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(54) A REMEDIAL SYSTEM FOR ELECTRICALLY STIMULATING MUSCLES OF THE HUMAN BODY

(71) We, MARUBISHI SANGYO CO. LTD., a Japanese Corporation, of No. 2-396 Minami Eguchicho, Higashiyodogawa-ku Osaka, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a low-frequency remedial system for generating electric signals for stimulating muscles of the human body.

It is known that electric signals, when given to the muscle of the human body, act to contract the muscle. The application of electric signals is useful for various remedial purposes for example in reducing or eliminating the stiffness and looseness of muscles. The mode of the contraction of muscles produced by a stimulating signal and the resulting therapeutic effect delicately vary with the wave form and level of the signal, so that it is desired to provide a remedial system which is adapted for the selection or adjustment of the wave form and level of the stimulating signal as required.

According to the present invention there is provided a remedial system for electrically stimulating muscles of the human body, said system having a power supply circuit, a stimulating signal generating circuit, an output circuit, a circuit for temporarily interrupting operation and an output current regulating circuit, the stimulating signal generating circuit comprising an oscillation circuit for generating a periodically changing signal, and an oscillation control circuit for periodically interrupting the output signal of the oscillation circuit and associated with a change-over switch for selecting either a continuously repetitive stimulating signal generated from the oscillation circuit or a stimulating signal periodically interrupted by the oscillation control circuit, the output circuit including an output transformer and an amplifying element connected in series with the primary winding of the output transformer, the amplifying element being controllable by the output of the stimulating generating circuit, the operation interrupting circuit including a switching circuit provided between the power supply circuit and the output circuit, the switching circuit being operatively connected with the change-over switch and becoming non-conductive when the change-over switch is changed over, the output current regulating circuit including a slide rheostat for varying the output current of the output circuit, wherein the switching circuit is operatively connected with a contact member of the slide rheostat of the output current regulating circuit and is not brought into a conductive state unless the contact member is once returned to its limit position to reduce the output current of the output circuit to zero.

An embodiment of the present invention will now be described by way of example only with reference to the accompanying drawings, in which:—

Fig. 1 is an electric circuit diagram illustrating an embodiment of this invention; and

Figs. 2 (A) and (B) are diagrams each showing the wave form of an output signal of a stimulating signal generating circuit.

Fig. 1 shows a low-frequency remedial system consisting mainly of a power supply circuit 1, an output circuit 2 and a stimulating signal generating circuit 3.

The power supply circuit 1 includes input terminals 11 of a commercial a.c. power supply, a main switch 12 connected to the terminals 11, an input voltage step-down transformer 13 and a rectifier circuit. The rectifier circuit, connected to the secondary winding of the transformer 13, comprises diodes 14 and a smoothing capacitor 15. A series circuit including a power supply indicating pilot lamp 16 and a current limiting resistor 17 is connected to the primary winding of the transformer 13. A fuse 18 is connected between the primary winding of the transformer 13 and the main switch 12.

The output circuit 2 includes an output transformer 21, a switching transistor 22 connected to the primary winding of the transformer 21 and output terminals 23. Between the collector of the transistor 22 and its emitter is provided a backlash preventing diode 24, i.e. a diode which prevents current

flow in a reverse direction when a switch changes condition. Another backlash preventing diode 25 is connected between the secondary winding of the transformer 21 and one of the terminals 23. A series circuit including an output indicating pilot lamp 26 and a current limiting resistor 27 is connected to the secondary winding of the transformer 21. The switching transistor 22 is controlled by the output signal of the stimulating signal generating circuit 3 applied to its base. The output terminals 23 are connected to electrodes 28 across which a stimulating current flows through the human body.

Current is fed from the power supply circuit 1 to the stimulating signal generating circuit 3 by way of a voltage divider circuit 6. The voltage divider circuit 6 comprises voltage divider resistors 61 and 62 connected in series therewith, and the voltage appearing at the resistor 62 is applied to the generating circuit 3. The resistor 61 limits the current flowing through the silicon controlled rectifier (hereinafter referred to as "SCR") 95 to be described later when the SCR is rendered conductive.

