March 17, 1942. A. S. MILINOWSKI, JR 2,276,994

ELECTROTHERAPY

Filed Jan. 22, 1938

Fig. 1.

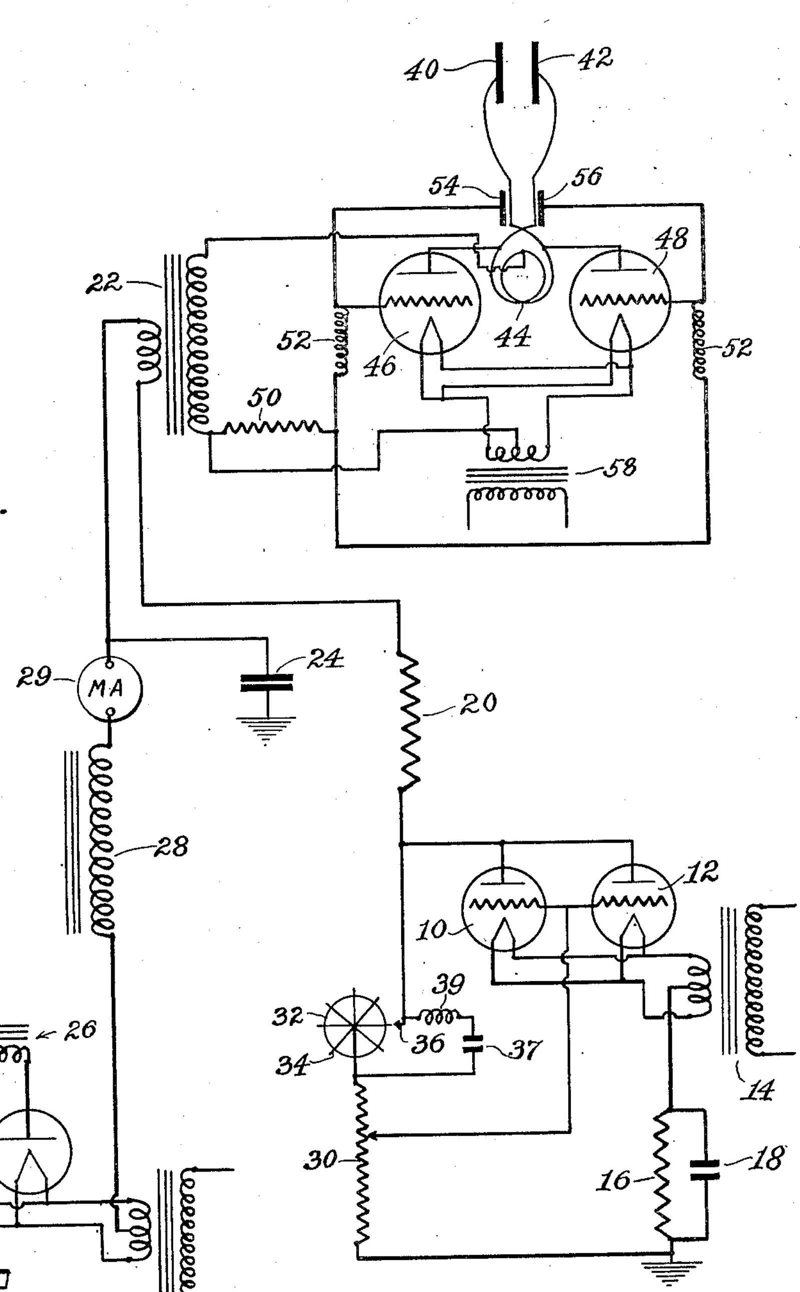


Fig. 2.

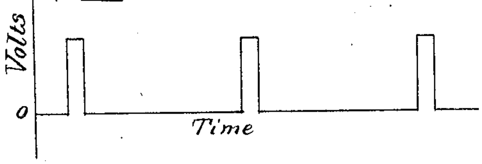
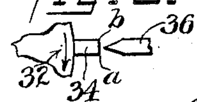


Fig. 3.



