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ELECTRICAL SURGICAL APPARATUS

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Fig. 1

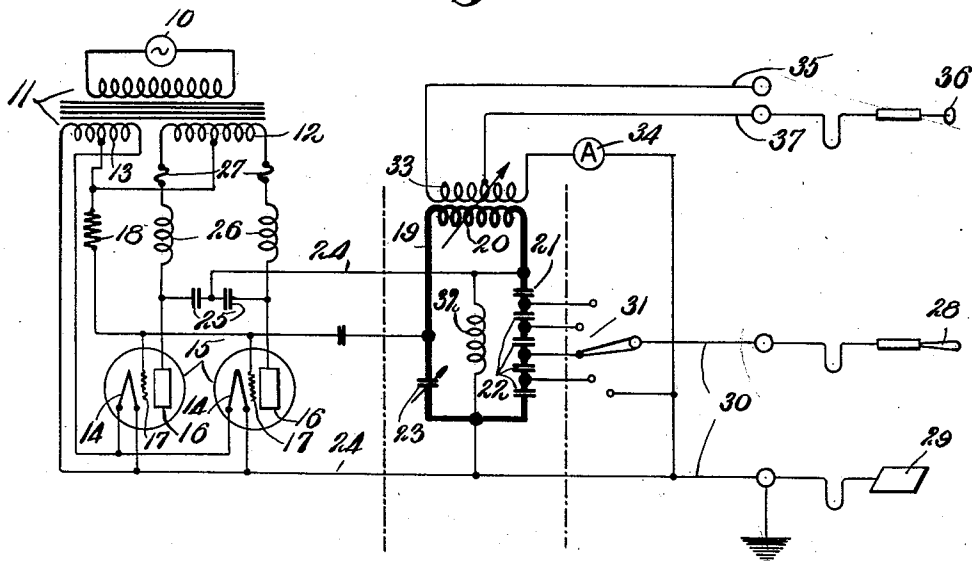
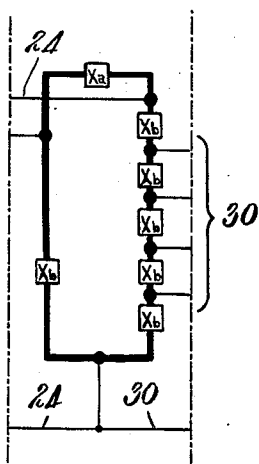


Fig. 2



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ELECTRICAL SURGICAL APPARATUS.

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This invention relates to the production and transmission of high frequency electrical oscillations for cutting, coagulating, heating and otherwise operating upon organic tissue or other matter, and particularly to apparatus adapted to supply high frequency oscillations for surgical and other medical work.

In apparatus available in the prior art for producing high frequency oscillations for surgical and medical purposes, such as for cutting, heating and other operations, many difficulties have been experienced in obtaining stable operation of the apparatus so as to obtain oscillations of suitable constancy of amplitude and effect, free from the influence of undesired currents. Various disturbing components of energy, particularly those of low frequency accompanying the high frequency oscillations, interfere with the desired operation of the apparatus and produce very unpleasant sensations and nervous reactions, sometimes making it impossible to carry out the desired operations. In many forms of apparatus serious injury or even death may be caused by abnormal currents resulting from maladjustment of the apparatus or failure of the insulation.

In prior apparatus for generating high frequency oscillations, the internal impedance of the output circuit for the high frequency current is so high that the terminal voltage varies considerably with slight variations of the current transmitted to the body being treated. As a consequence of this condition, it is very difficult to maintain the proper current density at the desired points in the medium being treated, especially when the area of contact of the operating electrode is varied. When contact is broken between the electrode and the medium being treated, the terminal voltage increases to such a high value that excessive sparking and consequent injury occurs in the vicinity of the spark. When tissue is being heated by high frequency currents, any increase in the density of the current above a critical value at a given point in the tissue results in coagulation or permanent injury to the tissue and similarly objectionable effects are produced when the current density is increased above the critical value while performing other operations.

One object of the present invention is to overcome the above difficulties and to provide apparatus for efficiently cutting, coagulating, heating or otherwise treating organic tissue or other matter by high frequency electrical oscillations, and to suppress undesired components of energy so that high frequency oscillations of a high degree of purity are produced and efficiently controlled as regards both amplitude and frequency, without the liability of the oscillations suddenly stopping when the load is varied.

Another object is to provide apparatus having an output circuit of such low internal impedance in comparison with that of the path of the current in the medium to which the high frequency oscillations are applied that the effect of the current at a given point in the path is substantially independent of the area of contact of the active electrode supplying the current, and a minimum amount of sparking occurs when contact is broken between the electrode and the medium.