The stimulating signal generating circuit 3 comprises an oscillation circuit 4 for producing a train of pulses and an oscillation control circuit 5 for periodically interrupting the output signal from the oscillation circuit 4. The circuits 4 and 5 each include a relaxation oscillator circuit in which a programmable unijunction transistor (or n-gate thyristor, to be hereinafter referred to as "PUT") 41 (51) is used. The oscillation circuit 4 includes a charging circuit comprising a resistor circuit and a capacitor 42. The resistor circuit comprises a variable resistor 43 and a fixed resistor 45 connected in parallel thereto. An auxiliary resistor 44 is connected in series with the variable resistor 43. The charging circuit includes a change-over switch 46 for selecting either the variable resistor 43 or the fixed resistor 45. The anode of the PUT 41 is connected to the junction between the change-over switch 46 and the capacitor 42 of the charging circuit. Resistors 47 and 48 are connected to the gate of the PUT 41. The operation of the PUT 41 is dependent on the values of these resistors 47 and 48. Connected to the cathode of the PUT 41 is an integration circuit 31 comprising a resistor 32 and a capacitor 33. The output terminal of the integration circuit 31 is connected to the switching transistor 22 of the output circuit 2 and to the base of a transistor 49 for short-circuiting the capacitor 42. When the change-over switch 46 is in contact with either a terminal *a* or terminal *b*, current flows through the above-mentioned resistor circuit to charge the capacitor 42. When the voltage across the capacitor 42 reaches a predetermined value, the PUT 41 is broken down into a conductive state, with the result that current flows through the PUT 41 and the resistor 32, charging the capacitor 33. When the voltage across the capacitor 33 reaches a predetermined level, the transistor 49 becomes conductive, permitting the charge on the capacitor 42 to discharge through the transistor 49. The voltage across the capacitor 33 also brings the switching transistor 22 of the output circuit 2 into conduction, permitting current to flow through the primary winding of the transformer 21. As a result, a stimulating current flows through the human body by way of the output terminals 23 and electrodes 28. Since the charge on the capacitor 33 discharges through the base and emitter of the transistor 22, the transistor 49 returns to an off state, and the capacitor 42 starts to charge again. Since the current through the PUT 41 is lower than the holding current when the transistor 49 becomes conductive, the PUT 41 returns to an off state. In this way, the foregoing operation is repeated, giving a stimulating pulse current whose frequency is dependent on the charge time constant of the charging circuit.

The oscillation control circuit 5 includes a charging circuit comprising a variable resistor 52, a fixed resistor 53 and a capacitor 54. The anode of the PUT 51 is connected to the junction between the resistor 53 and the capacitor 54. The gate of the PUT 51 is connected to the junction between a resistor 56 by which the operation of the PUT 51 is governed. The cathode of the PUT 51 is connected to a discharging circuit comprising a capacitor 57 and a resistor 58. The resistor 58 is connected to the base of a transistor 59 whose collector and emitter are connected to the terminals of the capacitor 42 respectively. A change-over switch 35 for short-circuiting the capacitor 54 is connected in parallel to the capacitor 54. With the change-over switch 54 in contact with a terminal *a*, the capacitor 54 is short-circuited and will not be charged. In this case, the oscillation control circuit 5 is entirely held out of operation. When the contact of the switch 35 is brought into contact with a terminal *b*, current flows through the resistors 52 and 53, charging the capacitor 54. When the voltage on the capacitor 54 reaches a predetermined value, the PUT 51 becomes conductive, permitting current to flow through the PUT 51 to charge the capacitor 57. The charge on the capacitor 54 discharges through the conductive PUT 51, and the current flowing through the PUT 51 thereafter becomes lower than the holding current, whereupon the PUT 51 becomes non-conductive. The capacitor 54 starts to charge again. The relaxation oscillator circuit including the PUT 51 repeats the above operation with a period T which is determined by the resistance values of the resistors 52 and 53 and the capacitance of the

