Jan. 13, 1948. W. K. KEARSLEY 2,434,497

THERAPEUTIC APPARATUS

Filed June 18, 1945 2 Sheets-Sheet 1

Fig. 1.

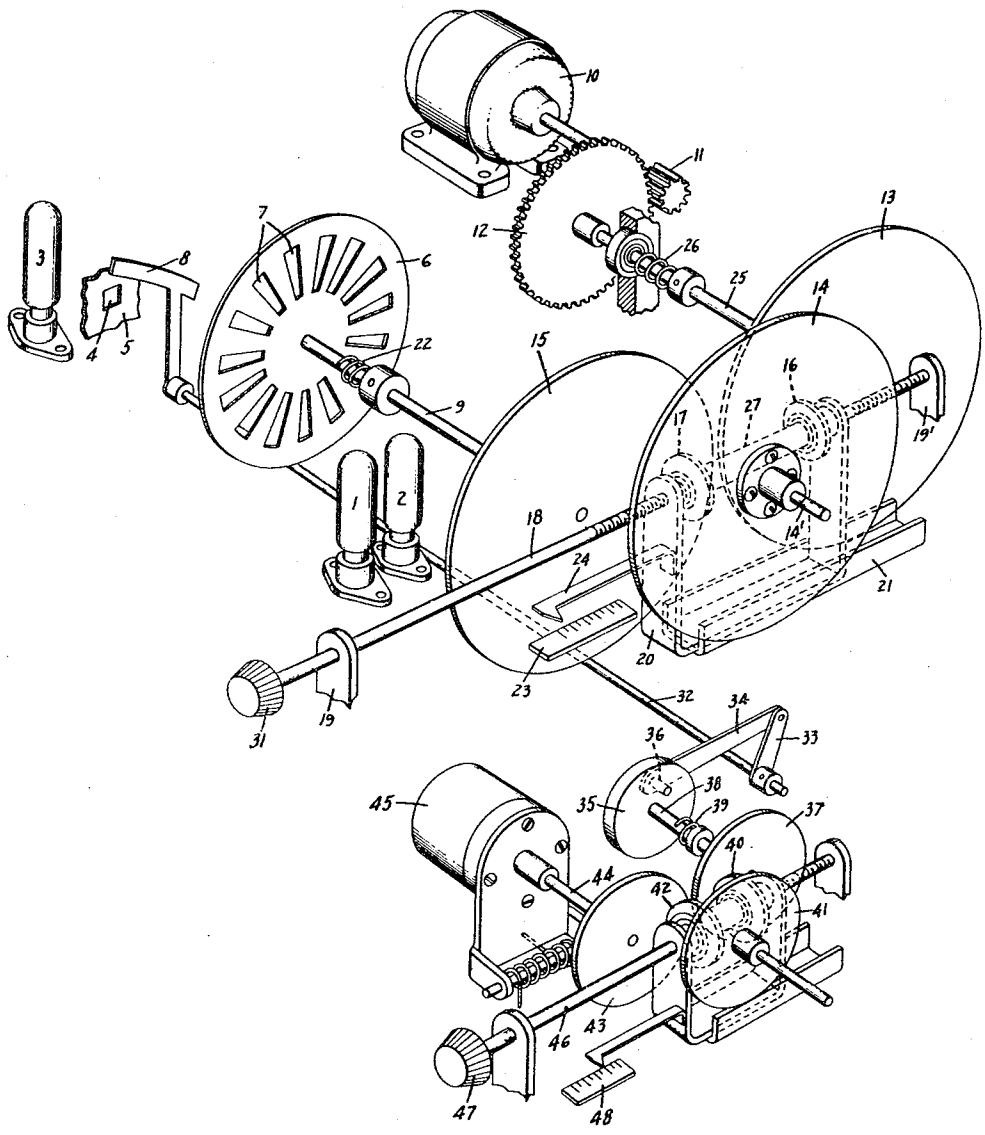

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Fig. 2.