In accordance with the present invention, high frequency oscillations of a high degree of purity are transmitted to one or more electrodes adapted for applying the oscillations to organic tissue or other matter to be operated upon. A closed tuned circuit having a natural frequency corresponding with that of the high frequency oscillations to be employed has a circuit of such low impedance in comparison with that of the path of the current in the matter being operated upon that the effect of the current at a given point in the path is substantially independent of variations in the area of contact of the electrode supplying current to the path. A high frequency choke coil is so connected with the tuned circuit that it shunts undesired current away from the output conductors of the apparatus and at the same time cooperates with a protective device located in the energizing circuit of the apparatus to interrupt the energizing current and prevent the transmission of abnormal current to the output conductors of the apparatus. The method of connecting the output conductors of the apparatus with the tuned circuit, in relation to the conductors which transmit oscillations to the tuned circuit, is such that the high frequency oscillations transmitted

to the output conductors are purified and the circuit operates with suitable stability over a wide range of loads.

These and other objects and features of the invention will be apparent from the following detailed description, in view of the accompanying drawing, in which:

Fig. 1 is a circuit diagram of one form of apparatus illustrative of the invention, and

Fig. 2 is a schematic diagram of a generic form of a portion of Fig. 1.

In Fig. 1, the source 10 of alternating electric current, ordinarily of commercial low frequency, transmits power to the primary winding of transformer 11 having a high voltage secondary winding 12 and a low voltage secondary winding 13. Winding 13 is connected to supply heating current to the cathodes 14 of vacuum tubes 15 of the electron discharge type, or other well known suitable space current devices. Winding 12 is connected with anodes 16 to supply space current to the tubes by rectification of the alternating current. Grids 17 of the tubes are connected to the midpoint of winding 13 by gridleak resistance 18. The midpoint of windings 12 and 13 are connected together.

The closed tuned circuit 19, having the inductance element 20 connected with a plurality of condensers 21, 22, 23 in series, is so connected with tubes 15 as to constitute therewith an oscillation generator of the well known Colpitts type, the frequency of the generated oscillations corresponding with that of the natural frequency of tuned circuit 19, being ordinarily of the order of a few hundred thousand to a few million cycles a second. The pair of conductors 24 transmit the generated high frequency oscillations from tubes 15 to a fractional part of the series of capacities 21, 22, 23 of tuned circuit 19, the upper conductor 24 being connected to the midpoint of the capacity coupling 25 consisting of two blocking condensers connected in series between anodes 16. Condensers 25 normally keep the high voltage direct current and most of the low frequency components of current from winding 12 and the rectifier from being applied to tuned circuit 19. Grids 17 are coupled with tuned circuit 19 by means of a capacity coupling. The frequency of the oscillations may be adjusted by variable condenser 23. A high frequency choke coil 26 in series with the conductor supplying current to each anode 16 prevents the transmission of high frequency oscillations from tubes 15 to winding 12. A fuse or other protective device 27 is provided in series with the conductor supplying space current to each anode to cause an interruption of the energizing current supplied to the tubes in case of an abnormally large current passing through the conductors.

The operating or active electrode 28 and the neutral electrode 29 are connected with the output conductors 30 of the apparatus, these conductors being directly connected with tuned circuit 19. The output conductors 30 are preferably connected, as shown, with a fractional part of the series of capacities 21, 22, 23, preferably with points in the series of capacitive elements 21, 22, 23 separated from each terminal of the series by at least one reactive element 21 and 23. The lower output conductor is preferably grounded. The neutral electrode 29 may be omitted by employing a return path by way of ground. The upper conductor 30 is connected with switch 31 which permits of varying the point of connection with the series of condensers 22 so that any desired voltage may be applied between the output conductors 30 or the internal impedance of the apparatus as seen from conductors 30, may be varied. To increase the voltage between the output conductors 30 or to increase the internal impedance of the apparatus as seen from output conductors 30, switch 31 is moved to its upper contacts while the converse movement of switch 31 produces a converse effect.

High frequency choke coil 32 is connected between one terminal of the series of condensers 21, 22, 23 at condenser 21 and a point in the series between condensers 22 and 23 for purifying the high frequency oscillations transmitted to output conductors, 30. Coil 32 is of high impedance to the high frequency oscillations which are to be employed and of low impedance to oscillations of lower frequency and undesired components of energy of low frequency are thus shunted away from the output conductors 30. At the same time, choke coil 32 cooperates with fuses 27 to cause either or both of the fuses to blow and interrupt the supply of space current to the tubes 15 in case of breakdown of the insulation of condensers 25. The impedance and resistance of the coil is so low that an excessive current is transmitted therethrough upon breakdown of either condenser 25, and the transmission of high voltage and undesirable low frequency currents to tuned circuit 19 is prevented. Condenser 21 provides added protection against the transmission to output conductors 30 of a high direct current voltage or low frequency components of voltage in case of breakdown of either condenser 25, and under normal operating conditions of the apparatus tends to increase the purity of the high frequency oscillations applied to output conductors 30.

