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Filed Sept. 3, 1941

Serial No.
409,384

2 Sheets-Sheet 1

Fig. 1.

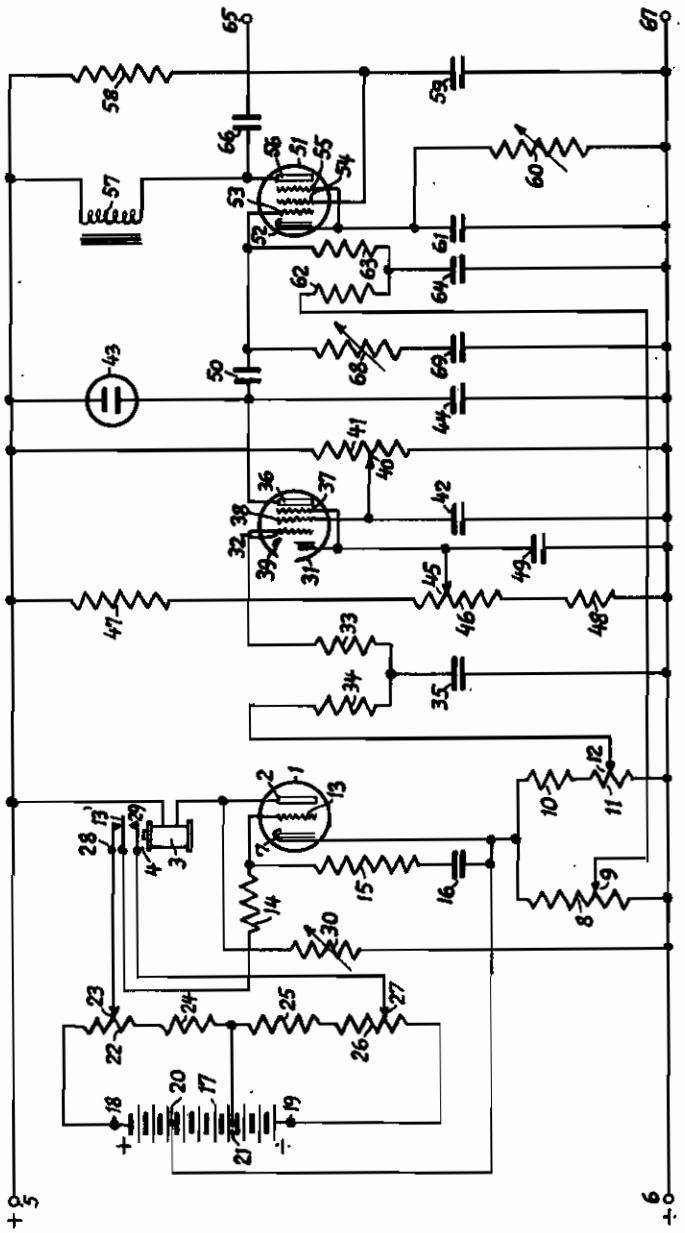

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Fig. 2.

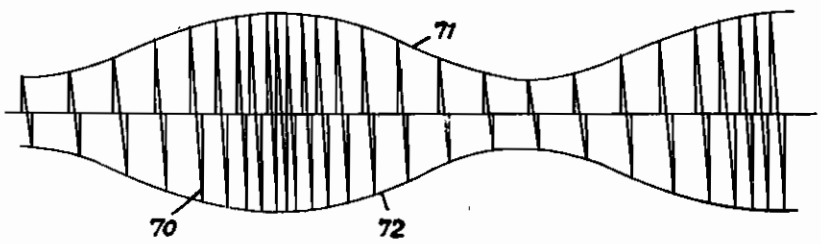
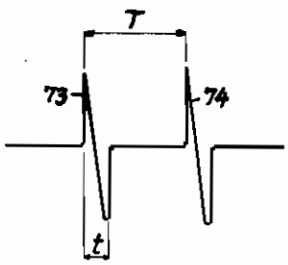


Fig. 3.



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ALIEN PROPERTY CUSTODIAN

APPARATUS FOR TREATMENT OF NERVES AND MUSCLES BY MEANS OF ELECTRIC IMPULSES

Preben Morland, Gentopte, and Jorgen Adolph Smith, Copenhagen, Denmark; vested in the Alien Property Custodian

Application filed September 3, 1941

The invention relates to an apparatus for treatment of nerves and mucles by means of electric impulses, especially for artificial innervation of muscles, for instance for therapeutic purposes. The apparatus according to the invention is especially adapted for use in the training of muscles.

