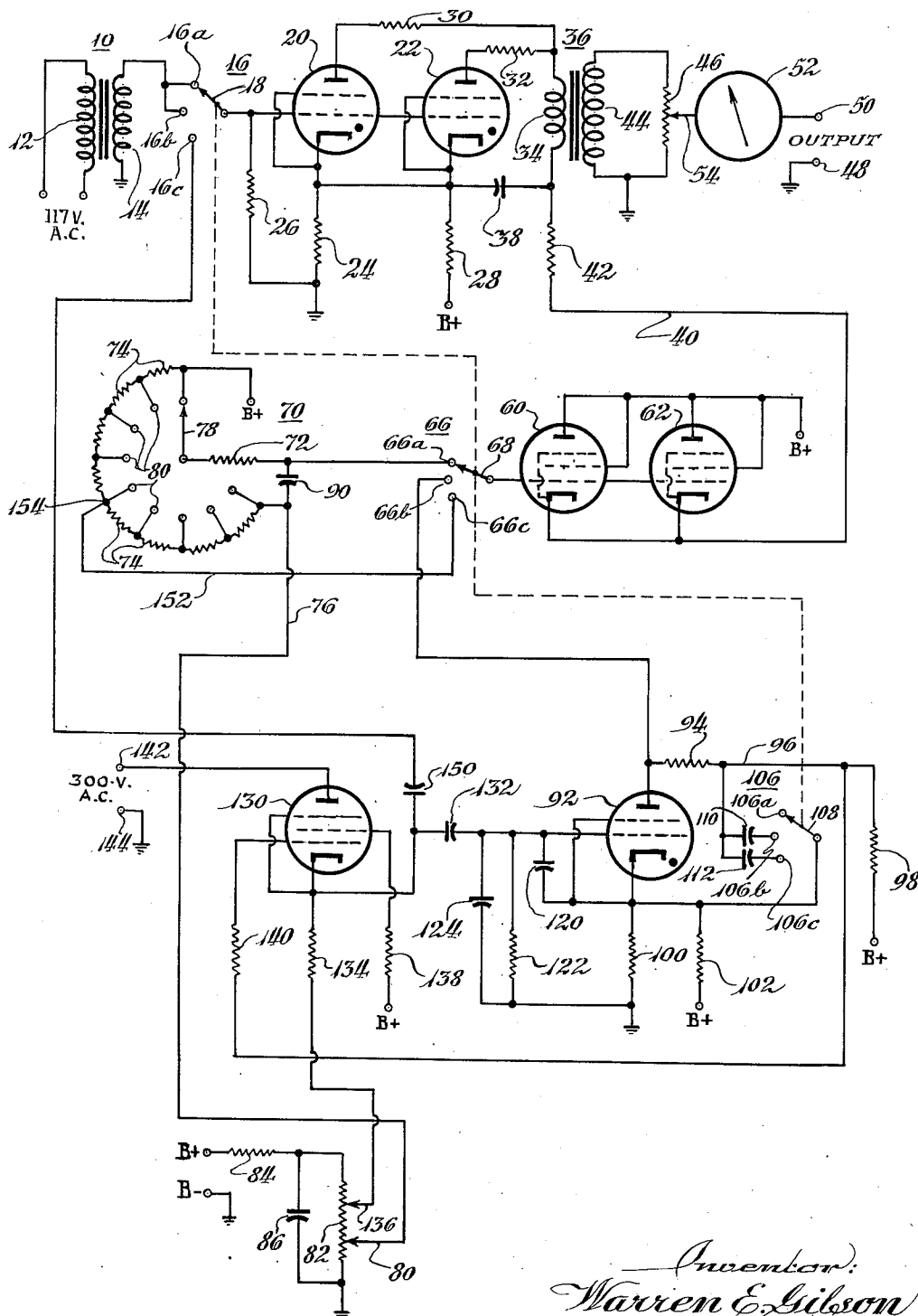
Sept. 2, 1952

W. E. GILSON

2,609,499

MUSCLE STIMULATOR

Filed Sept. 27, 1950



Inventor:
Warren E. Gilson
 By *Hinkle, Horton, Ahlberg & Wupper*,
 Attorneys.

