Nov. 20, 1956 K. GRATZL 2,771,554

IMPULSE GENERATOR FOR MEDICAL USE

Filed April 11, 1950 3 Sheets-Sheet 1

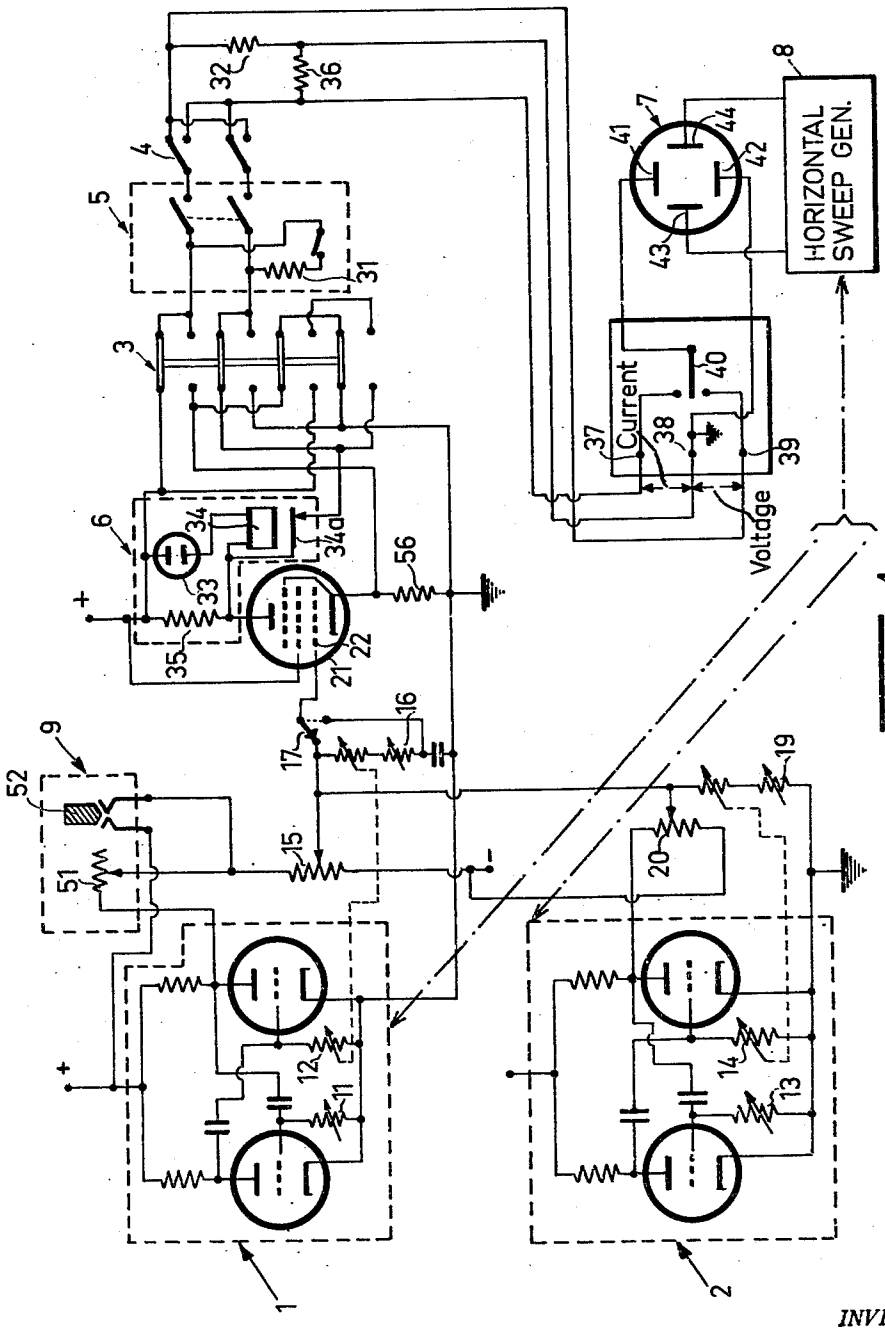