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ELECTROTHERAPY

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7 Claims. (Cl. 128—422)

Broadly stated my invention, in one of its aspects, relates generally to an apparatus for creating periodic high frequency pulses preferably of relatively short duration with relation to the time intervals between pulses, and the application of such high frequency pulses to matter to produce differential effects and in another of its aspects it relates to the use of high frequency pulses of the character referred to for therapeutic treatment by electrotherapy by which I mean broadly, the art of subjecting living matter to the action of electrical forces, and in particular it relates to a method of applying such electrical forces to living matter.

Recent investigations have shown that living cells, such as the cells of the human body and the various micro-organisms that are parasitic therein, such as protozoa and bacteria, have electrical charges associated therewith. When these are subjected to the action of electrical forces, changes in their normal condition are produced. In the case of bacteria their virulence varies with their electrical charge, while in the case of body cells it seems probable that departure from the normal condition will result in pathological conditions.

In the application of electrical forces to matter, and in particular to living matter, the thermal phenomena accompanying the passage of electrical currents therethrough are to be distinguished from effects that are purely electrical. It is only the latter that will directly affect the electrical characteristics of matter, while the effects of the former are those associated with heat. It is at once evident that independent control of the thermal factors associated with the application of electrical forces to matter are of the highest importance for the attainment of predetermined desired effects.

The importance of such independent control has been demonstrated in the practice of ultra short wave therapy. When the high frequency oscillations are applied for an appreciable time to a patient, it is found that the amount of current, or stated differently, the voltage, that may be applied, is limited because of the heat generated in the patient's body. That is, stated in technical language, the limit of heat tolerance of the patient cannot be exceeded.

It is among the general objects of my invention to raise the limit of the voltage that may be applied, without exceeding the limit of heat tolerance, and this end I attain as a result of the independent control of the thermal and electrical effects.

By so increasing the voltage I am enabled to bring into play more powerful electrical forces without increasing the thermal effects, and where the application is to living matter these powerful electrical forces produce effects hitherto impossible of attainment.

As the applications of my invention are further investigated it may be found that by the use of sufficiently high voltages, radiations, such as X-radiations, may perhaps be produced within the body, as a result of the increased electron velocities therein, and such radiations may have valuable therapeutic effects.

While I have pointed out the desirability of increased electrical effects, my invention in one of its phases also relates to the practice of diathermy, in which the heating effects of the electric current are utilized, and in which the electrodes are customarily placed in direct contact with the patient. As a result of the direct contact a large amount of current can be transmitted through the body at relatively low frequencies, but as a result of the heat produced in the body both the voltage and the frequency that are applied are limited because of the aforementioned heat tolerance of the patient. If it is attempted to practice diathermy by spaced electrodes it is necessary however to increase the voltage or to increase the frequency of the applied current in order to cause sufficient energy to pass into the patient's body. Heretofore higher frequency has been resorted to because it was found impossible with the existing apparatus to secure a sufficient input into the patient by raising the voltage, the latter being limited due to shortcomings of the apparatus employed. By the use of my apparatus however I am enabled to increase the voltage to such a point that it is possible to use lower oscillation frequencies than have been heretofore employed in contact diathermy, thus opening up a new branch of therapeutic technique.

It is further among the objects of my invention to increase the efficiency of ultra short wave treatment and apparatus by the employment in connection therewith of flat-topped electrical impulses, and to provide apparatus for producing such flat-topped impulses. The advantages thereof will be fully discussed hereinafter, but it may be briefly stated at this point that by their use the maximum efficiency of action is obtained throughout the duration of the pulse, whereas other pulse forms give a maximum efficiency only at the peak point or points and a reduced efficiency at other times, whereby of course the average efficiency during the pulse is reduced.

It is also among the objects of my invention to provide electrical circuits for the desired purposes that will perform their function efficiently and reliably, and that may be arranged compactly; and further to provide apparatus of the type described that will be economical in manufacture and operation.

For the attainment of these objects and such other objects as will hereinafter appear or be pointed out I have shown an illustrative embodiment of my invention in the drawing, in which:

Figure 1 is a diagram of the circuits of one embodiment of my invention;

Figure 2 is a voltage diagram of the electrical pulses that are used to generate the high frequency oscillations; and

Figure 3 is a diagrammatic view on an enlarged scale of a detail of the circuit of Figure 1.

In Figure 1 I have shown an electrical circuit that is adapted for the production of high frequency oscillations of the character called for by my invention.

