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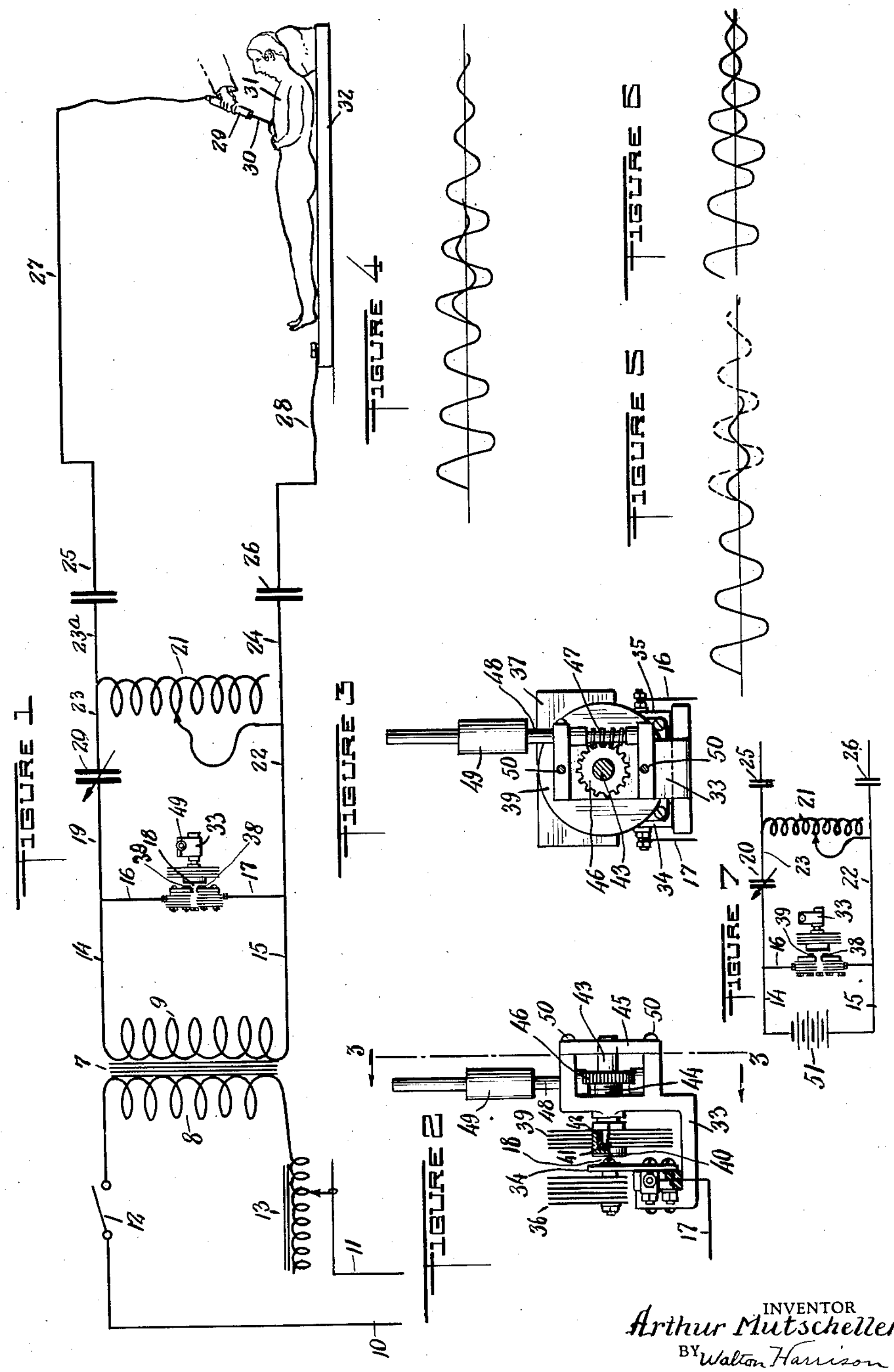

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ELECTRIC SYSTEM FOR ENERGIZING CUTTING ELECTRODES

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My invention relates to systems for energizing cutting electrodes of a type in which the electrode is used as a surgical knife, to sever living tissues.

As is well known in this art, much difficulty has been experienced in connection with the methods and systems heretofore used for energizing electrodes used for surgical cutting. Currents of low voltage are not appropriate, as they cause undue heating not only along lines where the tissues are severed, but also within the tissues. High voltage currents of low frequency must be avoided because they act electrolytically upon the tissues, and otherwise injure the same. For these reasons and various others which need not here be stated, oscillation currents of high potential and high frequency, for energizing the cutting electrodes, are greatly to be preferred.