For the above mentioned purpose, electric impulses are used the voltage curve of which may be monopolar, i. e. the voltage curve for each individual impulse is either entirely above or entirely below a voltage of repose which generally will be zero. Usually, however, the voltage curve will be dipolar, i. e. the voltage curve has one portion situated on one side of the voltage of repose, and an adjoining portion situated on the opposite side thereof. In therapeutics, such impulses are frequently called monophase and diphase or else galvanic and faradic impulses, respectively. The duration of each impulse will generally be constant and is referred to, in the following, as the impulse duration. The individual impulses are emitted in succession, in such a manner that the time interval between two successive impulses is always larger than the duration of each individual impulse.

Further, the time interval between the impulses as well as their amplitude should be able to be varied continuously and automatically. Apparatuses by which such electric impulses may be produced are known, but the possibilities of variation offered by these apparatuses are very limited, and the variations are effected by deficient mechanical means.

The present invention has for its object to provide an apparatus by which it is feasible to perform at any time the desired variations in the ranges of variation for the amplitude and time interval of the impulses, and in the manner in which the amplitude and time interval of the impulses are varying.

According to the invention, this result is attained in that the apparatus is fitted with means for producing a rhythmically pulsating current which is utilized for controlling the time interval between the individual impulses and similarly the amplitude of the same, in such a manner that the ranges of variation for the time interval and the amplitude of the impulses may be varied independently of each other. The lower limit of the said variation ranges may preferably be zero.

The rhythmically pulsating current is preferably formed by charging and discharging currents for a condenser or, maybe, by an amplification of such currents.

The apparatus may have two potentiometers through which the rhythmically pulsating current is passing, and from which the controlling voltages are taken that serve to control the time interval and the amplitude of the impulses.

The said rhythmically pulsating currents may be produced in the anode circuit of a discharging valve, by means of a relay the coil of which is inserted in the anode circuit of the valve, and which alternately charges and discharges a condenser inserted in the inlet circuit of the valve.

The anode circuit of the valve may contain potentiometers from which the voltages for controlling the time interval and the amplitude of the impulses are taken. In order to be able to reduce arbitrarily to zero the minimum value of the current through the potentiometers, without the relay being prevented from operating, a portion of the circuit containing the relay coil, the valve and the potentiometers may be shunted with a variable resistance.

In order to change the shape of the pulsating current, means may be found for altering the charging current and the discharging current of the condenser independently of each other.

The impulses may be produced by means of a condenser, by charging or discharging the same by way of a discharging bulb of the kind having an igniting voltage that is higher than the extinguishing voltage, and by charging or discharging the condenser by way of a discharging valve the grid voltage of which is controlled by the rhythmically pulsating current, the time interval between the impulses being thus altered in accordance with the said current. The minimum time interval between the impulses may be modified by altering a grid bias imposed on the valve. The discharging bulb may preferably be a glim lamp.

The adjustment of the amplitude of the impulses may be effected by an amplifier valve in which the impulses are amplified, and on the grid voltage of which the rhythmically pulsating current is superimposed, in such a manner that the impulse amplitude varies in accordance with the latter. The minimum amplitude of the impulses may be varied by varying a grid bias imposed on the said valve.

The invention is further explained in the following, reference being made to the drawing in which:

Fig. 1 shows a wiring diagram for one con-

struction of an apparatus according to the invention,

Fig. 2 the voltage curves for a series of impulses produced by means of the apparatus shown in Fig. 1, and

Fig. 3 the voltage curves for two individual impulses.

The apparatus shown in Fig. 1 consists of three parts, viz. one part for producing the rhythmically pulsating current, one part for producing the impulses and for controlling the mutual time interval between the latter, and one portion for controlling the amplitude of the impulses.