UNITED STATES PATENT OFFICE

2,609,499

MUSCLE STIMULATOR

Warren E. Gilson, Madison, Wis., assignor to The
Burdick Corporation, Milton, Wis., a corpora-
tion of Delaware

Application September 27, 1950, Serial No. 186,997

8 Claims. (Cl. 250-27)

1

This invention relates to apparatus for providing electrical impulses for nerve and muscle stimulation.

An object of the invention is to provide an apparatus for supplying muscle stimulating impulses which are substantially faradic and which have extremely brief, high amplitude peaks of one polarity.

A further object of the invention is to provide an apparatus for supplying repetitive muscle stimulating pulses of controllable amplitude.

A further object is to provide an apparatus supplying repetitive muscle stimulating pulses having a cyclically rising and falling amplitude envelope.

A further object is to provide such an apparatus in which the amplitude envelope is generally saw-toothed.

A further object is to provide an apparatus for supplying muscle stimulating pulses having cyclically varying amplitude, the apparatus including means accurately and dependably to limit the maximum amplitude of the pulses.

A still further object is to provide an apparatus selectively operable to supply relatively high frequency pulses of controllable amplitude, relatively high frequency pulses of cyclically varying amplitude, or relatively low frequency, constant amplitude pulses.

A still further object is to provide muscle stimulating apparatus selectively capable of supplying muscle stimulating impulses for either therapeutic or diagnostic purposes.

Further objects, advantages and principles of the invention will appear from the following description of an illustrative embodiment taken together with the drawing, which is a schematic wiring diagram of the embodiment.

The illustrated embodiment of the muscle stimulator most conveniently receives its operating power from a 117 volt alternating current electric power line. In some cases the muscle stimulating pulses produced by the apparatus have the same periodicity as the alternating current voltage from the power line.

For this reason the muscle stimulator includes a peaking transformer 10 having its primary winding 12 connected with the 117 volt alternating current supply as indicated in the drawing.

The transformer 10 is constructed in a known manner to distort the essentially sinusoidal input wave form and produce a sharply peaked alternating current output wave form across the secondary winding 14 of the transformer. This distortion is usually accomplished by designing the transformer so that partial saturation of the magnetic core takes place on the peaks of the input voltage.

One output conductor of the transformer sec-

2

ondary 14 is grounded and the other is connected with two contacts 16a and 16b of a single pole three-position switch 16. The switch 16 has an arm 18 which is movable to make contact with either of the contact points 16a or 16b or with a third contact point 16c.

The movable arm 18 of the switch 16 is connected with the grids of two arc discharge tubes or thyratrons 20 and 22 which are connected for parallel operation. The shield grids of the thyratrons 20 and 22 are connected to the cathodes, and the cathodes are connected in parallel. A resistor 24 connecting the cathodes to ground provides cathode biasing voltage, and a second resistor 26 connecting the grids of the thyratrons to ground provides a grid return path.

A resistor 28 connecting the cathodes with a suitable positive anode supply voltage terminal B+ provides a minimum cathode bias voltage sufficient to prevent initiation of arc discharges in the thyratrons 20 and 22 in the absence of grid-cathode signals. A current flows from B+ to ground through the resistors 28 and 24 and produces a cathode biasing voltage drop across the resistor 24.

The anodes of the thyratrons 20 and 22 are connected by low value current equalizing resistors 30 and 32 to one side of a primary winding 34 of a step-up pulse output transformer 36. The other side of the primary 34 is connected with the cathodes of the thyratrons by a pulse forming capacitor 38. The same side of the primary is also connected with a positively charged conductor 40 by means of a charging resistor 42. The positive voltage appearing upon the conductor 40 may vary, as will presently be explained.

A high voltage secondary winding 44 of the transformer 36 is shunted by a potentiometer 46. One side of the secondary 44 is grounded and is thereby connected with a grounded output terminal 48. A second output terminal 50 is connected by a current measuring meter 52 with the movable arm 54 of the potentiometer. The potentiometer provides means to adjust the magnitude of the muscle stimulating impulses supplied to the output terminals 48 and 50 by the apparatus.

When the movable arm 18 of the switch 16 is brought into contact with either of the contact points 16a or 16b, the apparatus produces muscle stimulating pulses at the frequency of the 117 volt alternating current power line. Of course this frequency is usually 60 cycles per second. During the negative half cycle of the sharply peaked alternating current voltage produced by the transformer secondary 14, the thyratrons 20 and 22 are nonconducting. The capacitor 38 is charged through the resistor 42 substantially to the positive voltage appearing upon the conductor

3

40, and the voltage appearing across the capacitor 38 is applied to the anodes of the thyratrons by the transformer primary 34 and the current equalizing resistors 30 and 32. The voltage drop across the cathode resistor 24 caused by the current flowing from the B+ terminal through the resistor 28 is sufficient to prevent the voltage appearing at the anodes of the thyratrons from initiating arc discharges in the tubes.