Fig. 2 is a schematic representation of tuned circuit 19 of Fig. 1, showing generically the relation between the reactance elements in the tuned circuit and the connections therewith. The element X^a repre-

sents generically an element of any form having reactance of one sign, while elements X^b represent elements of any form having reactances of opposite sign from that of element X^a .

Inductance 20 serves as a primary winding for inducing high frequency oscillations in the secondary winding 33, one terminal of which is connected through ammeter 34 to the lower output conductor 30, the other terminal of winding 33 being connected with output conductor 35 with which an operating or active electrode, such as electrode 36, may be connected. Output conductor 37, shown connected with electrode 36, leads from an intermediate point in winding 33 for supplying low voltage and for providing a very low internal impedance between conductor 37 and lower conductor 30. The degree of coupling between winding 33 and winding 20 may be varied in any well known suitable manner to provide the desired voltage in windings 33 and to vary the reaction of winding 33 on winding 20.

Output conductors 30 are particularly adapted for supplying high frequency oscillations for cutting organic tissue as in surgery. The voltage may be varied at will by adjusting switch 31. The arrangement of condensers 21, 22, 23 is such that a wave of high purity is obtained free from disturbing effects of low frequency components of energy. The impedance of the apparatus, as seen from conductors 30, is so low that large variations may be made in the area of contact of the operating electrode without serious loss of operating efficiency. When employing cutting electrode 28, large variations may be made in the depth of the cut without loss of cutting power, the cutting effect of the current being satisfactory whether the cutting is being made at the surface of a body, or deep below the surface of the tissue, or below a liquid which covers the tissue, as in bladder operations.

Cutting electrode 28 may consist of a fine hair-like wire normally straight or looped back on itself, preferably supported in an insulating handle or may be of any well known suitable form of cutting electrode. The direct connection of electrode 28 with tuned circuit 19 and the grounding of the circuit permits a large current to be efficiently supplied at the desired point of cutting or other operations. Suitably steady oscillations may be obtained when the load on the oscillator is varied and the oscillations persist even up to the point where the output conductors are short-circuited. In case of excessive voltage being applied to conductors 24 through failure of the insulation of capacity coupling 25 or other cause, the patient or matter being operated is protected against abnormal current by the cooperating action of choke coil 32, fuses 27 and the terminal

condensers 21 and 23 of the series 21, 22, 23.

Electrode 36, as shown in the drawing, is a simple well known form of electrical conducting disc electrode adapted for coagulating, heating or otherwise operating on organic tissue or the like. When connected with output conductor 35 high frequency current of sufficient intensity may be obtained for coagulating tissue to which the electrode is applied. The intensity of the current is controlled by varying the coupling with winding 20. The low impedance of winding 33 permits of considerable variation in the area of contact of electrode 36 without serious variation in the desired effect. The impedance of the winding is high enough to keep the current from increasing at any one point near the electrode to a critical value above which cutting of the tissue would occur.

When electrode 36 is connected with output conductor 37, it is adapted for heating the body to which it is applied, the impedance of the portion of winding 33 between conductor 37 and lower conductor 30 being so low that the density of current at any point close to the electrode in the path of current through the tissue is substantially independent of the area of contact of the electrode. The density of the current in the tissue is thus maintained suitably constant, the voltage being low enough to keep the current below the critical value above which coagulation or cutting would occur and the area of the electrode may be considerably increased to provide heating current to a large section of tissue without seriously decreasing the desired heating effect at any point. By observing the indication of ammeter 34 and varying the coupling of windings 20 and 33, the high frequency heating current may be adjusted to any desired value below the critical value referred to above.

When electrode 36 is connected with output conductor 35 it is adapted for coagulating the tissue to which it is applied. The current density is higher than is obtained by connection to conductor 37.

The low impedance of winding 33, as seen from its full voltage terminals or its low voltage terminals, is so low that the voltage does not rise to an excessive value upon reducing the load connected with the electrodes. Serious sparking is thus avoided when the circuit is completed or broken at one of the electrodes.

I claim:

1. In apparatus for applying high frequency electrical oscillations to organic tissue or other matter to be operated upon, connections for an electron discharge device for producing said oscillations, said connections including a closed tuned circuit having a reactance element of one sign connected with

a series of separate reactance elements of opposite sign, and a pair of output conductors connected with said series of reactance elements at points in said series separated from each terminal thereof by at least one of the elements of the series.