The rhythmically pulsating current is produced by means of a triode valve 1 the anode 2 of which is connected, by way of a relay coil 3 for a relay 4, to the positive terminal 5 of a source of voltage. The cathode 7 in the valve 1 is connected to the negative terminal 6 of the source of voltage by way of two parallel current paths, viz. partly by way of a potentiometer 8 with a sliding contact 9, and partly by way of a series connection consisting of a resistance 10 and a potentiometer 11 with a sliding contact 12. The two current paths may be alike, and are merely shown different in order to indicate that each current path may either consist merely of a potentiometer or of a potentiometer connected in series with a fixed resistance. The two potentiometers may further be replaced by one single potentiometer having two sliding contacts adapted to be adjusted independently of each other. Across a resistance 14 the armature of the relay 4 is connected to the grid 13 of the valve 1, which grid is further connected to the cathode 7 by way of a resistance 15 and a condenser 16. A battery 17, the positive and negative terminals of which are marked 18 and 19 respectively, has two outlets 20 and 21, the voltage being more positive at the outlet 20 than at the outlet 21. The outlet 20 is connected to the cathode 7. The positive terminal 18 of the battery is connected, by way of a potentiometer 22 with a sliding contact 23 and, by way of a resistance 24, to the outlet 21 which by way of a resistance 25 and a potentiometer 26 with a sliding contact 27 is connected to the negative terminal 19 of the battery. The sliding contacts 23 and 27 are connected, respectively, to a circuit-breaking contact 28 and a circuit-closing contact 29 in the relay 4.

When the current in the relay coil 3 alternately assumes various values, the armature 13' will alternately close a contact with the contacts 28 and 29. At the moment when a contact is closed for instance between the armature 13' and the contact 28, the current in the relay coil will be relatively small. Across the potentiometer 22, the sliding contact 23, the contact 28 and the resistance 14, the grid 13 will receive a voltage that is higher than the voltage imparted subsequently thereto by way of the potentiometer 26, the sliding contact 27 and the contact 29, when the armature 13' is attracted. The grid 13, however, does not at once receive the voltage possessed by the sliding contact 23, as the condenser 16 must first be charged by way of the resistances 14 and 15 which limit the current. Gradually, as the condenser is charged and, consequently, the voltage of the grid 13 is increased, the current through the relay coil 3 will be augmented until the said coil attracts the armature 13' which subsequently closes a contact with the contact 29. Thus a negative voltage is imparted to the condenser 16, and the grid 13 becomes more negative, gradually as the condenser 16 is discharged, and becomes charged with a negative voltage on the grid side. When the grid voltage and, consequently the current through the relay coil 3 has dropped to a certain value, the armature 13' recedes, and closes again a contact with the contact 28 causing the condenser 16 to be charged again with a positive voltage on the grid side. By the chargings and dischargings of the condenser 16 produced in this manner, a rhythmically pulsating current is produced in the anode circuit of the valve 1, and corresponding voltages will occur on the potentiometers 8 and 11. The form of these voltages may be varied by varying the magnitude of one or more of the coupling elements in the circuits having connection to the grid 13. When these values have been fixed, the time required by the voltage for rising and for dropping may be varied, independently of each other, by means of the sliding contacts 23 and 27. If for instance the sliding contact 23 is approached to the positive end of the potentiometer 22, the voltage difference between the cathode 7 and the sliding contact 23 will increase. The condenser 15 will consequently be charged more quickly, and the anode current of the valve will increase more quickly.

By the arrangement described heretofore the current through the potentiometers 8 and 11 does not vary down to the minimum limit zero. In order to attain this result, there is provided, between the anode 2 and the negative terminal 6 of the source of voltage, a variable resistance 30 serving to shunt the series connection of the valve 1 and the potentiometers 8 and 11 inserted in parallel. The resistance 30 is adjusted in such a manner that the current through the valve 1 and the potentiometers 8 and 11 will approach zero as closely as desired, when the current in the relay coil 3 has dropped to its minimum value at which the relay armature 13' recedes. The varying current through the relay coil 3 will not be altered in consequence hereof.

Every point of the potentiometer 22 has a voltage that is higher than the voltage required in order that the current passing through the relay coil 3 may be sufficiently intense to cause the coil to attract the armature 13', and every point of the potentiometer 26 has a voltage that is lower that the voltage required in order that the current through the relay coil 3 may be so small that the armature 13' recedes.

The portion of the apparatus in which the impulses controlled by the rhythmically pulsating current are produced, and in which the mutual time interval of the impulses is adjusted, contains a pentode valve 31 the controlling grid 32 of which is connected, by way of a filter chain consisting of two resistances 33 and 34 and a condenser 35, to the sliding contact 12 on the potentiometer 11. The valve 31 has further an anode 36, an intercepting grid 37, a shielding grid 38 and a cathode 39. The intercepting grid 37 is connected to the cathode 39. The shielding grid 38 receives a positive voltage by way of a sliding contact 40 on a potentiometer 41 inserted between the terminals 5 and 6 of the source of voltage. A condenser 42 is provided between the shielding grid 38 and the negative terminal 6. By way of a glim lamp 43, the anode 36 is connected to the positive terminal 5 and, by way of a condenser 44, to the negative terminal 6. The cathode 39 is connected to a sliding contact 45 on a potentiometer 46 which is inserted in a resistance chain containing further the resistances 47 and 48, and being connected by way of the terminals 5 and 6 of the source of voltage. The cathode 39 is

coupled to the negative terminal 6 by means of a condenser 49.