The positive peaks of the alternating current signal from the transformer secondary 14 raise the voltage between the grids and the cathodes of the thyratrons to such an extent that arc discharges are initiated in the tubes. When the discharges are started, the capacitor 38 discharges very rapidly through the circuit including the thyratrons, the equalizing resistors 30 and 32, and the transformer primary 34. The transformer primary 34 and the resistors 30 and 32 have such low impedances that the discharge of the condenser is not substantially impeded or retarded.

After the discharge of the capacitor 38 the arc discharges in the thyratrons 20 and 22 are extinguished because the anode-cathode thyatron voltage drops to a value insufficient to maintain the discharges in the tubes. This occurs at least partly because the inductive transformer primary 34, in conjunction with the capacitor 38, tends to produce an oscillatory discharge current, and consequently tends to swing the anode voltage of the thyratrons to a negative value momentarily.

The values of the input voltage from the transformer secondary 14, the cathode biasing voltage and the capacitance of the capacitor 38 are selected so that the grid-cathode voltage of the thyratrons has dropped sufficiently to cut off the discharges by the time the condenser 38 has discharged through the thyratrons. Consequently, a single brief current impulse is produced through the primary 34 of the output transformer in synchronism with each of the positive peaks of the input voltage from the transformer 14. The current impulses in the primary 34 produce brief high voltage impulses across the secondary 44 of the output transformer 36, and the voltage pulses are transmitted to the output terminals by the potentiometer 46 and the meter 52.

After the thyratrons 20 and 22 are extinguished, the capacitor 38 is charged rapidly through the resistor 42 to the positive voltage appearing on the conductor 40. The capacitor 38 and the resistor 42 have small values, such as 0.5 microfarad and 4,000 ohms, respectively, so that the charging time constant of the capacitor and the resistor is small with respect to the half period of the input voltage from the transformer 14. In the above example the time constant of the capacitor and the resistor is 2.0 milliseconds as compared with approximately 8 milliseconds for the half period of the usual 60 cycle power line voltage.

The amplitude of the output voltage impulses is a function of the quantity of electrical charge stored in the capacitor 38, which in turn is a function of the voltage appearing upon the conductor 40. The voltage on the conductor 40 is controlled by means of a pair of vacuum discharge coupling tubes 60 and 62 having their cathodes connected to the conductor 40. The tubes 60 and 62 preferably are pentodes of the type commonly used in the power output stages of radio receivers. However, the tubes are operated as triodes by connecting their screen grids to their anodes. The anodes are connected directly to a suitable anode voltage supply terminal B+.

4

The grids of the tubes 60 and 62 are connected with a movable arm 68 of a three-position switch 66 having three contact points 66a, 66b and 66c. As indicated on the drawing, the switch 66 may be ganged with the switch 16.

The first contact point 66a is connected with a potentiometer 70 through a current limiting resistor 72. The potentiometer 70 comprises a plurality of resistance elements 74, illustrated as eight in number, connected in series between a suitable positive anode voltage supply terminal B+ and a conductor 76. The potentiometer 70 is adjustable by means of a multi-position switch having an arm 78 movable into contacting engagement with any one of a plurality of contact points 80 respectively connected with the end points of the resistors 74.

The conductor 76 is connected to a slider 80 of a voltage dividing resistor 82 to impress an adjustable relatively low positive voltage upon the conductor. The voltage dividing resistor 82 is grounded at one end and is connected with an anode voltage terminal B+ at the other end by means of a filtering resistor 84. The voltage dividing resistor 82 is bypassed by a filter capacitor 86. As indicated, the negative terminal B- of the anode voltage supply (not shown) is grounded.

The first contact point 66a of the switch 66 is connected through the resistor 72 with the switch arm 78 of the potentiometer 70 and is bypassed to the conductor 76 by a filter capacitor 90.

When the switch arm 68 is brought into contacting engagement with the first contact point 66a, the grids of the coupling tubes 60 and 62 are connected with the potentiometer 70, and the voltage of the grids can be varied between the voltage of the anode supply terminal B+ and the voltage appearing upon the conductor 76, which is determined by the adjustment of the slider 80 on the voltage divider 82.