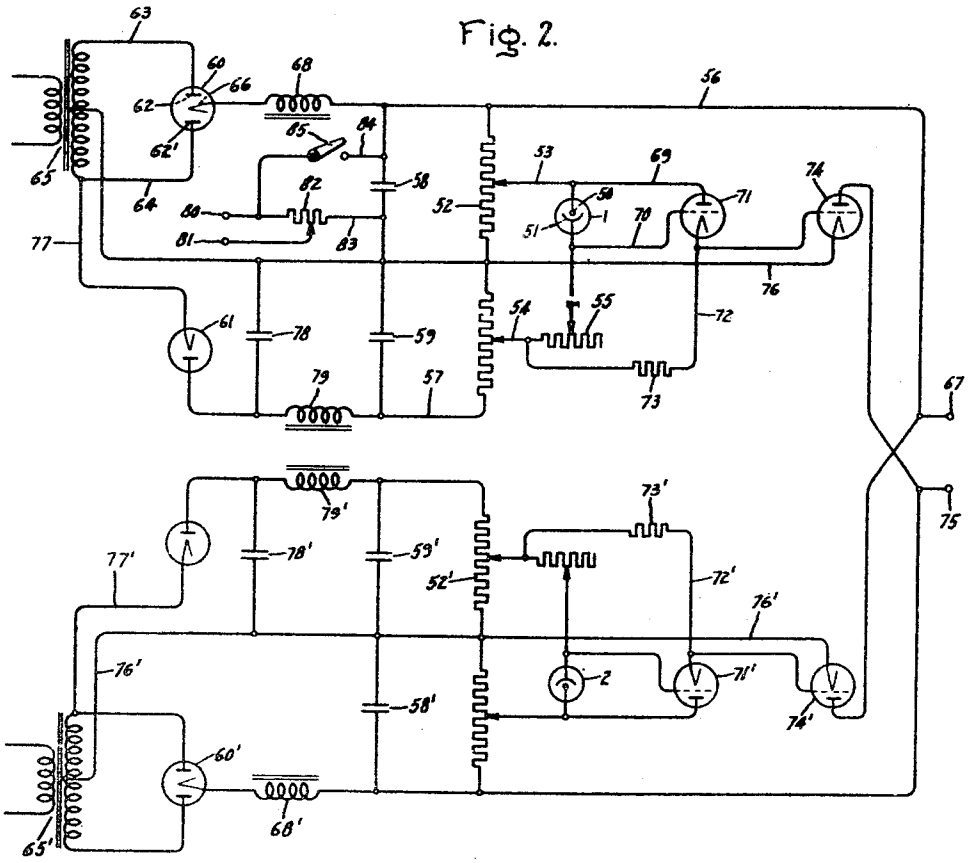
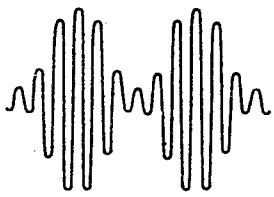


Fig. 3.



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UNITED STATES PATENT OFFICE

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THERAPEUTIC APPARATUS

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10 Claims. (Cl. 128—421)

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The present invention relates to the production of electric currents for therapy purposes, and in general to the production of currents of controlled frequency and amplitude. The objects of my invention are to provide an apparatus for producing alternating currents over a wide range of frequency and which are adapted to the needs of patients being treated.

It is desirable that the frequency of electric currents which are employed for the treatment of patients should be smoothly regulated, that is, the frequency should be capable of being varied in a continuous or stepless manner as contrasted with step-by-step or intermittent change from one frequency to another. A therapist having at his disposal a source of alternating (sinusoidal) currents, the frequency of which is readily controllable by stepless gradations, is in a position to readily arrive at the frequency having the most favorable therapeutic effect. For example, when it is desired to produce muscular response in the case of injured nerves to prevent atrophy of muscles of a patient, it is found that the greatest response with minimum current value is obtained at a critical range of frequency which is likely to be different for different patients. An apparatus permitting rapid determination of optimum frequency insures that the discomfort to the patients due to the heating effect of the current at the areas of application will be reduced to a minimum.