On the other hand, systems for developing oscillation currents of suitable voltage and frequency involve more or less difficulty. Such systems usually contain one or more vacuum tubes, along with circuits which are unduly complicated, and difficult to balance. The mechanism, if not heavy and cumbersome, is apt to be frail. Besides, the vacuum tubes are quite delicate, and are oftentimes lacking in uniformity.

I have invented a method and a system closely associated therewith whereby a good cutting current can be produced without the aid of a vacuum tube; this current being maintained by means of apparatus quite simple in character and adapted to be cheaply produced.

My improved system, which embodies a circuit containing a spark gap, can be regulated with great nicety, and its capabilities varied within wide limits, by simply adjusting the spark gap, or by controlling, independently of the spark gap the inductance or capacity or both, of the oscillation circuit.

Reference is made to the accompanying drawing forming a part of this specification, and in which like reference characters indicate like parts throughout all of the figures.

Figure 1 is a diagram of a form of my system as energized by alternating currents.

Figure 2 is a side elevation of a spark gap mechanism used in connection with my invention.

Figure 3 is a section on the line 3—3 of Figure 2, looking in the direction indicated by the arrows.

Figure 4 is a diagram, indicating by graphic lines the manner in which successive trains of oscillations are made to overlap and thus form a practically continuous train of undamped oscillations.

Figure 5 is a diagram, indicating by full lines the effect of a single spark, and indicating by broken lines how in my system the effect of one spark is qualified by the effect of the next successive spark.

Figure 6 is a diagram, indicating by full and broken lines an accidental discordant effect due to want of adjustment of the spark gap, the cutting circuit being thereby disabled for purposes of cutting.

Figure 7 is a fragmentary diagram of a form of my system differing slightly from the one illustrated in Figure 1.

A transformer is shown at 7, and is provided with a primary winding 8 and a secondary winding 9. The proportions of the transformer windings may be varied within wide limits, but as a rule should be such that the potential developed by the secondary winding is rather low, preferably not more than two thousand volts.

The primary winding 8 is energized by means of leads 10, 11. The lead 10 is interrupted by a circuit closer 12, which may conveniently be a foot switch of ordinary construction.

The lead 11 is interrupted by a regulator 13, which as here shown is a variable inductance but which may as well be a variable resistance. It matters but little whether the regulator 13 be used to control current or voltage, the ultimate result being substantially the same for the purposes here contemplated.

Connected with the secondary winding 9 are a pair of conductors 14, 15, and connected with these conductors are a pair of other conductors 16, 17. These conductors lead to a spark gap 18.

Connected with the conductors 14 and 16

is a conductor 19, which leads to a variable condenser 20. A variable inductance is shown at 21, and may for example be made up of about thirty-eight turns of number 10 wire, forming a helix two and one-quarter inches in diameter.

The condenser 20 has in this instance a capacity of about four hundred centimeters, but may be made larger, as hereinafter more fully described.

The inductance winding 21 is connected with the conductors 15 and 17 by a conductor 22, and is connected with the condenser 20 by a conductor 23.

A conductor 23*a* is connected with the inductance winding 21 and with the conductor 23, and extends therefrom to a condenser 25. Similarly a conductor 24 is connected with the inductance winding 21 and with the conductor 22, and leads therefrom to a condenser 26.

The condensers 25 and 26 are quite small, each having a capacity which need not be more than 2,000 to 3,000 centimeters. The purpose of the condensers 25 and 26 is to avoid the possibility of low frequency impulses passing into the portion of the circuit located at the right of these condensers according to Figure 1, and thus reaching the cautery electrode and the patient.

A conductor 27 is connected with the condenser 25, and another conductor 28 is connected with the condenser 26. The two conductors 27 and 28 are preferably cord conductors.

The conductor 27 is connected with a cutting electrode 29, having an electrically energized operating member 30 which serves as a cutting blade.

A patient is shown at 31, and reclines upon a metallic plate 32, with which the conductor 28 is connected.

I will now describe the spark gap mechanism. A metallic frame is shown at 33. Mounted upon this frame and insulated therefrom are a pair of spark plates 34, 35. Connected with the spark plate 34 are a number of metallic radiator plates 36, and connected with the spark plate 35 are a number of other radiator plates 37. The spark plates 34 and 35 are provided respectively with spark terminals 38 and 39, each of these spark terminals being simply a boss, projecting slightly in a lateral direction from the plate.

