May 14, 1963 J. DEGELMAN 3,089,496

CONTROL SYSTEM FOR SURGICAL APPARATUS

Filed Aug. 19, 1959 2 Sheets-Sheet 1

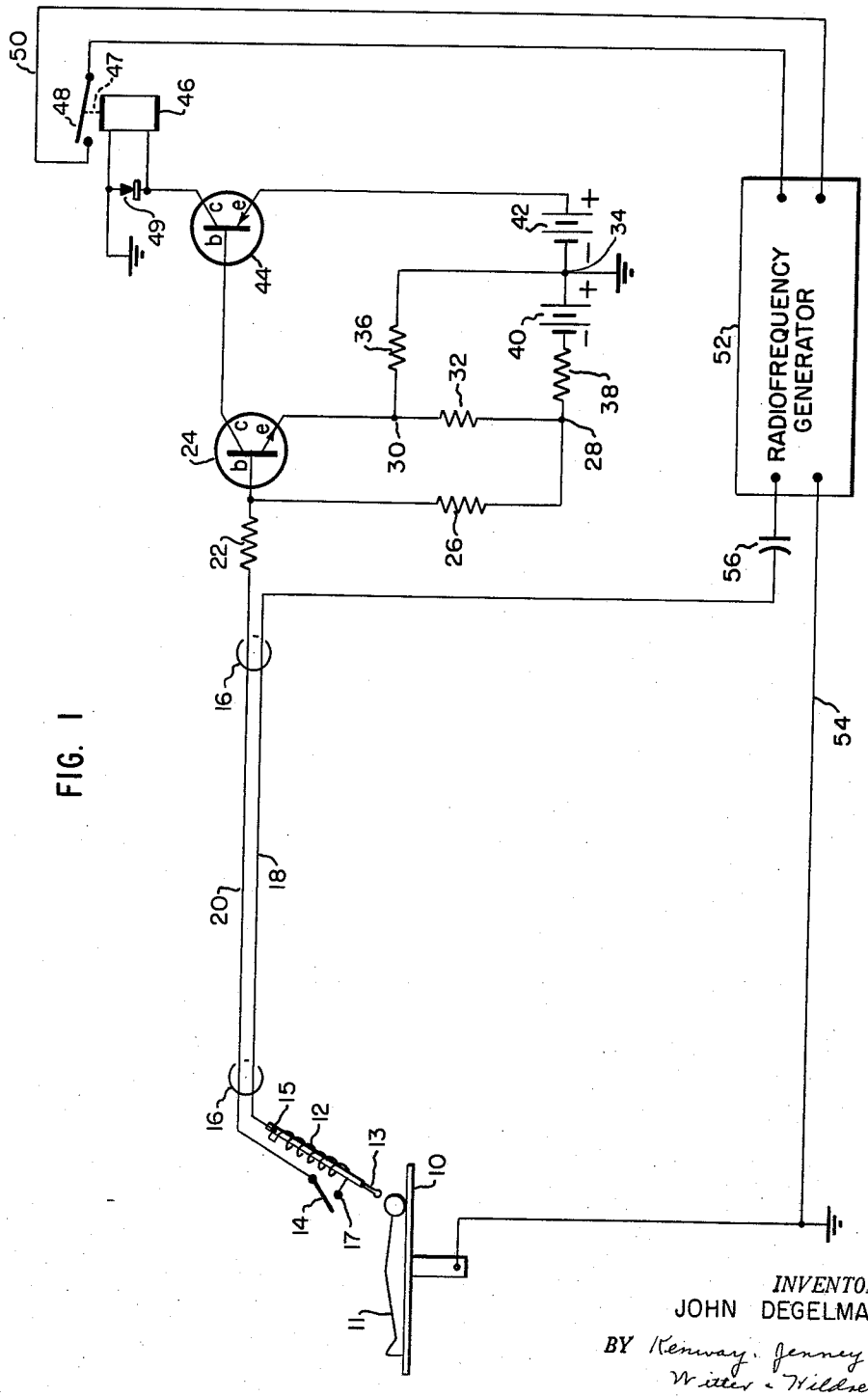


FIG. 1

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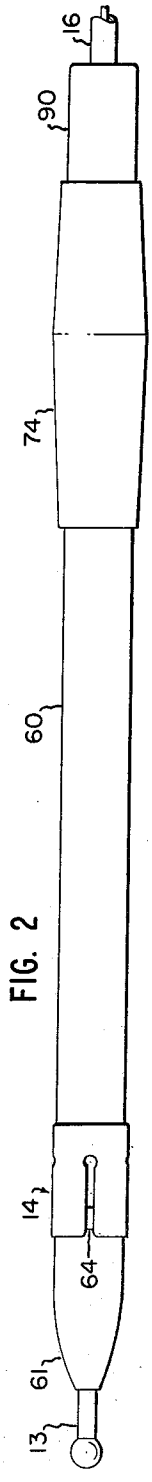