The valve 31 acts as a variable resistance disposed as a shunt across the condenser 44. When the condenser is charged by way of the glim lamp 43, the latter is extinguished, and the condenser 44 is discharged by way of the valve 31, until the voltage over the condenser has become so low that the glim lamp 43 is ignited again, and charges the condenser 44, etc. An impulse is produced at each charging and subsequent discharging of the condenser 44.

The voltage impulses occurring by way of the condenser 44 have a duration that is mainly equal to the time interval between the individual impulses. The voltage rises quickly and in a rectilinear manner to a certain value, and drops then relatively slowly to a certain lower value, after which it rises quickly again, etc. The voltage curve for the condenser 44 assumes consequently a toothed appearance, each tooth corresponding to one single impulse. The shape of the impulses, however, is changed during their further passage through the apparatus, as further described in the following.

The time interval between the impulses may be modified by altering the resistance in the valve 31. This resistance is depending on the voltage of the grid 32 in comparison with the cathode 39. If the grid voltage rises, the resistance in the valve 31 is reduced and, consequently, the time interval between the impulses becomes shorter. The grid voltage and, consequently, the time interval between the impulses are controlled by the voltage of the sliding contact 12 relatively to the cathode 39, and this voltage is determined partly by the rhythmically pulsating current passing through the potentiometer 11 and partly by the dorp of voltage across the resistance that is inserted between the sliding contact 45 and the negative terminal 6 of the source of voltage. This drop of voltage may be regulated by means of the sliding contact 45, the position of which determines the maximum time interval between the impulses. By means of the sliding contact 12, the range of variations for the time interval is adjusted. Gradually as the sliding contact 12 is approached to the negative end of the potentiometer 11, the range of variations for the time interval becomes smaller and smaller, and finally a constant time interval between the impulses is reached which is determined by the position of the sliding contact 45.

When the maximum time interval for the impulses is altered, the minimum time interval will be altered at the same time, provided that the range of variations remains the same. In order to be able to alter the maximum time interval, without altering the minimum time interval, the range of variations for the time interval must be altered correspondingly. This may be done for instance by inserting, between the sliding contact 12 and the negative terminal of the source of voltage, a variable resistance which is dimensioned in such a manner, and the controlling shaft of which is coupled mechanically to the controlling shaft of the potentiometer 46 in such a manner that a change in the maximum time interval will not influence the minimum time interval, but will solely influence the range of variations. Such a variable resistance is not shown on the drawing.

The maximum time interval is further dependent on the position of the sliding contact 48 on the potentiometer 41, in such a manner that by approaching this contact to the positive end of the potentiometer the time interval between the impulses may be reduced, independently of the grid bias for the valve 31.

The voltage variations produced on the condenser 44 are directed, by way of a coupling condenser 50, to the last part of the apparatus in which the amplitude of the impulses is controlled. This part contains an amplifier valve 51 in the shape of a pentode with a cathode 52, a controlling grid 53, a shielding grid 54, an intercepting grid 55 and an anode 56. The impulses are directed from the coupling condenser 50 to the controlling grid 53. The anode 56 receives a positive voltage by way of a choking coil 57. The intercepting grid 55 is connected to the cathode 52. The shielding grid 54 receives positive voltage by way of a resistance 58, and is coupled to the negative terminal 6 of the source of voltage, by means of a condenser 59. The cathode 52 is connected to the negative terminal 6 by way of a variable resistance 60 which is shunted with a condenser.

The voltage taken from the potentiometer 8 by means of the sliding contact 9 is directed to the grid 53 by way of a filter chain consisting of two resistances 62 and 63 and a condenser 64, in such a manner that the constant grid bias determined by the magnitude of the variable resistance 69 is superimposed with the voltage determined by the rhythmically pulsating current passing through the potentiometer, by way of the lower part of the potentiometer 8 determined by the position of the sliding contact 9. The amplification produced in the valve 51 is varied in time with the rhythmically pulsating current. The amplified impulses are delivered from a terminal 65 which is connected to the anode 56 by way of a condenser 66, and a terminal 67 which is connected to the negative terminal 6 of the source of voltage. The range of amplification variations for the impulses may be adjusted by means of the sliding contact 8 on the potentiometer 8, and is varied from zero and upward, while the minimum amplitude may be adjusted by means of the variable resistance 60.