FIG. 1

INVENTOR:
KURT GRATZL

BY C. P. Goepel
his ATTORNEY

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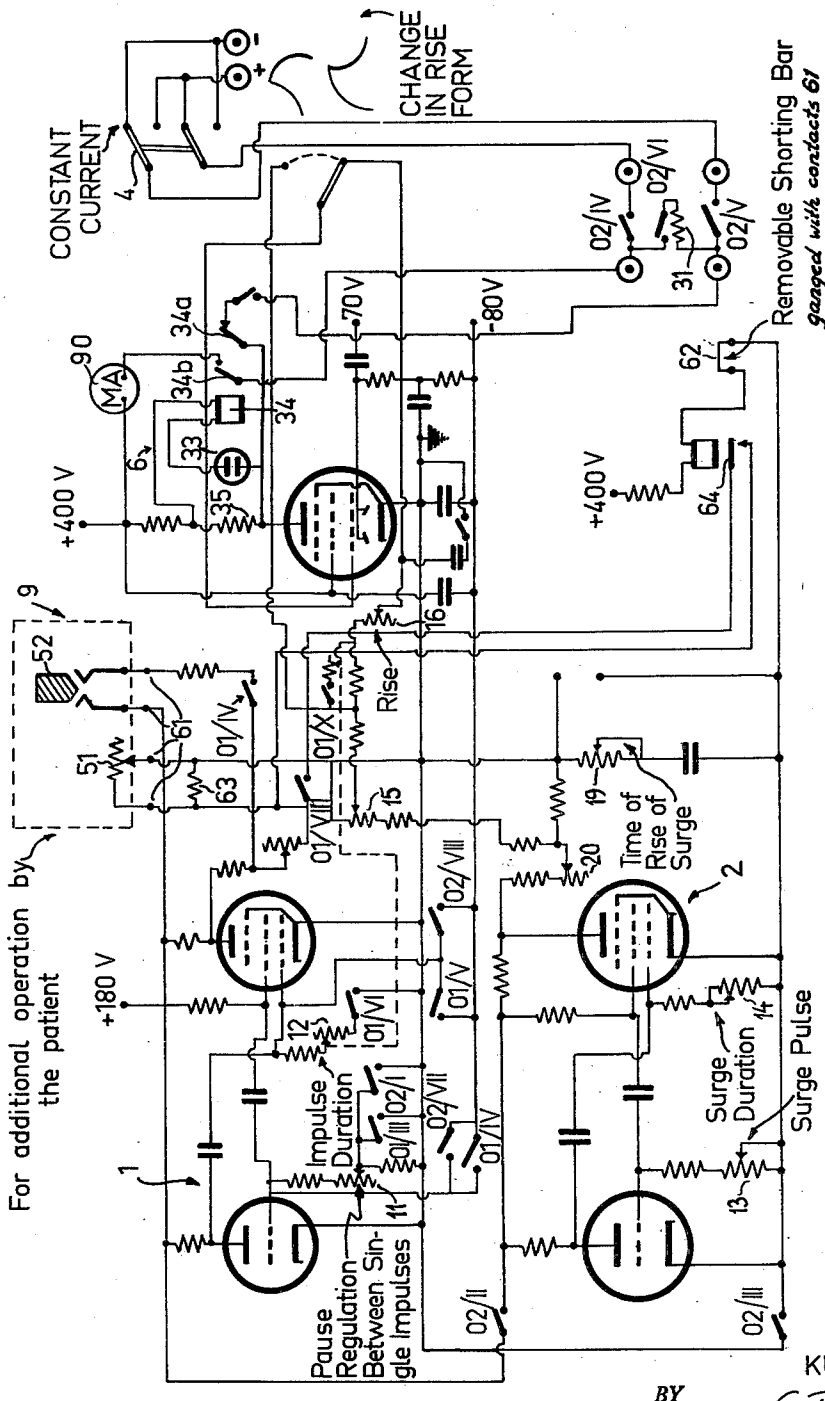