Facing the spark plates 34 and 35, and located in close proximity to the spark terminals 38 and 39, is a tungsten plate 40, serving as a terminal spark plate. The tungsten plate 40 has the form of a disk, and is mounted upon an end cap 41, which is carried by a sleeve 42 of insulating material, this sleeve being fitted upon and carried by the end of a shaft 43.

The shaft 43 is provided with a screw thread 44, which engages a plate 45 forming a part of the frame and serving as a bearing. Thus the shaft 43 with its screw thread 44 is essentially a screw, which is not only revoluble, but which in turning moves slightly endwise; that is, toward the right or left according to Figure 2.

The shaft 43 carries a worm wheel 46, secured rigidly upon it and by means of which it is turned. A worm 47 engages the worm wheel 46, as may be understood from Figure 3. The worm 47 is carried by a worm shaft 48, this worm shaft being provided with a tubular handle 49 of insulating material.

The worm shaft is journaled upon the metallic frame, and is revoluble by means of the handle 49. The plate 45 is held in position by two screws 50, 50.

The operator, by grasping the handle 49 and turning the worm shaft 48, causes the worm 47 to turn the worm wheel 46. The rotation of the shaft 43 varies the distance between the tungsten plate 40 to the adjacent spark plates 34 and 35, thus varying the length of the spark gap 18, which is here illustrated as a multiple spark gap. However, a single spark gap may be used in instances where it may be found preferable.

As the variation in the length of the spark gap is small as compared with the extent of a given turning movement of the worm shaft 48, the operator's control over the spark gap is quite decisive; or in other words, that the spark gap may be adjusted, as to its length, with great precision.

The ohmic resistance of the various conductors above mentioned should be as low as practicable. On this account, none of the wires or other conductors should be very long. No. 6 copper wire, or its equivalent in cord conductors, will answer the purpose.

With the various parts constructed as above described and suitable proportioned relatively to each other, and the leads 10, 11 connected with a source of ordinary commercial alternating current of, say, sixty cycles per second and one hundred and ten volts, the system can be made to produce good results, in accordance with my method.

With the secondary winding 9 developing about 800 to 900 volts, the frequency of sparks crossing the spark gap 18 is about 5,000 per second. While the train of oscillation following each spark is decidedly damped, the high frequency of the sparks causes each train to be overlapped by the next successive train, in the manner indicated by graphic lines in Figure 4. The oscillation frequency thus attained, with this particular apparatus, is about 500,000 per second, as may be shown by means of a wave meter.

I find, however, that the beginning of each train of oscillations must be as far as practicable in phase with the other trains, as indicated by full and broken lines in Figure 5. So long as the several successive trains are in phase with each other, the cutting circuit is energized by current of the kind indicated diagrammatically in Figure 4; these currents being, for purposes here contemplated, the virtual equivalent of a single continuous train of undamped or sustained oscillation, of a frequency of about five hundred thousand per second.

The cutting electrode 29, with its electrically energized operating member 30, when energized by currents of the kind just described, is very efficient in severing the tissues and in otherwise performing the work of a surgical knife.

The manner in which the cutting electrode does its work need not here be described. The cutting is accomplished without any appreciable loss of blood, and otherwise in a manner known in this art.

In order to maintain the cutting circuit in good working order, it is necessary to maintain a proper proportion between the capacity, the inductance and the ohmic resistance of the various parts. The inductance and capacity being determined by the proportions of the various parts, and particularly the sizes of the condensers and the amount of inductance in the winding 21, the ohmic resistance of the spark gap may be relied upon for purposes of adjusting and balancing the system as a whole. To obtain the best results, the spark gap should be maintained quite short, and its length should be adjusted from time to time as required by variations in conditions of operation.

It is important that the spark gap mechanism be so constructed and arranged as to cool the spark gap as far as practicable.

The variable condenser 20 should not be too large. By giving this condenser a maximum capacity of about four hundred centimeters, the other parts being proportioned as above described, the cautery electrode may be so energized as to cut efficiently, without causing the formation of any crust within or upon the tissues. This is a result much to be desired.

By giving the variable condenser 20 a maximum capacity of about eight hundred centimeters the cutting may be even more thorough, but some crust is produced. Hence, in most cases this much capacity for the condenser 20 is too great.