FIG. 2

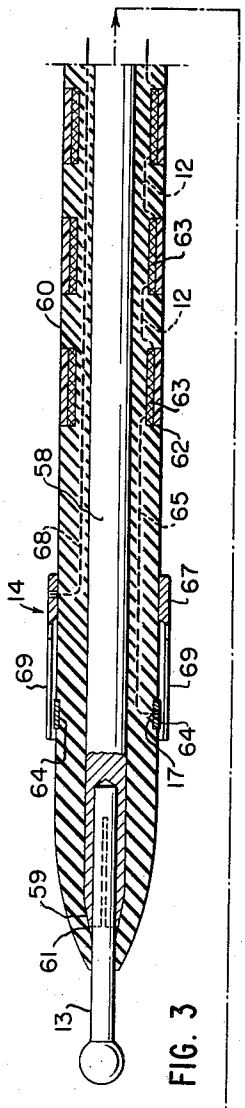
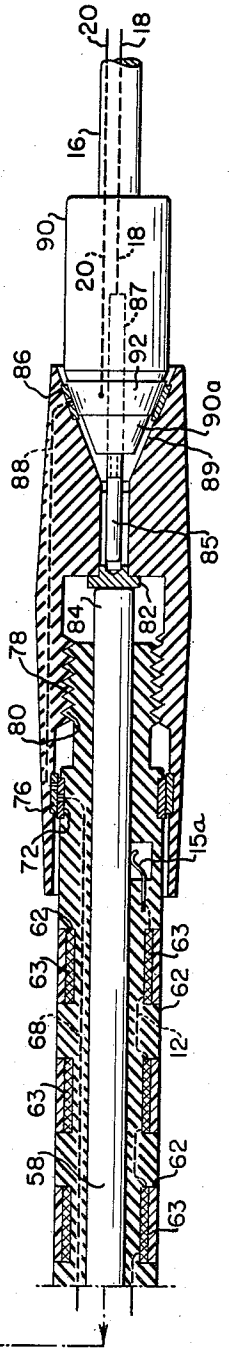


FIG. 3



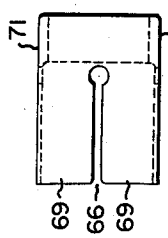


FIG. 4

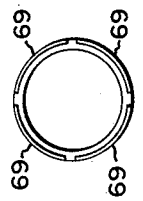


FIG. 5

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CONTROL SYSTEM FOR SURGICAL APPARATUS

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My invention relates in general to new and improved surgical apparatus, and in particular to surgical apparatus wherein high frequency electrical current is used for the cutting of tissue as well as for the coagulation of blood and the sealing of small blood vessels in the tissue to stop bleeding in the course of surgery.

Apparatus presently available for the use of high frequency currents for surgical purposes generally consists of a non-conductive, pencil shaped electrode holder or probe in one end of which a surgical electrode is positioned. A suitably insulated cable, attached to the other end of the electrode holder supplies high frequency energy to the surgical electrode which is derived from an appropriate radio frequency generator. When in use, the surgeon applies the electrode to the tissue, while simultaneously operating a foot switch which governs the output of the radio frequency generator. This arrangement forces the surgeon to assume a position which is difficult to maintain for long periods of time. Some surgical procedures may last for hours during which time intense concentration is required on the surgeon's part. Since practically no weight can be placed on the foot which operates the foot switch, except during such time as high frequency energy is to be supplied to the electrode, the surgeon is forced to stand on one foot with the other foot poised over the switch on the floor. The situation is not improved materially where an assistant is charged with operating the foot switch at the command of the surgeon. The presence of such an assistant creates an additional distraction for the surgeon and increases by one the number of persons required to assemble around the operating table. When the foot switch is operated by the surgeon or by an assistant, it and the cable connected thereto are generally located under the operating table and thereby add to the clutter and confusion of the operation.