It is one of the objects of my present invention to provide means for obtaining sinusoidal currents of a wide range of smoothly controllable frequency. Such currents are sometimes referred to as carrier currents by the therapists.

It is another object of my invention to provide means for continuously modulating the carrier currents at chosen modulating frequencies by stepless gradations.

As will be described in greater detail in connection with the accompanying drawings, apparatus embodying my invention includes phototubes and means for subdividing and varying light received by the phototubes into pulses. With properly correlated amplifying means, therapy currents are produced in response to such light pulses and by the means provided in this new apparatus the characteristics of therapy currents best adapted for the treatment of patients may be quickly and efficiently regulated.

In the drawings, Fig. 1 is a somewhat conventionalized perspective view of apparatus provided with hand-controlled regulators for varying and regulating therapy currents over a wide range of characteristics; Fig. 2 is a diagram of an electrical converting system; and Fig. 3 is a graph illustrating modulated carrier currents produced by the apparatus.

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Referring to Fig. 1, the drawing shows two photocells 1, 2, arranged to receive light from a source 3 through a window 4 in an opaque housing which has been shown broken away except for a wall part 5 surrounding the window. In the path of the beam of light passing from the source 3 to the photocells is located an opaque rotatable mask or screen 6 which is provided with a plurality of radially arranged apertures 7, constituting light-transmitting windows whereby the light beam is subdivided into pulses which activate the respective photocells.

The amount of light transmitted to the photocells also may be modulated by a shutter 8 which, as will be described hereinafter, is caused to pass in a controlled manner between the source of light and the photocells.

The screen 6 is mounted for rotation on a shaft 9 which is connected by a train of gears (later described) to an electric motor 10. The gear train includes conventional toothed gears 11, 12 and a plurality of adjustable frictional gear disks 13, 14, and 15. Cooperating with the gear disks are small rubber-tired wheels 16 and 17 which are arranged to be moved by a shaft 18 between the centers and the peripheries of the disks 13, 14, and 15, the supports for the shaft 18 being only conventionally indicated at 19, 19' to simplify the drawing. The shaft 18 is screw-threaded into a U-shaped cradle 20, the purpose of which is to adjust the position of the wheels 16, 17. The cradle 20 slides in a trough 21. The position of the disk and ring members with respect to one another is indicated on a scale 23 by a pointer 24 which is attached to the cradle 20.

The disk 13 is mounted on the shaft 25 which is driven by the motor 10 and is urged by the spring 26 on the shaft 25 into frictional engagement with the rubber-tired wheel 16. The latter is rotatably mounted on the horizontal support 27 which does not rotate. The rubber-tired wheel 16 in turn drives the disk 14 which is mounted on the shaft 14'. The bearing for the shaft 14' has not been shown in order to simplify the drawing. The disk 14 in turn engages the rubber-tired wheel 17 which frictionally engages the disk 15 against which it is urged by the spring 22.

By turning the adjusting knob 31, the regions of engagement of the rubber-tired wheels 16 and 17 may be adjusted on the disks 13, 14, and 15;

that is, the frictional engagement of the wheels 16 and 17 may be caused to occur at various distances from the center of the disks outwardly to the periphery, thereby varying the relative speeds of the driven members. The highest speed is obtained when the wheel 16 bears adjacent the outer periphery of the disk 13 and also near the center of the disk 14, the wheel 17 then engaging near the periphery of the disk 14 and near the center of the disk 15. Conversely, lower speeds can be obtained when the wheel 16 engages near the center of the rotation of the disk 13 and the periphery of the disk 14, the wheel 17 then engaging at a region near the center of the disk 14 and with the periphery of the disk 15. By the resulting wide variation of speeds, the rotation of the apertured disk 6 may be varied several thousandfold. By this means the operator may cause subdivision of the light beams falling alternately upon the photoelectric cells into shorter or longer pulses.