If the maximum capacity of the condenser 20 be increased to sixteen hundred centimeters, other conditions remaining unchanged, the cautery electrode can be made to cut tissues very rapidly, and to readily sever them even under water. In this instance however, crust is formed so rapidly that except under extraordinary conditions, and particularly where for some reason the cutting must be done very quickly, the large capacity of the condenser 20 becomes very objectionable. Still, emergencies may arise in which there are distinct advantages in having the condenser 20 of large size.

Care must be exercised by the operator to keep the spark gap so adjusted as to maintain, as far as practicable, the resonance conditions indicated in Figures 4 and 5.

If for any reason the successive trains of oscillations are thrown out of phase with each other, as indicated by full broken lines in Figure 6, the cautery electrode ceases to cut properly, and may even cease to cut altogether; and when this happens the current may even produce other effects, more or less injurious to the tissues, or objectionable in other ways.

I find that in practice it is an easy matter to bring the successive trains of oscillation into and out of phase with each other, by simply adjusting the spark gap; or, practically speaking, by turning the tubular handle 49 back and forth, as conditions may require. However, if desired, the phase relations may also be adjusted by means of the variable capacity or the variable inductance, or both.

In Figure 7, I show a slightly different form of my invention.

Here instead of alternating current I use a direct current, supplied by a battery 51 or other appropriate source. Otherwise, the system and method are as above described, with reference to Figures 1 to 6 inclusive. If for any reason it be desirable to maintain the spark gap of a constant length, the adjustment of the phase may be accomplished as just stated.

As may be understood from the foregoing description, my system has both a spark frequency and an oscillation frequency, these frequencies being so related as to develop virtual or constructive resonance, in that part of the circuit which energizes the cautery electrode. It will also be noted that in order to maintain a proper phase relation between these two frequencies, one of the frequencies must be controllable by the operator; and that in the particular embodiment here shown and described, the phase relation is controlled by adjusting the spark gap and thus varying the frequency of the sparks.

It will also be noted that the various parts of my system must be so proportioned and adjusted, as to phase and otherwise, as to produce and maintain undamped oscillations of a voltage and frequency sufficiently high to produce disruption of protein molecules.

I do not limit myself to the precise mechanism above shown and described, nor to the precise method above outlined, as variations may be made therein without departing from my invention.

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

1. In a system of the character described

the combination, with a cutting electrode, and a circuit connected with said cutting electrode for energizing the same, of a spark gap bridged across said circuit and a suitable measure of inductance and capacity included in said circuit and coacting with said spark gap for developing trains of damped oscillations, said spark gap being adjustable by the operator for the purpose of bringing the oscillations of one train into phase with the oscillations of another train, in order to energize said cutting electrode by means of oscillations practically free from effects of damping.

2. In a system of the character described the combination, with a cutting electrode, of a circuit connected with said cutting electrode for energizing the same by means of cutting currents, said circuit including a spark gap and a suitable capacity and inductance associated with said spark gap and co-acting therewith for producing successive trains of damped oscillations, the parts being so proportioned that one of said trains is started before another of said trains is ended, said spark gap being adjustable for the purpose of enabling the operator to change the phase of oscillations in one of said trains relatively to oscillations in another of said trains.

3. In a system of the character described the combination, with a cutting electrode, and a circuit for energizing said cutting electrode, of means for developing successive trains of damped oscillations in said circuit, said means including a spark gap, capacity and inductance elements adjustable by the operator for the purpose of controlling said trains of oscillations in order to bring one of said trains into phase with another of said trains and said cutting electrodes to be energized by oscillations practically free from the effects of damping.

4. In a system of the character described, the combination, with a cutting electrode, together with a circuit connected with said cutting electrode and means for energizing said circuit and adapted to develop successive trains of damped oscillations therein, of capacity and inductance elements in said circuit and a spark gap connected with the latter and adjustable as to spark frequency by the operator together with said capacity and inductance elements, for enabling one of said trains of damped oscillations to start before another train is ended to thus control the oscillations of said circuit for the purpose of energizing said cutting electrode by oscillations practically free from the effects of damping.

5. In a system of the character described, the combination, with a cutting electrode, of a circuit connected with said cutting electrode for energizing the same, said circuit including a spark-gap, together with suitable capacity and inductance elements co-acting with said spark-gap, for developing successive trains of damped oscillations in said circuit, and mechanism connected with said spark gap and controllable by hand for changing the spark frequency of said spark gap, and said capacity and inductance elements being also adjustable in order to bring the oscillations of one train into phase with the oscillations of another train and energize said cutting electrode by oscillations practically free from the effects of damping.

Signed at Long Island City, in the county of Queens and State of New York, this 19th day of July 1928.

ARTHUR MUTSCHELLER.