The illustrative apparatus shown in the drawing comprises first of all a pulse producing circuit, which includes electronic means such as triodes **10** and **12** connected in parallel, and having their filaments energized from a transformer **14** connected to an alternating current source such as a standard 110 volt alternating current lighting circuit. While a single triode would serve my purpose I have shown a pair to obtain sufficient power. The triodes **10** and **12** are normally biased beyond cut-off by means of a cathode resistor **16** shunted by an electrolytic condenser **18** of sufficient capacity to keep the bias voltage nearly constant. The resistor **16** and condenser **18** are connected as shown, between the midpoint of the secondary of the transformer **14** and the ground. The plate circuit of the triodes **10** and **12** includes the primary of the pulse transformer **22** and across it is connected the condenser **24**, the latter being energized from a center-tapped power transformer and a full wave rectifier indicated as a whole by **26**, which is connected to a source of alternating current such as the aforementioned 110 volt lighting circuit and which may, by way of example, deliver current at up to 3000 volts. A ballast resistor **20** may also be placed in the plate circuit of the triodes **10** and **12**. The circuit also includes a choke coil **28** and a milliammeter **29**. The coil **28** may have a capacity of 20 henrys. The grids of the pulse tubes **10** and **12** are connected periodically to their plates through the resistor **30** by means of a rotating contactor **32**, having studs thereon that are adapted to make contact with a knife edge **36**. A condenser **37**, which may have a capacity of .002 microfarad and a choke coil **39** are shown as placed across the contactor gap and serve to prevent arcing. The result is the transmission of intermittent pulses through a primary of the pulse transformer **22**.

Coupled to the pulse producing circuit just described, through the transformer **22**, which may have a step-up ratio of the order of 11:1, is a high frequency oscillating circuit comprising at its output end the electrodes **40** and **42** in the form of plates, which in the normal use thereof are spaced from the patient who is placed between them. The electrodes **40** and **42** are shown as connected to the terminals of an inductance **44** to which are also connected the plates of the triodes **46** and **48**. The grids of triodes **46** and **48** are connected in parallel through a resistor **50** with that terminal of the secondary of the pulse transformer **22** that becomes negative during the pulse, and each grid has an inductance **52** in series with it and is further connected with one of a pair of condenser plates **54** and **56**, the condenser plate **54** being electrically adjacent to the electrode **40** and the condenser plate **56** being electrically adjacent to the electrode **42**.

The other terminal of the pulse transformer **22** is connected to the inductance **44** at the midpoint thereof. The filaments of the triodes **46** and **48** are energized from the transformer **58**, connected to a source of alternating current such as the aforementioned 110 volt lighting circuit, the midpoint of the secondary of which is connected to the grid end of the pulse transformer. It will therefore be observed that the triodes **46** and **48** are in "push pull" relation to the electrodes **40** and **42**.

The transformer **58** is preferably of special design so as to provide sufficient insulation and low capacity between the primary and the secondary coils. I have found that a transformer consisting of a coil of soft iron wire nine inches in diameter, on which the primary is wound, and a secondary coil of about eight inches in diameter looped about the primary and so spaced that it is everywhere more than two inches from the primary, is very satisfactory in practice.

In the operation of my device it will be understood that the pulse transformer **22** receives electrical impulses from the pulse producing circuit and steps up the voltage to that desired to be applied to the plates of the oscillating tubes of the high frequency oscillating circuit, while the latter functions to supply high voltage ultra high frequency waves during each pulse to the electrodes **40** and **42**.

In Figure 2 will be found a time-voltage diagram indicating the flat top voltage wave form that may be produced in the pulse circuit for transmission to the high frequency circuit. This flat top wave form may be obtained by suitable adjustment of the resistor **30** in the grid circuit of the pulse tubes **10** and **12**. It is found that when the resistance is reduced to a point where the heat loss in the resistor becomes appreciable the voltage drops substantially without slope and the voltage pulse ends abruptly, as shown in Figure 2, which represents the results of actual oscillograph tests.

The pulse frequency and duration are determined by the characteristics of the contactor **32**, which may be driven by an electric motor. The pulses may be produced as the studs **34** thereof move past the knife edge **36** and contact the same. Figure 3 is a detail view of a contactor in which a stud **34** is shown spaced from the knife edge **36**. It will be evident that the pulse frequency is determined by the number of studs on the contactor and the contactor speed, while the pulse duration will be determined by the length *a* to *b* of the stud and the contactor speed.