As will be later explained, the currents generated by the light pulses falling alternately upon the photoelectric cells are caused, by appropriate electronic relays, to result in carrier current of chosen milliamperage and voltage which are suitable for use in the therapy field, and the frequency of such currents may be smoothly varied over a wide range. For example, by this means the carrier frequency of the output currents may be varied readily from one per minute to 120 per second, although wider variations are possible.

In some cases it is desirable in the therapy treatment of patients to modulate the carrier frequency to produce a train of carrier waves rising from zero to a maximum, and then falling to zero, as indicated in Fig. 3. Such modulation of the carrier currents is carried out by the shutter 8 which is caused to be oscillated to cover and uncover the window 4 at a predetermined rate.

The shutter 8 is given an oscillating motion by a shaft 32 which is mounted between bearings as indicated in the drawing, the supports not having been shown. The shaft 32 is connected by levers 33 and 34 to a rotating disk 35. The pin 36 on the disk 35 engages with the end of the lever 34 to cause the motion of rotation of the disk 35 to be converted into oscillating motion, thereby modulating the light falling on the photocells as will be evident from the drawing.

The disk 35 is rotated by the disk 37 which is mounted on the common shaft 38. A spring 39 presses the disk 37 against a rubber-tired wheel 40 which in turn engages with and rotates a disk 41. The latter engages with a rubber-tired wheel 42 which in turn engages with a disk 43 in a manner already described in connection with the main driving mechanism for the apertured disk 6. The disk 43 is mounted upon a shaft 44 driven by a slow speed electric motor 45. The mountings and engagement of the driving and driven members are similar to those of the first-described adjustable gear train. The position of the shaft 46 is similarly adjusted by a thumb-screw 47 to indicate on a scale 48 the relative position of the gears and hence the rate of modulation.

The oscillating shutter is shown as an example of a light modulator, but my invention is not to be considered as limited to this particular form of modulator.

The wave form of the therapy currents delivered to the applicator terminals 67 and 75 (Fig. 2) is determined by the rate of change or cross-sectional area of the light pulses falling on the photocells. The light variations are in turn determined by the configuration of the windows in the screen 6 and the configuration of the shutter 8. The photocells 1 and 2 should be so positioned with respect to the source of light and the spacing of the windows in the screen 6 that a desired effect is obtained. The operation may be made more evident if it is assumed that the screen 6 has but a single window. The beam of light shining through this window would sweep across photocell 1, producing in an amplifying system hereinafter described one-half of the carrier frequency wave. It would next sweep across the photocell 2 thereby producing the opposite half of the carrier frequency wave. By providing a plurality of windows this operation is repeated rapidly and results in a continuous train of waves.

By modulating the pulses, as by shutter 8, the amplitude of the carrier frequency waves may be varied, as shown in Fig. 3. By suitably choosing the shape of the windows in the screen 6, and the shape of the shutter with respect to the configuration of the active cathode surface of the photocells, variations in the wave form of the therapeutic currents are produced.

The variable currents in the phototube circuits resulting from the variable pulses of light falling on the photocells is amplified by relay tubes to produce desired therapy currents. A system of connections for this purpose is shown in Fig. 2. Referring to this figure, a photocell, conventionally indicated at 1, has its anode 50 and its cathode 51 connected to spaced points of a variable resistor 52 by the conductors 53, 54. A variable resistor 55 is provided in circuit with the cell. The terminals of the resistor 52 are connected by the conductors 56, 57 to the extremities of the series-connected capacitors 58, 59. The capacitor 58, which is of relatively large capacity (e. g. 32 microfarads), is charged by the full wave rectifier 60. The capacitor 59, having a smaller capacity, is maintained charged by a half-wave rectifier 61. The anodes 62, 62' of the rectifier 60 are connected by the conductors 63, 64 to the respective terminals of the secondary winding of a transformer 65. The thermionic cathode 66 of the rectifier 60 is connected by a conductor 56 to one terminal of the resistor 52 and from thence to the applicator terminal 67 of the therapy outfit, a choke 68 being included between the cathode 66 and the capacitor 58.