The magnitude of the impulses directed on to the grid 53 may be limited by means of a variable resistance 68, one end of which is connected to the grid 53, and the other end of which is connected to the negative terminal 6, by way of a condenser 69. When the resistance 68 is reduced, the impulses will be reduced.

As mentioned above, the shape of each individual impulses is altered during the passage through the apparatus. The curve of voltage for the voltages occurring on the condenser 44 has a toothed appearance, each tooth corresponding to one single impulse. When the impulses have passed the condenser 50, which for instance may be about 100 cm, their voltage curve has about the shape of a triangle with a relatively short base, and the duration of the impulses is consequently smaller than the time interval between two successive impulses. In consequence of the impedances contained in the outlet circuit of the valve 51, the impulses become dipolar, and assume the shape shown in Fig. 3.

In the construction shown of the apparatus, the time interval and amplitude of the impulses vary in such a manner that the maximum amplitude occurs simultaneously with the minimum time interval, and the minimum amplitude occurs simultaneously with the maximum time interval. Fig. 2 shows such a series of impulses 70, the

voltage on the outlet terminals of the apparatus being plotted as a function of the time. The finely drawn lines 71 and 72 through the voltage maxima and minima, respectively, of the individual impulses do not indicate the voltages occurring at the outlet terminals of the apparatus, but are merely enveloping curves for the series of impulses, and they illustrate the rhythmically pulsating variation of the impulse amplitude. The portion of the enveloping curves for which the impulse amplitude is increasing and decreasing are called, respectively, the wave rise and the wave drop. By the selection of various amplifier valves, and by a suitable selection of the coupling elements contained in the inlet circuit of the valve 1, and by the introduction of capacities, resistances and self inductions in the grid circuit for the valve 51, the shape of the wave rise and the wave drop may be adjusted as desired. Analogously, the modification of the time interval between successive impulses at various points of the enveloping curves may be adjusted as desired. The difference in height between the maxima and minima of the enveloping curves indicates the range of amplitude variation, and the minima of the enveloping curves indicate the minimum amplitude. The corresponding time interval between the impulses is the maximum time interval which may be adjusted to any desired value by means of the sliding contact 40, and may be altered inside of any desired range by means of the sliding contact 45. The minimum time interval occurs in the maxima of the enveloping curves, and the difference between the latter and the maximum time interval is the variation range which may be modified by the sliding contact 12, and has the lower limit zero, independently of the maximum time interval.

The time passing between two wave summits of the enveloping curve may be varied by means of the sliding contacts 23 and 27. A change in this range of variations may be effected by altering the magnitudes of the coupling elements entering in the grid circuit for the valve 1, or by the addition of further coupling elements. The charging of the condenser 16 may also be effected by means of one valve more instead of the battery shown, or by means of a mechanically driven sliding contact which alters the voltage of the grid 13.

Instead of the triode valve 1, there may be used a valve with more grids, any one of which may be used as a controlling grid. A combination grid may also be used having such a number of electrodes that both the production of the rhythmically pulsation current and the amplitude variation or the variation of the time interval between the individual impulses may be effected in the same valve.

The coupling between the valves 31 and 51 may be altered in such a manner that the impulses are directed from both sides of the glim lamp 43 to cathode 52 and the grid 53, respectively, by means of suitable coupling elements.

The bulb 43 may be a glim lamp or other known discharging valve, the ignition voltage of which is higher than the extinguishing voltage, for instance a so-called gas triode. In order to gain stability, the condenser 44 is coupled to the negative terminal 6 of the source of voltage, but it may also be disposed in parallel to the discharging bulb 43. When a glim lamp is used, the individual impulses occur with the shape shown in Fig. 3, at the outlet terminals of the apparatus. The Figure shows the voltage variation for two successive impulses 73 and 74. The oscillations are dipolar, and the two halves of each impulse variation may be rendered more or less symmetrical by the insertion of impedances in the circuits in which the glim lamp is inserted. The duration and the time interval of the impulses are marked *t* and T, respectively.

The amplifier valve 51 and its coupling may be varied, the impulses, however, being constantly delivered to one of the grids of amplifier valve. The ratios between the shown combinations of fixed resistances and potentiometers should preferably be selected in such a manner that the desired variation will be attained by a full rotation of the controlling shafts of the potentiometers.

The time interval T between the impulses varies mainly between 10 seconds and $\frac{1}{150}$ of a second. The amplitude varies between zero and about 20 volts.

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