capacitor 54. On the other hand, when the voltage across the capacitor 57 reaches a predetermined value, the transistor 59 is brought into a conductive state, short-circuiting the capacitor 42. Since the capacitor 42 will no longer be charged, the oscillation circuit 4 is de-energized. The charge on the capacitor 57 is discharged through the resistor 58 and the base and emitter of the transistor 59. In a specified time *t*, the transistor 59 becomes non-conductive, whereupon the oscillation circuit 4 is energized again. The time *t*, during which the oscillation circuit 4 is held out of operation is determined by the discharge time constant of the capacitor 57 and resistor 58.

The change-over switch 46 is operatively related to the change-over switch 35. When the change-over switch 35 is closed at the terminal *a*, the change-over switch 46 is also closed at the terminal *a*. While the change-over switch 35 is connected to the terminal *a*, the oscillation control circuit 5 is held out of operation, permitting the stimulating signal generating circuit 3 to continuously produce a pulse signal as illustrated in Fig. 2(A). The repetition frequency of the stimulating pulse signal is variable as desired, for example, within the range of 0.5 to 100 Hz by varying the resistance value of the resistor 43. Such continuous stimulating signal gives a tapping effect to the muscle of the human body. When the change-over switch 35 is closed at the terminal *b*, the change-over switch 46 is closed also at its terminal *b*. In this case, the oscillation circuit 4 is so controlled by the oscillation control circuit 5 that it is held out of operation only for the period of time *t* within the time interval T. Accordingly, the stimulating signal generating circuit 3 intermittently repeatedly produces series of pulses with the period T. The frequency of the pulse signal is maintained by the fixed resistor 45 at a constant value, for example at 100 Hz. The period T, which can be altered by the variable resistor 52, is set usually at about 1 to 4 seconds. The intermittent stimulating signal gives a kneading effect to the muscle of the human body.

The low-frequency remedial system includes an output current regulating circuit 7 and a circuit 8 for temporarily interrupting the operation. The output current regulating circuit 7 includes a transistor 71 connected between the positive terminal of the rectifier circuit of the power supply circuit 1 and the primary winding of the output transformer 21 of the output circuit 2, and a slide rheostat 72 for varying the bias voltage on the transistor 71. The slide rheostat 72 is connected in series with a resistor 73 for protecting the transistor 71, and the series resistor circuit is connected in parallel to the power supply circuit 1. A capacitor 74 stabilizes the bias voltage. The contact member 72*a* of the slide rheostat 72, when slidingly moved, controls the base current for the transistor 71, thus regulating the current flowing through the output circuit 2 over a wide range of from zero to a predetermined maximum value.

The operation interrupting circuit 8 comprises an SCR 81 provided between the negative terminal of the rectifier circuit of the power supply circuit 1 and the emitter of the switching transistor 22 of the output circuit 2, a turn-off switch 82 connected between the anode of the SCR 81 and the emitter of the transistor 22 and a trigger circuit including a trigger switch 83. When the SCR 81 is in a conducting state, current flows through the resistors 73, 72 and the switch 82 to the SCR 81. A change-over switch is employed as turn-off switch 82. The change-over switch 82 is operatively related to the change-over switch 35. When the change-over switch 82 is changed over from terminal *a* to terminal *b* or from terminal *b* to terminal *a*, the anode of the SCR 81 is momentarily (to be effective, for at least 10 to 20 microseconds) freed from the power supply, whereupon the SCR 81 turns off. The trigger circuit comprises the switch 83, a protecting resistor 84 and a resistor 85 for reducing the sensitivity of the SCR 81 which are connected together in series. The gate of the SCR 81 is connected to the junction between the resistor 84 and the resistor 85. The switch 83 is operatively associated with the slide rheostat 72 and is closed only when the contact member 72*a* is returned to its limit position once to reduce the current through the output circuit 2 to zero and thereafter moved in the direction in which the output current increases from zero.