The output circuit conductors 69, 70 of the phototube are connected respectively to the anode and the grid of a pliotron (vacuum) tube 71 and by the conductors 72 in series with a resistor 73 to the potentiometer 52. The cathode of the pliotron 71 is connected to the grid of a second pliotron 74. The anode of the pliotron 74 is connected to the opposite applicator terminal 75 of the therapy apparatus. The cathode of the pliotron 74 is connected by the conductor 76 to a point of intermediate potential on the secondary of the transformer 65. The half-wave rectifier 61 is connected to the secondary of transformer 65 by the conductor 77. A filter capacitor 78 and a choke 79 are provided in the charging circuit of the capacitor 59.

The pulses of light falling on the photocell 1 cause variations in the resistivity of the photocell which produce variations of the potential of the grid of the pliotron 71. The resulting change in the current in the circuit 72 varies the potential of the cathode of the pliotron 71 and in turn varies the potential of the grid of the pliotron 74. Consequently the output currents derived

from the capacitor 58 and transmitted by the pliotron 74 are varied in accordance with the variations of the light pulses. The characteristics of the transformer secondary and the described circuits are chosen to obtain therapy currents of desired characteristics.

The described circuit elements constitute one-half of the system and alone will produce variable unidirectional currents. By the duplicating of the described circuits, as indicated in the lower part of Fig. 2, unidirectional carrier currents of opposite polarity are impressed on the applicator terminals 67, 75. The corresponding parts of the lower half of Fig. 2, which contains the photocell 2, are identified by the same numerals as the upper part with the addition of a prime sign.

The grids of the pliotrons 74 and 74' are normally biased at a negative cutoff potential by the capacitors 59 and 59'. As previously explained, only when light activates the phototubes is the cutoff potential modified to permit current flow. As the light shines on only one photocell at any instant the potentials of the tubes 74, 74' are alternately modified, which results in the production of alternating potentials at the applicator terminals 67, 75.

For some purposes, non-pulsating direct current is desired for therapeutic purposes. Unidirectional current may be obtained from applicator terminals 80, 81 which are connected to a variable potentiometer 82. The latter is connected by the conductors 83, 84 to the terminals of the capacitor 58 in circuit with a switch 85.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. An electrotherapeutic apparatus comprising the combination of applicator terminals, a source of unidirectional electric energy, thermionic means for transmitting said energy to said terminals, photoelectric means operatively related to said thermionic means whereby the currents delivered by said thermionic means may be controlled, means for activating said photoelectric means with light pulses and means for varying steplessly the frequency of said light pulses whereby the frequency of therapeutic currents delivered to said terminals may be correspondingly varied.

2. A therapy apparatus for furnishing electric currents at a desired therapeutic characteristic which comprises the combination of a source of unidirectional current, thermionic tubes for transmitting said energy, photoelectric means connected to control the operations of said thermionic tubes, a source of light positioned to transmit a beam of light to said photoelectric means, a rotatable opaque disk having a plurality of light-transmitting windows located in the path of said light beam whereby said beam may be subdivided, means for rotating said disk, means for steplessly and uninterruptedly varying the rate of rotation of said disk in order to vary the frequency of light subdivision, and means for independently modulating said light beam.

3. An apparatus for transmitting an electric current at a desired frequency and amplitude which comprises the combination of a photoelectric cell, a source of light positioned to transmit light to said cell, a rotatable mask having a plurality of light-transmitting windows located in the path of light between said source to said cell whereby the transmitted light may be subdivided, means for rotating said mask, means for uninterruptedly and steplessly varying the rate of rotation of said mask, an energy source, a thermionic device connected to transmit currents from said source in response to the currents transmitted by said cell, and applicator terminals circuit connected to said thermionic device.