FIG. 2

INVENTOR:
KURT GRATZL
BY
C. P. Goepel
his ATTORNEY

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FIG. 5

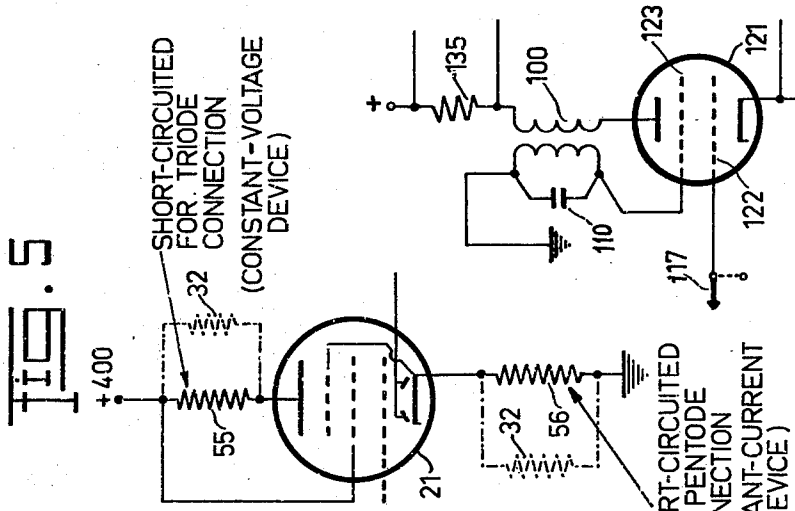


FIG. 6

FIG. 3

MAIN SWITCH 01
(12-POSITION 5-SECTION SWITCH)
SCHEME OF CONNECTIONS

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
G				X			X	X				
T				X		X			X			X
E_1		X	X		X	X		X		X		
E_2	X					X				X	X	
E_3						X				X		

FIG. 4

MAIN SWITCH 02
(8-POSITION 4-SECTION SWITCH)
SCHEME OF CONNECTIONS)

	I	II	III	IV	V	VI	VII	VIII
THERAPY CONSTANT	X			X	X			
THERAPY SURGE	X	X	X	X				
DIAGNOSIS IMPULSE				X	X			
DIAGNOSIS MEASURE	X					X	X	X

INVENTOR:
KURT GRATZL

BY
C. P. Goepel
his ATTORNEY

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IMPULSE GENERATOR FOR MEDICAL USE

Kurt Gratzl, Vienna, Austria

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18 Claims. (Cl. 250—27)

The problem to be solved by this invention consists in the selective testing, stimulation, and curative treatment, by means of electric impulses, of individual nerves, or portions of tissues or muscles, with regard to certain physiological properties. The main difficulty encountered is the fact that frequently such nerves, or portions of tissues or muscles, are located close to other nerves, or portions of tissues of muscles, of very similar reaction. For this reason it is impossible in most cases to exercise a morphologically, that is, locally, directed influence. The vagus nerve, e. g., carries in a slender trunk a multitude of nerves which supply several internal organs. As has been stated, the problem is to selectively influence by means of electric impulses a nerve portion associated with a particular function, e. g., that portion which retards the action of the heart.

This problem has been solved in the invented electronic impulse generating device for medical use in that the impulse characteristics, viz., magnitude of momentary values and duration (in respect of the excitability), time of rise and form of rise curve (in respect of the power of accommodation), and recurrence time, that is, duration of intervals between the impulses (in respect of the refractory period and iterativity) can be adjusted continuously and within wide limits for a functionally directed simulation for purposes of diagnosis and therapy.

The accompanying drawings show an embodiment of the invention by way of example.

Fig. 1 is a simplified wiring diagram of the invented device;

Fig. 2 a more detailed wiring diagram;

Fig. 3 a diagrammatic representation illustrating the connections established by the main switch O1;

Fig. 4 a diagrammatic representation illustrating the connections established by the main switch O2;

Fig. 5 a representation of a detail of connections; and

Fig. 6 diagrammatically illustrates a modification of certain circuit elements of the device illustrated in Figs. 1 and 2.

From the principal diagram of connections, shown in Fig. 1, it is seen that the most essential components of the device are an impulse generator 1 for the generation of individual impulses, a surge generator 2 for the automatic generation of surges, a change-over switch 3 enabling the device to be used either as a constant-current device or as a constant-voltage device, a double-pole, double-throw reversing switch 4 for reversal of voltages applied to the patient, a device 5 to which may be connected means for measuring the peak value of short impulses, a patient cut-out device 6, an oscilloscope 7 for the simultaneous visible indication of the voltages applied to the patient and of the currents flowing through him, with a suitable sweep oscillator 8, and a supplementary device 9 for the manual generation of swells or surges and of individual impulses. Both generators 1 and 2 may consist of multivibrators of conventional design having compound tubes.

As regards the elements for controlling the impulses and swell or surge characteristics, the intervals between the impulses are set by means of a variable resistance 11 in the grid circuit of one of the tubes of the multivibrator 1, and the duration of the impulses by means of a variable resistor 12 in the grid circuit of the other tube in the impulse generator 1. For the swell or surge generator 2, the intervals are controlled by means of a variable resistor 13 in the grid circuit of one of the tubes of the multivibrator 2, and the duration of the swells or surges by means of a variable resistor 14 in the grid circuit of the other tube of said multivibrator.