When the user of the low-frequency remedial system manipulates the change-over switch 35 to change a tapping stimulation to a kneading stimulation and vice versa, the SCR 81 turns off, de-energizing the output circuit 2, stimulating signal generating circuit 3 and like circuits and reducing the output current to zero regardless of the value of the stimulating output current before the change. The SCR 81 will not be brought into a conductive state, unless the slide rheostat 72 is subsequently returned to the zero point. Thus when the system is changed over for a different stimulation, the stimulating current is always gradually increased from zero and an abrupt high current will in no way be applied to the human body to ensure safety. In the event of commercial a.c. power failure, the SCR 81 turns off, producing no output current. When the system is used after the power failure has been remedied, the stimulating current is gradually increased, thus assuring safety without any possibility of giving a shock to the human body due to a high current.

The low-frequency remedial system further includes an overcurrent detecting circuit

9 and an output discontinuing circuit 10. The overcurrent detecting circuit 9 includes an output ammeter 91 connected in series with the output terminal 23 and with the secondary winding of the output transformer 21 of the output circuit 2, and a Zener diode 93 connected in parallel to the ammeter 91. The output discontinuing circuit 10 includes the SCR 95 connected between the voltage divider circuit 6 and the stimulating signal generating circuit 3 in parallel thereto. The gate of the SCR 95 is connected to the anode of the Zener diode 93 with a reverse current preventing diode 94 provided therebetween. A resistor 96 acts to reduce the sensitivity of the SCR 95. When the output current abnormally increases due to a variation in the impedance of the human body or the like, the voltage on the internal resistor 92 of the ammeter 91 exceeds the Zener voltage of the Zener diode 93, breaking down the Zener diode 93 and permitting a trigger current to flow into the gate of the SCR 95. Consequently, the SCR 95 turns on and short-circuits the input terminals of the stimulating signal generating circuit 3, whereupon the circuit 3 is de-energized. The output circuit 2 produces no output current, therefore. The operation described above eliminates the possible danger to the human body and protects the system.

Reference is made to our copending Application No. 26738/77 (Serial No. 1,587,665) entitled 'A remedial system for electrically stimulating muscles of the human body'.

WHAT WE CLAIM IS:—

1. A remedial system for electrically stimulating muscles of the human body, said system having a power supply circuit, a stimulating signal generating circuit, an output circuit, a circuit for temporarily interrupting operation and an output current regulating circuit, the stimulating signal generating circuit comprising an oscillation circuit for generating a periodically changing signal, and an oscillation control circuit for periodically interrupting the output signal of the oscillation circuit and associated with a change-over switch for selecting either a continuously repetitive stimulating signal generated from the oscillation circuit or a stimulating signal periodically interrupted by the oscillation control circuit, the output circuit including an output transformer and an amplifying element connected in series with the primary winding of the output transformer, the amplifying element being controllable by the output signal of the stimulating generating circuit, the operation interrupting circuit including a switching circuit provided between the power supply circuit and the output circuit, the switching circuit being operatively connected with the change-over switch and becoming non-conductive when the change-over switch is changed-over, the output current regulating circuit including a slide rheostat for varying the output current of the output circuit, wherein the switching circuit is operatively connected with a contact member of the slide rheostat of the output current regulating circuit and is not brought into a conductive state unless the contact member is once returned to its limit position to reduce the output current of the output circuit to zero.

2. A system as defined in claim 1, wherein the operation interrupting circuit comprises a thyristor provided between the power supply circuit and the output circuit, a turn-off switch connected to the thyristor and a trigger circuit having a trigger switch provided between the gate of the thyristor and the anode thereof, the turn-off switch being operatively connected with the change-over switch and being momentarily openable when the change-over switch is changed over to switch off the thyristor, the trigger switch being operatively connected with the contact member of the slide rheostat and being not closable unless the contact member is once returned to its limit position to reduce the output current of the output circuit to zero.