The voltage appearing upon the conductor 40 connected with the cathodes of the coupling tubes 60 and 62 tends to be approximately equal to the voltage impressed upon the grids of the coupling tubes. Any rise in the cathode voltage above the grid voltage is inhibited by the consequent rise in the cathode-grid bias toward the cut-off value. Such a rise in the cathode-grid voltage is effective to limit conduction by the coupling tubes 60 and 62.

On the other hand, if the cathode voltage of the coupling tubes 60 and 62 drops, the cathode-grid voltage also drops and tends to increase conduction in the coupling tubes.

Of course the capacitor 38 is charged from the B+ terminal through the parallel coupling tubes 60 and 62 and the resistor 42. The extent to which the capacitor is charged depends upon the voltage applied to the grids of the coupling tubes.

Consequently, when the switch arms 18 and 68 are set in their first positions contacting the switch points 16a and 66a, respectively, the muscle stimulator produces extremely brief muscle stimulating pulses at the frequency of the 117 volt A. C. power line. The amplitude of the pulses depends upon the voltage applied to the grids of the coupling tubes 60 and 62 by the potentiometer 70. Consequently, the amplitude may be varied manually over a relatively wide range.

When the switch arms 18 and 68 are brought into contacting engagement with the contact points 16b and 66b, respectively, a third thyatron

92 is connected into the circuit. The thyatron 92 provides cyclical signals of generally saw-toothed wave form for varying the amplitude envelope of the sharp impulses produced by the circuit comprising the thyatrons 20 and 22.

The second contact point 66b of the switch 68 is connected with the anode of the thyatron 92. The anode of the thyatron 92 is connected with a suitable positive anode supply terminal B+ by a relatively small value resistor 94, a conductor 96, and a relatively large value resistor 98.

The cathode of the thyatron 92 is connected to ground by a resistor 100 and to an anode supply terminal B+ by a resistor 102. A current from the B+ terminal through the resistors 100 and 102 produces a voltage drop across the resistor 100 which biases the cathode of the thyatron 92 with respect to the grid.

The cathode of the thyatron 92 is also connected with a movable arm 108 of a switch 106 having three contact points 106a, 106b and 106c. As indicated, the switch 106 may be ganged with the other two switches 16 and 66. The contact point 106a is left unconnected and the contact points 106b and 106c are connected with the conductor 96 by capacitors 110 and 112, respectively.

The shield grid of the thyatron 92 is connected with the cathode. The control grid of the thyatron is bypassed to the cathode by a filtering capacitor 120 and the grid is connected to ground by a grid return resistor 122 shunted by a filtering capacitor 124.

The thyatron 92 produces the saw-toothed voltages by the alternate charging and discharging of the capacitor 110, when the switch arm 108 is moved into contacting engagement with the contact point 106b. The capacitor 110 is charged through the resistor 98 and is discharged through the resistor 94 and the thyatron 92. The resistance of the resistor 94 is much smaller than that of the resistor 98 so that the discharge of the capacitor is effected in a brief interval, compared with the time required for charging the capacitor.

The maximum amplitude of the saw-toothed voltage which appears at the anode of the thyatron 92, is closely regulated by a circuit including a pentode 130 of a type commonly employed for voltage amplification in radio receivers. The cathode of the pentode 130 is connected with the suppressor grid and is coupled with the control grid of the thyatron 92 by a current limiting capacitor 132. The cathode of the pentode 130 is connected by a relatively high value resistor 134 with a second slider 136 contacting the voltage dividing resistor 82.

The screen grid of the pentode 130 is connected to an anode supply terminal B+ by a resistor 138. The control grid of the pentode is connected through a current limiting resistor 140 with the conductor 96 in the anode circuit of the thyatron 92.

The anode of the pentode 130 is connected to a terminal 142 of an alternating current voltage supply at approximately 300 volts. The other terminal 144 of the alternating current supply is grounded. The alternating current supply may provide a voltage at the frequency of the electric power line, and the 300 volt potential may easily be obtained from a high voltage secondary winding of a transformer (not shown) connected with the ordinary 117 volt power line. The transformer may also be employed in con-

junction with rectifier and filter components to provide the B+ voltage.