The amplitude of the impulses is controlled by the potentiometer 15 connected as an output gain control, as shown, and the rise by the variable dampening resistor 16 connected across the output circuit of the multivibrator 1. By reversing the switch 17 the impulse to be delivered can be given either a convex or a concave rise curve. The rise of swells or surges is controlled by a variable dampening resistor 19 in the output circuit of multivibrator 2, and their amplitude by the potentiometer 20, connected as a gain control in said output circuit.

The output stage of the device comprises a pentode 21 connected as an output amplifier tube which is fed by the multivibrators 1 and 2 through the wave-form controlling switch 17. The operating point of this output tube, the control grid 22 of which is supplied with trains of individual impulses, is displaced, when the trains of impulses are increased in ampltude, by the slower surges of the surge generator 2, corresponding to the desired resultant amplitude.

The terminal device 5 for measuring the peak values of short impulses has a phantom resistance 31 which is connected at times in place of the patient, designated by the load 32, the device being then switched over to deliver direct current which flows through the phantom resistance and is determined only by the setting of the amplitude rheostat 15. This current can be measured by a suitable instrument, such as the milliammeter 90 in Fig. 2. This current is equal to the peak value to be measured.

The patient cut-out 6 with the diode 33 and the relay contact 34 is provided in order to prevent sudden changes in impulse characteristics to values which might be dangerous to the patient. The contact 34*a* is normally closed. When there is a sudden voltage rise there will be a discharge in the diode 33. The relay 34 is energized and opens the contact 34*a* so that the loop through switch 3 is broken and only the limiting resistance 35 is now connected in the anode circuit of the output tube 21. Owing to the mode of operation of switch devices of this type there will be a delay in the discharge in the diode (at an apparently higher voltage) when the voltage rises slowly so that the cut-off takes place later in the case of slowly rising waves. This characteristic is fully in accordance with the phsiological conditions. If such patient cut-outs are provided in both leads, as shown at 34*a*, 34*b* in Fig. 2, the need for a mains or net transformer is eliminated and the device can be operated with any type of current.

It is of the utmost significance for the physician (as well as for the patient) to have before his eyes always an image of the current and voltage impulses delivered to the patient. For this purpose the oscilloscope 7 is connected with its input terminals for voltage indication parallel to the patient resistance 32, and for current indication parallel to a purely ohmic resistance 36 connected in series with the patient resistance 32, as shown. For this last indication a pre-amplification may be employed, which is not shown. The current indication takes place across the terminals 37 and 38, the voltage

indication across the terminals **38** and **39**. From the single-pole, double-throw switch **40**, whose pole is connected to one of the vertical deflection plates of oscilloscope **7** and whose contacts are connected respectively to terminals **37** and **39**, which is provided for two-ray registration, the impulses to be registered travel to the vertical deflection plates **41**, **42** of the oscilloscope **7**. The horizontal deflection plates **43**, **44** control the velocity of the recording ray by means of the sweep oscillator **8**, which is synchronized for the visible indication of individual impulses by the impulse generator **1**, and for the visible indication of surge periods by the surge generator **2**.

The supplementary device **9** is used for intentional curative gymnastics carried out by the patient himself. For this purpose the operating point of the output tube **21** is displaced by a manually operable rheostat **51** for increasing the amplitude of tetanizing trains of impulses where cramps are present. For the delivery of individual impulses the key **52** is depressed so that a positive voltage is supplied to the grid **22** of the output tube **21**, which grid is normally blocked by a high negative bias. This positive voltage is sufficient to cause a direct-current impulse to be delivered at the output terminals of the device. The magnitude of this impulse depends only on the setting of the amplitude rheostat **15**, that is, on the setting of the operating point and on the setting of the rise by the known resistance-capacitance circuits indicated, so that it is possible to deliver an individual impulse with controlled rise.