2. In surgical and therapeutical apparatus, circuit connections for a source of high frequency electrical oscillations, said connections including a closed circuit tuned to the frequency of said oscillations, and connections for a space current device, said tuned circuit having an inductance connected with a series of condensers, said space current device connections including a pair of conductors connected in parallel with a fractional part of said series of condensers for transmitting oscillations from the space current device to said tuned circuit, and a pair of output conductors connected in parallel with a fractional part of said first mentioned fractional part for transmitting high frequency oscillations to the body to be treated.

3. In apparatus for applying high frequency electrical oscillations to organic tissue or other matter to be operated upon, connections for an electron discharge device for producing said oscillations, said connections including a closed tuned circuit having an inductance connected with a series of condensers, a pair of output conductors connected with said series of condensers at points therein spaced from each terminal of said series by at least one of the condensers of the series, and a high frequency choke coil connected to shunt current from said output conductors.

4. In apparatus for applying high frequency electrical oscillations to organic tissue or other matter to be operated upon, connections for an electron discharge device for producing said oscillations, said connections including a closed tuned circuit having an inductance connected with a series of condensers, a pair of output conductors connected with said series of condensers at points therein spaced from each terminal of said series by at least one of the condensers of the series, and a high frequency choke coil connected between one terminal of said series and the output conductor adjacent the other terminal of said series.

5. In apparatus for applying high frequency electrical oscillations to organic tissue or other matter to be operated upon, a space current device, means associated with said device including a tuned circuit and a source of space current whereby oscillations are produced, a pair of conductors connected with said circuit for transmitting high frequency oscillations to the organic tissue for other matter to be operated upon, means associated with said circuit for preventing the transmission of low frequency oscillations to said conductors, and a protective de-

vice associated with said circuit so arranged with respect to said transmission preventing means as to be operated to interrupt the supply of space current to said device when a predetermined abnormal condition occurs in said apparatus.

6. In apparatus for applying high frequency electrical oscillations to organic tissue or other matter to be operated upon, an active electrode, a neutral electrode, a pair of conductors for supplying the oscillations to said electrodes, a closed tuned circuit having an inductance connected with a series of condensers, said supply conductors being connected with said series of condensers at points in said series separated from each terminal thereof by at least one condenser of the series, an energizing circuit for said tuned circuit including a protective device and a capacity coupling, and means in shunt with a portion of said tuned circuit for preventing the application of abnormal current to said electrodes in case of breakdown of said capacity coupling and for cooperating with said protective device to cause the operation thereof.

7. In apparatus for applying high frequency electrical oscillations to organic tissue or other matter to be operated upon, an active electrode, a neutral electrode, a pair of conductors for supplying the oscillations to said electrodes, a closed tuned circuit having an inductance connected with a series of condensers, said supply conductors being connected with said series of condensers at points in said series separated from each terminal thereof by at least one condenser of the series, an energizing circuit for said tuned circuit including a fuse and a capacity coupling, and a high frequency choke coil in shunt with a portion of said tuned circuit for preventing the application of abnormal current to said electrodes in case of breakdown of said capacity coupling and for cooperating with said fuse to cause the interruption thereof.

8. In apparatus for applying electrical current to organic tissue or other matter to be operated upon, an active electrode, a neutral electrode, and a source of high frequency oscillations connected with said electrodes, said source having such a low impedance in comparison with that of the path of the current in the tissue that the effect of the current at any one point in the tissue close to the active electrode end of said path is practically independent of variations in the area of contact of said active electrode.

9. The method of employing a closed tuned circuit consisting of an inductance and a capacity for supplying high frequency electrical oscillations of a high degree of purity to surgical and therapeutical electrodes, which method comprises subdividing said capacity into a plurality of ca-

capacities connected in series, transmitting to said tuned circuit oscillations of a frequency corresponding to that of said tuned circuit, connecting said electrodes with said series
5 of capacities at points therein separated from both terminals of the series by at least one capacity, and shunting the connections for said electrodes with a path of high impedance to said high frequency oscillations
10 and of low impedance to currents of lower frequency.

10. In apparatus for supplying high frequency electrical oscillations for surgery and therapeutics, a closed tuned circuit, means
15 for transmitting waves thereto comprising a source of the type which produces a com-

plex wave containing high frequency oscillations adapted for surgery and therapeutics and components objectionable in surgery and therapeutics, a plurality of output con-
20 ductors for the desired high frequency oscillations adapted for surgery and therapeutics, connections for said conductors arranged with respect to said tuned circuit to transmit therefrom substantially only said
25 desired oscillations, certain of said connections being in parallel with portions of said tuned circuit, and other of said connections being reactively coupled therewith.

In witness whereof, I hereunto subscribe
30 my name this 10th day of November, 1925.

FREDERICK E. BAUER.