The circuit including the pentode 130 acts to limit the maximum amplitude of the saw-toothed signal produced by the thyatron 92 to the approximate value of the voltage appearing at the slider 136 connected with the cathode of the pentode 130. Immediately after a discharge of the capacitor 110, the grid of the pentode 130 is approximately at ground potential because the grid is connected by the resistor 140 with the conductor 96. Consequently, the potential of the grid is approximately equal to the voltage across the capacitor 110. At this time the voltage at the cathode of the pentode 130 is considerably greater than the voltage at the grid, and the pentode 130 is thereby rendered non-conductive.

As the capacitor 110 charges through the resistor 98 the potential of the grid of the pentode rises, and when the difference in potential between the grid and the cathode of the pentode 130 becomes less than the cut-off bias value, the pentode begins to conduct on the peaks of the positive half cycles of the alternating current voltage applied to the anode of the pentode. The momentary conduction in the pentode on the positive peaks of the alternating current anode voltage provides positive voltage impulses at the cathode of the pentode because of voltage drop across the load resistor 134. The positive impulses are coupled to the grid of the thyatron 92 by the capacitor 132. The capacitor 132 in cooperation with the grid return resistor 122 produces a pulse sharpening effect.

One of the first few pulses impressed upon the control grid of the thyatron 92 causes initiation of an arc discharge in the thyatron. The capacitor 110 discharges rapidly and the potential of the grid of the pentode drops so that the pentode is again rendered nonconductive. The thyatron is extinguished when the capacitor 110 discharges to such an extent that the voltage across the capacitor is insufficient to maintain conduction in the thyatron.

Thus, when the switch arms 18, 68 and 108 make contact with the second contact points 16b, 66b and 106b, respectively, the apparatus produces a series of sharp high voltage impulses at the frequency of the 117 volt supply, and the amplitude of the successive pulses cyclically increases and decreases in accordance with the saw-toothed wave form produced by the thyatron 92. The saw-toothed voltage from the thyatron is impressed upon the grids of the coupling tubes 60 and 62 through the second switch contact 66b. As previously explained, the voltage on the conductor 40 which connects the coupling tubes with the thyatrons 20 and 22 varies in accordance with the voltage impressed on the grids of the tubes.

The capacitor 110 and the resistor 98 have relatively high values such as 3 microfarads and 1 megohm, respectively, so that the thyatron 92 produces a saw-toothed signal having a relatively long period, of a few seconds, for example.

When the switch arms 18, 68 and 108 are brought into contacting engagement with the third contact points 16c, 66c and 106c, respectively, the capacitor 112 is connected in the anode circuit of the thyatron 92. The capacitance of the capacitor 112 may be somewhat smaller than the capacitance of the capacitor 110 so that the thyatron 92 produces a higher frequency saw-toothed signal when the capacitor 112 is in the circuit. For example, the capacitance of the

capacitor 112 may be approximately .5 microfarad to provide a saw-toothed signal having a frequency of a few cycles per second.

In the third position of the switches 16, 66 and 106, the grids of the pulse producing thyratrons 20 and 22 are coupled to the cathode of the pentode 130 through a current limiting capacitor 150 connected between the cathode and the switch contact point 16c. Consequently the thyratrons 20 and 22 produce a sharp output pulse each time a sufficiently large positive pulse appears at the cathode of the pentode 130. In the third position of the switches a fixed positive direct current potential is applied to the grids of the coupling tubes 60 and 62 by a conductor 152 connecting the third contact point 66c with a junction point 154 between a predetermined pair of the series connected resistors 74 comprising the potentiometer 70. The junction point 154 may be approximately midway between the end terminals of the potentiometer 70 so that the voltage impressed on the grids of the coupling tube is intermediate the voltage of the B+ terminal and the voltage of the slider 80 on the voltage divider. Consequently, the output pulses produced by the apparatus have a relatively moderate amplitude suitable for diagnostic applications of the muscle stimulator.

For the third setting of the selector switches, the output pulses are timed by the operation of the thyatron 92. As previously explained in connection with the second setting of the selector switches, the capacitor 112 charges through the resistor 98 until the rise in the potential of the grid of the pentode 130 produces a positive pulse on the cathode of the pentode by virtue of conduction on a positive peak of the alternating current anode voltage applied to the terminals 142 and 144. The positive pulse at the cathode of the pentode 130 is transmitted to the control grid of the thyatron to initiate conduction therein and to cause the capacitor 112 to discharge through the thyatron. At the same time the positive pulse at the cathode of the pentode 130 is transmitted through the capacitor 150, the switch point 16c, and the switch arm 18 to the grids of the pulse forming thyratrons 20 and 22. The thyratrons 20 and 22 thereupon produce a brief pulse in the manner previously described.