Fig. 2 shows the diagram of connections of the invented device with more details, with the several individual switches which are co-ordinated with the multiple-position, multiple-contact main switches O1 and O2. Fig. 3 shows that the main switch O1 may be of a conventional type which comprises twelve segments and five positions. Position G signifies that constant direct current is deliverable, position T that the key of the supplementary device is operable. In positions E1, E2 and E3, the impulses and intervals can be controlled within the limits which will be stated later in this specification. Fig. 4 shows that the main switch O2 may be of a conventional type having eight segments and four positions. In the position "Therapy Const." all operations according to the main switch O1 may be performed. In the position "Therapy Surge" automatic surging is possible when the main switch O1 is in position E2 or E3. In all other respects the functions of the positions G, T, and E1 of the main switch O1 remain the same as for "Therapy Const." In the position "Diagnosis Impulse" the device can be used, as has been stated hereinbefore, for positions G, T, and E1, E2 and E3 have the same impulses as stated at the main switch O1 but their intervals are prolonged to 750 milliseconds and 500 milliseconds, respectively. In the position "Diagnosis Measurement" the peak value of individual impulses can be measured by means of the direct current flowing through the phantom resistance **31**, the patient resistance **32** being disconnected.

In the more detailed diagram of connections, according to Fig. 2, the several contacts are designated accordingly, O1/III, e. g., referring to main switch O1, segment III (this becomes operative in position E1 as is seen from the cross in the respective square in Fig. 3). In the diagram of connections shown in Fig. 2, the contacts for range change-over for the setting of the duration of and the intervals between the impulses (contacts of the capacitor sets not shown in the drawings) have been omitted; also omitted is the switch **3**, the device being shown connected for constant-current operation.

By these control ranges and the corresponding components (known resistance elements and resistance-capacitance combinations) the individual impulses can be controlled continuously, in respect of magnitude of momentary values between 0 and 90 milliamperes, in

respect of duration between 25 to 500 milliseconds, between 1 and 20 milliseconds, and between 0.05 and 1 millisecond, in respect of time of rise between 0 and 50% of the duration of each impulse, in respect of form of rise curve either for linear or exponential (convex or concave) curves, in respect of intervals between 50 and 1000 milliseconds, between 1 and 20 milliseconds, and between 0.1 and 2 milliseconds, and for purposes of diagnosis, if desired to 750 milliseconds or 500 milliseconds. Moreover, the supplementary device enables the continuous control of individual impulses of 0.05 to 20 milliseconds duration and with intervals between 0.1 and 20 milliseconds, which impulses can be increased in amplitude by hand, and the manual key S2 enables the continuous control of individual impulses of a duration of 500 milliseconds, having a time of rise between 0 and 500 milliseconds, and also of direct current between 0 and 90 milliamperes. The surges can be controlled continuously in respect of duration and interval from 1 second to 6 seconds, and in respect of time of rise between 0 and 3 seconds.

The continuous control is effected, e. g., by the use of carbon rheostats, that is, of rheostats not consisting of a wire coil so that a discontinuous resistance step from one convolution to the next, which would be unavoidable otherwise, is avoided. Carbon rheostats are suitable here because all controls, including the amplitude control, are effected without current changes (pure voltage controls).

Brief mention may be made of the change-over switch **3**, shown in Fig. 1, for changing-over the device from constant current to constant voltage. In principle the mode of operation of this switch is shown in detail in Fig. 5. In one position of the switch (constant-current device) a resistance **55**, which represents the resistance of network **6** and is very large as compared with the average patient resistance schematically indicated at **32**, is connected in the anode circuit of the output tube **21**; the tube is connected as a pentode and the cathode directly connected to earth. In the other position of the switch (constant-voltage device) a resistance **56**, which is very small relative to the patient resistance, is connected in the cathode circuit, the tube being used as a triode and the anode being directly connected to the operating voltage. Constant-current instrumens have the advantage of permitting of absolutely accurate measurements (which is of importance for exact diagnosis) independently of the ohmic and complex resistances of the patient because in this case the total resistances of the patient is much smaller than the internal resistance of the instrument. The disadvantage of the constant-current devices in therapy consists in that according to the wiring connection indicated, high voltages are applied to the object to be treated and will unavoidably cause a very painful breakdown of the double layers of the skin. For this reason constant-voltage devices are used in therapy.

The use of the supplementary device **9** has been described hereinbefore. When the box **9** is removed after use, the contacts **62** (Fig. 2) are opened together with the contacts **61**, being arranged at the same plug. Otherwise the resistance **63** would become effective after the removal of the box **9** and would, by a displacement of the operating point, lead to a strongly reduced amplitude. To prevent this the contact **62** is opened too so that the relay contact **64** is closed to ensure a normal amplitude height. (This is of importance only in positions E2 and E3, when tetanising trains of impulses are produced).