3. A system as defined in claim 1 or 2 wherein the output current regulating circuit has a transistor connected between the power supply circuit and the output circuit, the bias voltage on the transistor being variable by means of the slide rheostat.

4. A system as defined in any of the preceding Claims, wherein the oscillation control circuit includes a relaxation oscillator circuit.

5. A system as defined in any of the preceding Claims, wherein the oscillation circuit includes a relaxation oscillator circuit.

6. A system as defined in any of Claims 1 to 3, wherein the oscillation circuit includes a first relaxation oscillator circuit provided with a charging circuit having a capacitor, the oscillation control circuit including a second relaxation oscillator circuit provided with a charging circuit having a capacitor, a discharging circuit connected to the output terminal of the second relaxation oscillator circuit and a transistor controllable by the output of the discharging circuit to short-circuit the capacitor of the charging circuit of the oscillation circuit when rendered conductive, the change-over switch being connected in parallel to the capacitor of the charging circuit of the oscillation control circuit and operative to de-energize the oscillation control circuit when short-circuiting the capacitor of the charging circuit of the oscillation control circuit.

7. A system as defined in Claim 5 wherein the relaxation oscillator circuit of the oscillation circuit comprises a charging

9 and an output discontinuing circuit 10. The overcurrent detecting circuit 9 includes an output ammeter 91 connected in series with the output terminal 23 and with the secondary winding of the output transformer 21 of the output circuit 2. and a Zener diode 93 connected in parallel to the ammeter 91. The output discontinuing circuit 10 includes the SCR 95 connected between the voltage divider circuit 6 and the stimulating signal generating circuit 3 in parallel thereto. The gate of the SCR 95 is connected to the anode of the Zener diode 93 with a reverse current preventing diode 94 provided therebetween. A resistor 96 acts to reduce the sensitivity of the SCR 95. When the output current abnormally increases due to a variation in the impedance of the human body or the like, the voltage on the internal resistor 92 of the ammeter 91 exceeds the Zener voltage of the Zener diode 93, breaking down the Zener diode 93 and permitting a trigger current to flow into the gate of the SCR 95. Consequently, the SCR 95 turns on and short-circuits the input terminals of the stimulating signal generating circuit 3, whereupon the circuit 3 is de-energized. The output circuit 2 produces no output current, therefore. The operation described above eliminates the possible danger to the human body and protects the system.

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WHAT WE CLAIM IS:—

1. A remedial system for electrically stimulating muscles of the human body, said system having a power supply circuit, a stimulating signal generating circuit, an output circuit, a circuit for temporarily interrupting operation and an output current regulating circuit, the stimulating signal generating circuit comprising an oscillation circuit for generating a periodically changing signal, and an oscillation control circuit for periodically interrupting the output signal of the oscillation circuit and associated with a change-over switch for selecting either a continuously repetitive stimulating signal generated from the oscillation circuit or a stimulating signal periodically interrupted by the oscillation control circuit, the output circuit including an output transformer and an amplifying element connected in series with the primary winding of the output transformer, the amplifying element being controllable by the output signal of the stimulating generating circuit, the operation interrupting circuit including a switching circuit provided between the power supply circuit and the output circuit, the switching circuit being operatively connected with the change-over switch and becoming non-conductive when the change-over switch is changed-over, the output current regulating circuit including a slide rheostat for varying the output current of the output circuit, wherein the switching circuit is operatively connected with a contact member of the slide rheostat of the output current regulating circuit and is not brought into a conductive state unless the contact member is once returned to its limit position to reduce the output current of the output circuit to zero.