When the ganged switch arms 18, 68 and 108 are set in their first positions contacting switch points 16a, 66a and 106a, respectively, the apparatus produces sharp substantially faradic voltage impulses at the frequency of the 117 volt power line. The amplitude of the pulses may be controlled by the operator of the muscle stimulator by adjusting the potentiometer 70. The physician operating the apparatus may manipulate the potentiometer to vary the magnitude of the muscle stimulating pulses between desired limits according to any desired rhythmic pattern. Consequently, the amount and character of the muscle stimulation produced by the apparatus is under the complete control of the physician.

When the switch arms 18, 68 and 108 are set at their second positions in contact with the switch points 16b, 66b and 106b, respectively, the apparatus produces muscle stimulating pulses at the frequency of the 117 volt power line. The pulses vary cyclically in amplitude in accordance with the saw-toothed signal produced by the thyatron 92 as previously explained. The cyclic rise and fall of the muscle stimulating pulses proceed at a relatively slow rate to produce a rhythmic pattern of alternate muscle stimula-

tion and relaxation which is beneficial for muscle therapy. The saw-toothed wave form of the amplitude envelope of the voltage impulses produces stimulation of the muscles followed by sudden relaxation. The maximum amplitude of the pulses is closely limited and regulated by the action of the pentode 130 which initiates conduction in the thyatron 92 at the amplitude selected by adjusting the slider 136. The voltage across the capacitor 110 closely approaches the voltage impressed upon the cathode of the pentode 130 by the slider 136 as previously explained.

For the safety, comfort and well being of the patient, it is quite important that maximum amplitude of the stimulating impulses be closely regulated. Consequently the close regulation provided by the circuit including the pentode 130 and the thyatron 92 is one of the important advantages of this invention.

When the switch arms 18, 68 and 108 are set in their third positions to contact the switch points 16c, 66c and 106c, respectively, the muscle stimulating apparatus produces a series of sharp voltage impulses of moderate, constant amplitude at a frequency of a few cycles per second. These muscle stimulating pulses are particularly useful for diagnostic purposes. The physician operating the muscle stimulating apparatus can apply the impulses to various portions of the skin by means of a probe connected to the output terminals. The twitching of the muscles produced by the pulses provides an indication of their condition.

The arrangement of the coupling tubes 60 and 62 is particularly advantageous since the tubes provide means for controlling the amplitude of the muscle stimulating impulses by a voltage source capable of developing only a small power output. The amplitude of the muscle stimulating impulses may be controlled accurately and dependably by adjusting the voltage applied to the grids of the coupling tubes. The grid voltage may be manually varied by manipulation of the potentiometer 70 if the switch arm 68 contacts the contact point 66a, or the grid voltage may be varied cyclically by means of the saw-toothed oscillation generator comprising the tubes 92 and 130, if the switch arm 68 contacts the second contact point 66b.

The arrangement of the switches is an important feature of the muscle stimulator. By manipulating the switches, the low frequency oscillation generator comprising the tubes 92 and 130 may be connected either to vary the amplitude of the muscle stimulating impulses or to time the impulses. When the switch arms 18 and 68 are in their first positions contacting the switch points 16a and 66a, the saw-toothed signal appearing at the anode of the tube 92 is applied to the grid of the coupling tubes for varying the amplitude of the muscle stimulating impulses cyclically. When the switch arms 18 and 68 are in their third positions contacting the switch points 16c and 66c, the low frequency impulses appearing at the cathode of the tube 130 are transmitted to the grids of the impulse producing gaseous discharge tubes 20 and 22. The grids of the coupling tubes are connected with a source of a constant potential so that the amplitude of the muscle stimulating impulses is constant.

For the convenience of those skilled in the art, the values of some of the components of the muscle stimulator are tabulated below. Of course most of the values are not critical and individual

values may be varied over wide limits, particularly if compensating changes are made in other values. Resistance values are given in ohms and capacitance values in microfarads.