4. A therapy apparatus for furnishing electric currents of desired therapeutic characteristics which comprises the combination of applicator terminals, a plurality of sources of unidirectional electric current, transmitting circuits each containing pliotron vacuum tubes connected between said sources and said terminals, photoelectric means connected to said tubes to control the transmission of current thereby, a light source whereby a beam of light is transmitted to activate said photoelectric means, a rotatable screen having windows for subdividing said beam, a motor for rotating said screen, mechanical means for steplessly regulating the rotational speed of said screen, a light-modulating shutter in the path of each of said light beams and means for varying the movement of said shutter and thereby modulating the currents impressed upon said applicator terminals.

5. An electrotherapeutic apparatus comprising the combination of applicator terminals, a source of electric energy, thermionic device for transmitting energy from said source to said terminals, a photoelectric device connected to control said thermionic device, means for delivering a beam of light to said photoelectric device, means for subdividing said beam into pulses of desired amplitude, and mechanical means for uninterruptedly varying the frequency of the resulting light pulses in the approximate range of one cycle per minute to about 120 cycles per second, thereby correspondingly varying the frequency of therapeutic currents delivered to said terminals.

6. An electrotherapeutic apparatus comprising the combination of a source of electric energy, thermionic means for converting said energy into therapeutic currents, a photoelectric device connected to control the operation of said thermionic means, means for activating said photoelectric device with light pulses the duration and frequency of which correspond to the desired characteristic of therapeutic carrier currents and means for modulating said light pulses at a frequency lower than the frequency of said carrier currents.

7. An electric apparatus comprising the combination of output terminals, duplicate energy supply circuits containing pliotron tubes connected to said terminals, means for biasing the grids of said pliotrons at cutoff potential, a photoelectric cell in each of said circuits respectively connected to initiate the flow of energy through said pliotron tubes, means for alternately illuminating said cells with pulses of light and means for steplessly varying the frequency of said pulses without interrupting the operation of said apparatus.

8. An electrical apparatus comprising output terminals, duplicate energy supply circuits each containing a pliotron connected to said terminals, means for biasing the grids of said pliotrons at cutoff potential, a photoelectric cell in each of said circuits, circuit elements between the cells and pliotrons in said respective circuits to initiate the flow of energy through said pliotrons when said photoelectric cells are illuminated, means for alternately illuminating said cells with pulses of light, means for steplessly varying the frequency of said pulses and means for modulating said pulses.

9. An electrical apparatus comprising output terminals, duplicate circuits containing electric capacitors, means for charging said capacitors, pliotron tubes respectively connected between said capacitors and said terminals, a photoelectric cell in each of said circuits, means for biasing the grids of said pliotrons at cutoff potential, electric connections between said cells and the grid circuits of said pliotrons whereby said grid potentials are modified to permit the transmission of current from said capacitors to said terminals, illuminating means, a screen having windows for transmitting pulses of light from said source alternately to said cells, means including adjustable friction disk gearing for rotating said screen and means for modulating said light pulses.

10. A therapeutic apparatus consisting of the combination of applicator terminals, paired duplicate circuits containing electric capacitors, transformers respectively associated with each of said capacitors, rectifiers connected to charge said capacitors from the associated transformer, a pliotron tube in each of said circuits connected between the capacitor of said circuits and said applicators, means for biasing the grids of said pliotron tubes at cutoff potentials, a photoelectric cell in each of said circuits, electric connections between said cells and the associated pliotron tubes in each circuit whereby upon illumination of said cells the grid potential of the respective association pliotron tubes may be modified to transmit current derived from the associated transformer to said applicator terminals, means for illuminating said cells alternately, a rotatable screen having windows and being so located that said cells will be alternately illuminated through each of said windows, a motor for rotating said screen, an adjustable disk mechanism connecting said motor to said screen, a shutter for modulating said light at a lower frequency rate than the frequency of light transmission through the windows of said rotating screen and means for oscillating said shutter in the path of a beam of light transmitted alternately to said cells.

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