The invented device is not restricted to the embodiment described with reference to Figs. 1 and 2. Thus, as shown in Fig. 6 a high-frequency generator **121** may be provided instead of the output tube **21**. In this case the impulses are supplied to the modulation grid **122** of the high-frequency generator. In this way a carrier wave modulated according to the impulses is obtained

so that pulses may be transmitted without pain through the capacitive double layers of the skin and after self-rectification at the polarized diaphragms to be excited, consisting of the nerves, or portions of tissues or muscles, produce impulses with characteristics which would cause a strong sensation of pain or would otherwise be dangerous to the patient if they were to be supplied to said nerves, or portions of tissues or muscles, by purely galvanic coupling.

The oscillator of Fig. 6 is of a conventional type in which energy from the plate circuit of tube **121** is fed back to a grid **123** of the tube by means of a transformer **100**. The frequency of oscillation is determined, in the known manner, by a resonant circuit here shown to comprise a condenser **110** in parallel with the secondary of transformer **100**. Switch **117**, plate resistor **135** and cathode resistor **156** correspond to elements **17**, **35** and **56** of Fig. 1 and are connected in identical manner to the associated impulse and load circuits.

The device may be used for the most varied purposes in diagnosis and therapy. In diagnosis the device may be used for the measurement of the rheobase threshold intensity and of the galvano-tetanus threshold intensity, of the chronaxie, and for the plotting of continuous I–T curves. I–T curves represent the dependence of the current (or voltage) intensity on the duration of the time of current flow. They are of interest in diagnosis, particularly in prognosis, such as in the evaluation of nerve lesions and nerve diseases.

In therapy, the patient can with the aid of the supplementary device perform electro-gymnastics. It is of the utmost importance that in all cases discussed the invented device enables the determination and adjustment of those impulses and impulse trains which by their functionally selective effect ensure optimum results whereas the sensible molestation of the patient is minimized.

What I claim is:

1. In a therapeutic apparatus for the generation if electrical impulses, in combination, an input stage comprising a source of impulses, an output stage comprising an electronic device having a cathode, a grid and a plate, circuit means for applying said impulses to said grid, control means for varying the amplitude of said impulses, a load circuit having a pair of terminals for transmitting impulses from said output stage to the body of a patient, said load circuit including a first and a second resistance connected, respectively, to said cathode and to said plate, and switch-over means inserted between said load circuit and said electronic device for selectively connecting the latter across said load circuit as a constant-current device or as a constant-voltage device, said switch-over means having a first position short-circuiting said first resistance while connecting said terminals across said second resistance and a second position short-circuiting said second resistance while connecting said terminals across said first resistance, said first resistance being small and said second resistance being large compared to the body resistance of the patient.

2. The combination according to claim 1, further including an ocilloscope, a first input circuit to said oscilloscope connectable to said load circuit in series with said terminal and the patient, a second input circuit to said oscilloscope connectable to said load circuit across said terminals and in parallel with the patient, and switch means for selectively rendering either of said input circuits effective for the registration of current and voltage impulses, respectively, on said oscilloscope.

3. The combination according to claim 1, further including a phantom resistance connectable in said load circuit across said terminals in place of the patient, and means for measuring the magnitude of current flowing through said phantom resistance.

4. The combination according to claim 1, further including a protective device sensitive to sudden voltage increases and circuit breaker means in said load circuit controlled by said protective device, said protective device being effectively connected across said load circuit in the constant-current condition of said electronic device for preventing voltage impulses of dangerous amplitudes from reaching the body of the patient.

5. The combination according to claim 4, wherein said load circuit comprises a pair of leads constituting ohmic connections between said electronic device and the body of the patient, said circuit breaker means being provided with a pair of contacts, one in each of said leads, for completely insulating the patient from said electronic device upon operation of said protective device.

6. The combination according to claim 1, wherein said control means includes biasing means for said electronic device, manually operable means for modifying the bias of said electronic device, a detachable connection between said manually operable means and said circuit means, and means responsive to a severance of said connection for automatically restoring said bias to a predetermined value.

7. The combination according to claim 1, wherein said electronic device is a high-frequency oscillator having means for modulating its output by said impulses.

8. The combination according to claim 1, further including an oscilloscope connectable to said load circuit for visually indicating said impulses, said input stage additionally comprising a surge generator adapted to superimpose its output upon that of said source of impulses, said oscilloscope having sweep means selectively synchronizable with said source of impulses and with said surge generator.