Resistors:

24	2,200
26	100,000
28	270,000
30 and 32	5
42	4,000
46	10,000
72	100,000
74	270,000
82	25,000
84	500
94	1,500
98	1,000,000
100	2,700
102	100,000
122	500,000
134	50,000
138	500,000
140	1,000,000

Capacitors:

38	0.5
86	40.
90	0.1
110	3.
112	0.5
120	0.0003
124	0.0001
132	0.002
150	0.001

Tubes:

20 and 22	2D21
60 and 62	7C5
92	2D21
130	6AU6

While I have shown and described a preferred embodiment of my invention, it will be apparent that numerous variations and modifications thereof may be made without departing from the underlying principles of the invention. I, therefore, desire, by the following claims, to include within the scope of the invention all such variations and modifications by which substantially the results of my invention may be obtained through the use of substantially the same or equivalent means.

What I claim is:

1. A muscle stimulator, comprising an impulse generator having output conductors for supplying muscle stimulating impulses and having a terminal, the potential of which determines the magnitude of the impulses; a saw-toothed wave modulation generator coupled to the terminal cyclically to vary the magnitude of the impulses, the modulation generator including a gaseous discharge device having an anode, cathode and control grid, a circuit including a capacitor connected between the anode and the cathode, a direct current potential source, and a circuit including a charging impedance connecting the source with the capacitor; a discharge tube having an anode, cathode and control grid; a circuit connecting the latter anode with the latter cathode including a supply of cyclically varying voltage and a load impedance coupled with the grid of the gaseous discharge device; a circuit connecting the grid of the tube with the anode of the gaseous discharge device; and a direct current potential source biasing the cathode of the discharge tube to a predetermined positive voltage value with respect to the cathode of the

gaseous discharge device, so that the discharge tube transmits an impulse from the supply of cyclically varying voltage to the grid of the gaseous discharge device to trigger the latter when the anode voltage of the gaseous device approaches the predetermined value.

2. A muscle stimulator, comprising an impulse generator having output conductors for supplying muscle stimulating impulses and having a terminal, the potential of which determines the magnitude of the impulses; a saw-toothed wave modulating generator coupled to the terminal cyclically to vary the magnitude of the impulses, the modulating generator including a discharge device having an anode, cathode and control grid, a circuit including a capacitor connected between the anode and the cathode, a direct current potential source, and a circuit including a charging impedance connecting the source with the capacitor; a discharge tube having an anode, cathode and control grid; a circuit connecting the tube anode with the tube cathode including a load impedance coupled with the grid of the discharge device; a direct current potential source connected with the discharge tube to provide a grid-cathode bias of a predetermined value substantially greater than sufficient to cut off the tube; a circuit connecting the grid of the tube with the anode of the device to render the tube conductive when the device anode voltage approaches the predetermined value of the biasing source; and a supply of cyclically varying voltage coupled to the tube to produce an impulse across the load impedance to render the discharge device conductive when the tube becomes conductive, so that the maximum device anode voltage is regulated approximately to correspond with the predetermined value of the biasing source voltage.

3. An apparatus to operate from an alternating current power line for producing muscle stimulating electrical impulses, comprising a gaseous discharge device having an anode, a cathode and a control grid; a step-up output transformer having a primary winding and having a secondary winding for supplying the muscle stimulating impulses; a capacitor; a circuit connected across the capacitor for charging the capacitor to a variable extent for controlling the magnitude of the muscle stimulating impulses including a source of a variable positive potential connected in series with a charging impedance; a discharging circuit including the primary of the output transformer connecting the capacitor with the anode and cathode of the discharge device; and an input peaking transformer cyclically to render the discharge device conductive for discharging the capacitor abruptly, the transformer including a primary for connection with the alternating current power line and a secondary connected with the grid and the cathode of the discharge device to furnish peaked alternating current signals to the device.

4. An apparatus to operate from an alternating current power line for producing muscle stimulating electrical impulses, comprising a gaseous discharge device having an anode, a cathode, and a control grid; a step-up output transformer having a primary winding and having a secondary winding for supplying the muscle stimulating impulses; a capacitor; a discharge tube having an anode, a cathode and a control grid; a direct current potential source; a circuit connected across the capacitor for charging the capacitor to a variable extent to control the

magnitude of the muscle stimulating impulses, the circuit including a direct current potential source and the anode and the cathode of the tube in series with a charging impedance; a source of variable voltage connected with the grid of the discharge tube to control the charging of the capacitor through the tube and the charging impedance; a discharge circuit including the primary of the output transformer connecting the capacitor with the anode and cathode of the gaseous discharge device; and an input peaking transformer cyclically to render the gaseous device conductive for discharging the capacitor abruptly, the transformer including a primary for connection with the alternating current power line and a secondary connected with the grid and cathode of the gaseous device to furnish peaked alternating current signals to the device.