2. A system as defined in claim 1, wherein the operation interrupting circuit comprises a thyristor provided between the power supply circuit and the output circuit, a turn-off switch connected to the thyristor and a trigger circuit having a trigger switch provided between the gate of the thyristor and the anode thereof, the turn-off switch being operatively connected with the change-over switch and being momentarily openable when the change-over switch is changed over to switch off the thyristor, the trigger switch being operatively connected with the contact member of the slide rheostat and being not closable unless the contact member is once returned to its limit position to reduce the output current of the output circuit to zero.

3. A system as defined in claim 1 or 2 wherein the output current regulating circuit has a transistor connected between the power supply circuit and the output circuit, the bias voltage on the transistor being variable by means of the slide rheostat.

4. A system as defined in any of the preceding Claims, wherein the oscillation control circuit includes a relaxation oscillator circuit.

5. A system as defined in any of the preceding Claims, wherein the oscillation circuit includes a relaxation oscillator circuit.

6. A system as defined in any of Claims 1 to 3, wherein the oscillation circuit includes a first relaxation oscillator circuit provided with a charging circuit having a capacitor, the oscillation control circuit including a second relaxation oscillator circuit provided with a charging circuit having a capacitor, a discharging circuit connected to the output terminal of the second relaxation oscillator circuit and a transistor controllable by the output of the discharging circuit to short-circuit the capacitor of the charging circuit of the oscillation circuit when rendered conductive, the change-over switch being connected in parallel to the capacitor of the charging circuit of the oscillation control circuit and operative to de-energize the oscillation control circuit when short-circuiting the capacitor of the charging circuit of the oscillation control circuit.

7. A system as defined in Claim 5 wherein the relaxation oscillator circuit of the oscillation circuit comprises a charging

circuit including a resistor and a capacitor connected in series therewith, a programmable unijunction transistor having the anode thereof connected to the charging circuit, resistors connected to the gate of the programmable unijunction transistor and a transistor for short-circuiting the capacitor when the programmable unijunction transistor is rendered conductive.

8. A system as defined in Claim 4 wherein the relaxation oscillator circuit of the oscillation control circuit comprises a charging circuit including a resistor and a capacitor connected in series therewith, a programmable unijunction transistor having the anode thereof connected to the charging circuit and resistors connected to the gate of the programmable unijunction transistor.

9. A system as defined in any of Claims 1 to 3 wherein the oscillation circuit includes a relaxation oscillator circuit comprising a charging circuit including a resistor and a capacitor connected in series therewith, a programmable unijunction transistor having the anode thereof connected to the charging circuit, resistors connected to the gate of the programmable unijunction transistor and a transistor for short-circuiting the capacitor when the programmable unijunction transistor is rendered conductive, and the oscillation control circuit includes a relaxation oscillator circuit comprising a charging circuit having a resistor and a capacitor connected in series therewith, a programmable unijunction transistor having the anode thereof connected to the second-mentioned charging circuit and resistors connected to the gate of the second-mentioned programmable unijunction transistor, a discharging circuit connected to the cathode of the second-mentioned programmable unijunction transistor and composed of a capacitor and a resistor, and a transistor controllable by the output of the discharging circuit to short-circuit the capacitor of the charging circuit of the oscillation circuit when rendered conductive.

10. A system as defined in Claim 9 wherein the change-over switch is connected in parallel to the capacitor of the charging circuit of the oscillation control circuit and de-energizes the oscillation control circuit when short-circuiting the capacitor of the charging circuit of the oscillation control circuit.

11. A system as defined in Claim 9 or 10 wherein the resistor of the charging circuit of the oscillation circuit comprises a parallel circuit composed of a fixed resistor and a variable resistor arranged in parallel thereto, the parallel circuit being provided with a selector switch for selecting either the fixed resistor or the variable resistor, the selector switch being operatively connected with the change-over switch for selecting either the continuously repetitive stimulating signal or the interrupted stimulating signal.

12. A remedial system for electrically stimulating muscles of the human body substantially as hereinbefore described with reference to the accompanying drawings.

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