In actual practice I have found a contactor consisting of a duralumin disc having eight equally spaced studs on its periphery and driven at a speed of 7000 R. P. M. to be very satisfactory, when used with a knife edge of phosphor bronze. At this speed the pulse frequency is about 900 per second. The length of the studs is such as to produce at this speed a pulse duration of about 1/20000 sec. I have found this pulse frequency and duration satisfactory for average conditions of use.

At the contactor speeds and voltages used it is not feasible to allow the contactor studs to make actual physical contact with the knife edge and the construction of Figure 3 is used. However, in order to produce a satisfactory flat top pulse, the electrical contact must be made instantaneously when the leading edge of the stud, *a*, is nearest the knife edge. Also, the electrical contact must be broken instantaneously when the trailing edge of the stud, *b*, leaves the knife edge. The circuit is uniquely designed to accomplish this by making use of the electronic action of the pulse tubes, in the following manner:

At the moment when the leading edge of the stud approaches the knife edge the full voltage of the filter condenser **24** is across the pulse tubes and across the contactor points. This voltage is sufficient to jump a small air gap between the contactor points and establish contact. During the pulse, however, a current flows in the pulse tubes and the voltage drop across these tubes is reduced to a small fraction of the voltage of condenser **24**, and it is only this greatly reduced voltage which must be broken when the trailing edge, *b*, of the stud leaves the knife edge. Any tendency to arc due to this smaller voltage is removed by placing the previously mentioned small condenser **37** of about .002 microfarad, across the contactor points. The radio frequency choke coil **39** is placed in series with this condenser to prevent oscillations in the condenser circuit during the pulse.

The following actual test will serve as an illustrative example of the comparative heating effects of continuous high frequency oscillations and of pulsating high frequency oscillations.

A 0.1 normal sodium chloride solution in water was placed in a special glass tube, 2 cm. in diameter by 15 cm. long, having metal electrodes at the ends and special provision for a thermometer. The tube was insulated with cloth to reduce heat loss and placed between the applicators of a therapeutic oscillator such as shown in the drawing.

When this oscillator was activated by a constant voltage of 3300 volts the temperature of the solution rose from 22 degrees centigrade to 45 degrees centigrade in ten minutes. The oscillator was then activated by 3300 volt pulses, the pulses having a duration of about $\frac{1}{20000}$ sec. and a frequency of about 900 per second. An identical solution in the tube placed in the same position rose from 22 degrees centigrade to less than 24 degrees centigrade in ten minutes. The frequency produced in the oscillator was 25 megacycles per sec.

It will be obvious that a flat top wave pulse as just described will have the advantage that the desired maximum voltage effects are attained throughout the duration of each pulse, so that no provision need be made for any higher voltages.

Among the many advantages of short duration pulses, and in particular of flat top short pulses may be mentioned that short duration pulses do not strain the insulation of the apparatus as severely as a continuously applied equivalent constant voltage would, and consequently the voltage used in the apparatus may be stepped up. As an example of how reducing the time of application of the voltage will increase the breakdown resistance it may be mentioned that, with a pulse duration of about one-tenth of the complete pulse cycle, a transformer secondary coil, intended for an output voltage of 2500 at 60 cycles, broke down at 11,000 volts, while when the pulse duration was reduced to one-twentieth of a cycle it did not break down at 20,000 volts.

The voltage of the pulses may be stepped up or down directly by means of a suitable transformer without further rectification. The transformer may be designed so that no appreciable flux is built up in the transformer core during the pulse, with the result that practically no inverse voltage occurs after the cessation of the pulse.

Any electrical spark-over that may take place either in the pulsating current circuit or in a high frequency circuit actuated thereby, is of the nature of a spark or corona discharge and does not take the form of a self-maintaining arc. This simplifies insulation problems and the protection of the apparatus from injury.

Higher voltages may be used on the oscillating high frequency tubes without overheating or tube failure. As an instance I may state that it has been found possible to use pulsating voltages up to 20,000 on a pair of PF 196 tubes which in normal service are not adapted for voltages over 3000.