5. An apparatus to operate from an alternating current power line for producing muscle stimulating electrical impulses, comprising a gaseous discharge device having an anode, a cathode and a control grid; a step-up output transformer having a primary winding and having a secondary winding for supplying the muscle stimulating impulses; a capacitor; a circuit connected across the capacitor for charging the capacitor to a variable extent cyclically to vary the magnitude of the muscle stimulating impulses, the circuit including a source of a cyclically varying positive signal connected in series with a charging impedance, the frequency of the signal being much less than the impulse frequency, a discharging circuit including the primary of the output transformer connecting the capacitor with the anode and cathode of the discharge device; and an input peaking transformer cyclically to render the discharge device conductive for discharging the capacitor abruptly, the transformer including a primary for connection with the alternating current power line and a secondary connected with the grid and the cathode of the discharge device to furnish peaked alternating current signals to the device.

6. In an impulse producing apparatus, a saw-toothed wave generator including a gaseous discharge device having an anode, a cathode and control grid; a circuit including a capacitor connected between the anode and the cathode; a direct current potential source; a circuit including a charging impedance connecting the source with the capacitor; a discharge tube having an anode, a cathode and a control grid; a circuit connecting the tube anode with the tube cathode including a load impedance coupled with the grid of the gaseous device; a direct current potential source connected with the discharge tube to provide a grid cathode bias of a predetermined value substantially greater than sufficient to cut off the tube; a circuit connecting the grid of the tube with the anode of the gaseous device to render the tube conductive when the device anode voltage approaches the predetermined value of the biasing source; and a supply of cyclically varying voltage coupled to the tube to produce an impulse across the load impedance to trigger the gaseous device when the tube becomes conductive, the cyclical period of the supply voltage being much less than the charging time constant of the capacitor and the charging impedance, so that the maximum device anode voltage is regulated approximately to correspond

with the predetermined value of the biasing source voltage.

7. A muscle stimulator, comprising a gaseous discharge device having an anode, a cathode and a control grid; a step-up output transformer having a primary winding and having a secondary winding for supplying the muscle stimulating impulses; a capacitor; a circuit connected across the capacitor for charging the capacitor, including a direct current potential source in series with a charging impedance; a discharging circuit including the transformer primary connecting the capacitor with the anode and cathode of the discharge device; a discharge tube having an anode, a cathode and a control grid; a direct current potential source connected with the tube to provide a grid-cathode bias of a predetermined value substantially greater than sufficient to cut off the tube; a second gaseous discharge device having an anode, a cathode and a grid; a circuit connecting the tube anode with the tube cathode including a load impedance coupled to the grid of the first and second gaseous devices; a second capacitor; a charging circuit connected across the second capacitor including a direct current potential source and a second charging impedance in series, the time constant of the second capacitor and impedance being much greater than the time constant of the first capacitor and impedance; a discharging circuit connecting the second capacitor with the second device anode and cathode; a circuit connecting the tube grid with the second device anode to render the tube conductive when the second device anode voltage approaches the bias value; and a supply of cyclically varying voltage coupled to the tube to produce an impulse across the load impedance to render the first and second devices conductive momentarily when the tube becomes conductive, the cyclical supply voltage period being substantially less than the time constant of the second capacitor and impedance.

8. A muscle stimulator for producing either high frequency electrical impulses varying cyclically in amplitude or low frequency impulses having constant amplitude, comprising an impulse generator for producing the muscle stimulating impulses in response to input signals, the generator having an input terminal for receiving the input signals and a control terminal, the potential of which determines the amplitude of the impulses; a constant potential supply; an oscillator for producing relatively low frequency saw-toothed waves; a sharpening circuit coupled to the oscillator for producing sharp impulses in synchronism with the saw-toothed waves; a source of relatively high frequency signals; and a two-pole switch having a first position for connecting the input terminal with the source and for connecting the control terminal with the oscillator and having a second position for connecting the input terminal with the sharpening circuit and connecting the control terminal with the supply.

WARREN E. GILSON

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,496,543	Kanner	Feb. 7, 1950
2,511,595	Loughren	June 13, 1950