9. In a therapeutic apparatus for the generation of electrical impulses, in combination, an input stage comprising a source of impulses, an output stage comprising an electronic device, circuit means for applying said impulses to said electronic device, control means for varying the amplitude of said impulses, a load circuit having means for transmitting impulses from said output stage to the body of a patient, said load circuit comprising a pair of conductors, said electronic device being provided with a pair of output circuits, one of said output circuits including an output resistance which is relatively high compared with the average patient resistance as seen from said load circuit, the other of said output circuits including an output resistance which is relatively low compared with said average patient resistance, and switch-over means for selectively connecting said conductors across either of said output resistances, thereby adapting said electronic device for operation as a constant-current device or as a constant-voltage device.

10. The combination according to claim 9, wherein said electronic device is a vacuum tube having a cathode and a plate, said relatively high output resistance being connected to said plate, said relatively low output resistance being connected to said cathode.

11. The combination according to claim 10, wherein said switch-over means includes means for short-circuiting one of said output resistances upon connecting said conductors across the other output resistance, and vice versa.

12. The combination according to claim 9, further including a protective device for preventing voltage impulses of dangerous amplitudes from reaching the body of the patient, said protective device including diode means and relay means connected in series across said relatively high output resistance, said diode means being adapted to become conductive in response to voltages exceeding a limit of safety, said relay means having contacts adapted to open said load circuit in response to current flowing through said diode means.

13. The combination according to claim 12, wherein said contacts are inserted in both of said conductors, thereby completely insulating the patient from said relatively high output resistance upon operation of said relay means.

14. In a therapeutic apparatus for the generation of electrical impulses, in combination, an input stage comprising a source of impulses, an output stage comprising an electronic device, circuit means for applying said impulses to said electronic device, a load circuit having means for transmitting impulses from said output stage to the body of a patient, said electronic device being provided with an output resistance which is high compared with the average patient resistance as seen from said load circuit, said load comprising a pair of conductors connected across said output resistance, manually operable control means for varying the amplitude, steepness and duration of said impulses, and protective means for preventing sudden voltage increments exceeding a safe amplitude limit from reaching the body of the patient, said protective means comprising normally nonconductive diode means connected across said output resistance, relay means in series with said diode means and contacts controlled by said relay means for interrupting said load circuit in response to current flow through said diode means.

15. The combination according to claim 14, wherein said contacts are inserted in both of said conductors, thereby completely insulating the patient from said output resistance upon operation of said relay means.

16. In a therapeutic apparatus for the generation of electrical impulses, in combination, an input stage comprising a source of impulse, an output stage comprising an electronic device, circuit means for applying said impulses to said electronic device, control means for varying the amplitude of said impulses, a load circuit having means for transmitting impulses from said output stage to the body of a patient, means for connecting said electronic device across said load circuit substantially as a constant-current device, a protective device sensitive to sudden voltage increases, and circuit breaker means in said load circuit controlled by said protective device, said protective device being effectively connected across said load circuit for preventing voltage impulses of dangerous amplitudes from reaching the body of the patient.

17. In a therapeutic apparatus for the generation of electrical impulses, in combination, an input stage comprising a source of impulses, an output stage comprising an electronic device, circuit means for applying said impulses to said electronic device, control means for varying the amplitude of said impulses, said load circuit including a resistance connected to be energized by said device, a pair of terminals and a pair of leads conductively connecting said terminals across said resistance, said terminals being adapted to transmit impulses from said output stage to the body of a patient, said resistance being small compared to the body resistance of the patient whereby said electronic device functions substantially as a constant-current device, circuit breaker means provided with a pair of normally closed contacts in at least one of said leads, and a protective device effectively connected across said load circuit, said circuit breaker means being controlled by said protective device for preventing voltage impulses of dangerous amplitudes from reaching the body of the patient.

18. In a therapeutic apparatus for the generation of electrical impulses, in combination, an input stage comprising a source of impulses, an output stage comprising an electronic device, circuit means for applying said impulses to said electronic device, control means for varying the amplitude of said impulses, said control means including biasing means for said electronic device, manually operable means for modifying the bias of said electronic device, a detachable connection between said manually operable means and said circuit means, means responsive to a severance of said connection for automatically restoring said bias to a predetermined value, and a load circuit having means for transmitting impulses from said output stage to the body of a patient.

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