The emission requirements of oscillating tube filaments for an equivalent power output are considerably reduced for pulsating current, due to the use of a higher effective voltage during the pulse.

The practical frequency limit of the tubes is increased due to the higher effective voltage made possible by the use of a pulsating voltage. The increased plate voltage reduces the transit time of the electrons from filament to plate, and since this transit time limits the frequency limit of a tube, shortening this time raises the frequency limit to a considerable degree.

By flattening the top of the wave pulse additional advantages are obtained. When used for the excitation of X-ray tubes mono-chromatic X-radiation may be attained, because the exciting voltage is constant. Where it is attempted to use a sustained high voltage for this purpose electrical insulation difficulties are usually encountered, or over-heating may result, or abnormal spark tension on the tube filaments. To overcome these difficulties high voltage pulses originating from spark discharges have been tried, but as these voltage pulses drop exponentially the radiation is not mono-chromatic. With a flat top voltage pulse, as in my apparatus, monochromatic radiation coupled with the advantages of interrupted voltage are obtained.

The same advantages also make this type of pulsating voltage useful for the excitation of Lenard ray tubes, or any ion accelerating devices.

While I have shown and described an illustrative embodiment of my invention and illustrative methods of practicing the same it is to be understood that the same may be embodied in many other forms and practiced in many other ways without departing from the spirit thereof, as will be obvious to those skilled in the art, and that the disclosure is by way of illustration only, and is not to be interpreted in a limiting sense, and that I do not limit myself in any way other than as called for by the prior art.

Having thus described my invention and illustrated its use, what I claim as new and desire to secure by Letters Patent, is:

1. In ultra short wave apparatus: a pulse producing circuit comprising a condenser, means for charging said condenser, a vacuum discharge

tube across said condenser, said vacuum discharge tube having at least one grid, and means for periodically connecting the plate and the grid of said vacuum discharge tube.

2. In ultra short wave apparatus: a pulse producing circuit comprising a condenser, means for charging said condenser, a vacuum discharge tube across said condenser, said vacuum discharge tube having at least one grid, means for energizing the filament of said vacuum discharge tube, biasing means associated with said filaments, and means for periodically connecting the grid and the plate of said vacuum discharge tube.

3. In ultra short wave apparatus: a pulse producing circuit comprising a condenser, means for charging said condenser, a pair of vacuum discharge tubes across said condenser, each of said tubes having at least one grid, means for energizing the filaments of said vacuum discharge tubes, biasing means associated with said filaments, and means for periodically connecting the grids and the plates of said vacuum discharge tubes through a resistor.

4. In ultra short wave apparatus: a pulse producing circuit comprising a condenser, means for charging said condenser, a vacuum discharge tube across said condenser, said vacuum discharge tube having at least one grid and means for periodically connecting the plate and grid of said vacuum discharge tube, and a resistor in series with said plate.

5. In ultra short wave apparatus: a pulse producing circuit comprising a condenser, means for charging said condenser, a vacuum discharge tube across said condenser, said vacuum discharge tube having at least one grid and means for periodically connecting the plate and the grid of said vacuum discharge tube, a resistor in series with said plate circuit, and means for stepping up the voltage and for transmitting the pulses generated in said pulse producing circuit to a high frequency oscillating circuit.

6. Ultra short wave apparatus comprising a condenser, means for supplying high potential rectified current to said condenser, a pulse producing circuit across said condenser and having therein a step-up transformer coupled to a high frequency circuit, and said pulse producing circuit comprising an electronic vacuum discharge tube having at least one grid, and means for periodically connecting the grid and plate of said vacuum discharge tube.

7. In ultra-short wave apparatus, a pulse producing circuit comprising a condenser, means for charging said condenser, a vacuum discharge tube connected across said condenser, said discharge tube having at least one grid, bias means for said grid normally preventing the discharge of said condenser through said tube, and means for periodically connecting the plate and grid of said discharge tube for permitting the discharge from said condenser through said tube, said discharge tube being in parallel with said means for periodically connecting the plate and grid and thereby activated therewith to reduce the voltage drop across said tube and said periodically connecting means to a small fraction of the voltage of said condenser, whereby only a small fraction of the total energy accumulated in said condenser is released.

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