The foregoing disadvantages are overcome in part by the apparatus disclosed in my United States Patent No. 2,827,056, issued March 18, 1958, wherein the radio frequency generator is turned on when contact between the surgical electrode and the tissue is established and is turned off upon removal of the electrode from contact with the tissue. However, in use it has been found that the probe also delivers radio frequency power when accidentally touched to any conductor, e.g. wet drapes or nearby personnel who must necessarily wear conducting shoes to carry off any static charges to the grounded floor of the operating room. The apparatus disclosed by the patent, although useful for sealing and coagulating blood vessels near the surface, has been limited in its application, particularly where the cutting of tissue proceeds at any appreciable depth. In the latter case it is not always practical to withdraw the electrode completely when no cutting is in progress. Furthermore, the surgeon frequently desires to make safe and tentative contact with the tissue prior to the actual cutting operation.

Accordingly, it is a primary object of this invention to provide high frequency surgical apparatus which overcomes the foregoing disadvantages.

It is another object of this invention to provide high frequency surgical apparatus of the type described which will enable the surgeon to give complete attention to this

work while permitting him to assume a relaxed position throughout the operation.

It is a further object of this invention to provide surgical apparatus of the type described which permits the precise control of high frequency current to a surgical electrode while allowing tentative contact with the patient's tissue without the application of high frequency current.

In brief, the invention comprises a probe having a surgical electrode which is energized from a radio frequency power generator. The application of power is controlled by means of a control circuit which is coupled to a point of reference potential as for example ground. A finger switch is provided on the probe and must remain closed so that the control circuit can permit the radio frequency generator to operate. The tissue to be cut is conductively coupled to the reference potential, e.g. through a conductive operating table, in order that the contacting surgical electrode may complete the circuit. As a result, the surgeon is enabled to interrupt the application of radio frequency power to the surgical electrode either by removing the electrode from contact with the tissue or by releasing pressure on the finger switch which is disposed on the probe itself. In order that the finger switch on the probe will be at a low radio frequency potential, I have developed an improved probe which incorporates therein a highly efficient radio frequency choke which has previously been mounted separately as part of the control circuit. I have also developed a control circuit utilizing transistors rather than vacuum tubes previously used with a consequent increase in reliability, shock resistance and economy.

These and other objects of my invention together with further features and advantages thereof will become apparent from the following detailed specification when read together with the accompanying drawings, in which:

FIG. 1 illustrates the invention in schematic form;

FIG. 2 is a side elevation of the improved probe used in my invention;

FIG. 3 is a longitudinal section (some parts being shown in full line for greater clarity) of the probe of FIG. 2;

FIG. 4 illustrates the finger switch in greater detail; and

FIG. 5 is an end view (of the left hand end) of the structure shown in FIG. 4.

With reference now to FIG. 1 of the drawings, reference numeral **11** generally indicates the patient upon whose body tissue surgical cutting or coagulating is to be performed, using high frequency surgical apparatus. The patient is supported on an operating table **10** which is conductively coupled to a point of reference potential, preferably ground. Since the table itself is conductive, the tissue which is to be operated upon is conductively coupled through the patient's body and the operating table to ground. Alternatively, grounded electrodes may be attached directly to the patient. A surgical electrode **13** performs the actual cutting or coagulating function and is connected to a radio frequency line **18** which is disposed in cable **16**. The line **18** supplies current at radio frequency to the electrode. This current is derived from a radio frequency generator **52** which is coupled to the line **18** by means of a blocking condenser **56**, which is sufficiently large so that it presents negligible impedance at the generator frequency. The other output terminal of the radio frequency generator **52** is tied to ground so that a complete radio frequency circuit is established when the electrode **13** contacts the tissue of the patient **11**. The radio frequency power generator further includes a control circuit **50** which includes an operating switch **48** connected in series. The switch **48** is normally open to

prevent the application of radio frequency energy to the surgical electrode 13.

A choke coil 12 mounted on the holder for electrode 13 has one terminal 15 connected to the electrode holder while its other terminal 17 is connected to one contact of the finger operated switch 14. The other contact of the switch 14 is connected to a control line 20 which is disposed in cable 16 together with the radio frequency line 18. The control line 20 is coupled, by means of a resistor 22, to the base of a control transistor 24, the electrodes of which are labeled with their corresponding initials i.e. "*b*" for base, "*c*" for collector and "*e*" for emitter. The base of transistor 24 is coupled to a junction point 28 by means of a resistor 26. The junction point 28 is connected to the emitter of transistor 24 by a resistor 32 and to a ground connection 34 by means of a resistor 36. A direct voltage bias source 40 has its positive terminal tied to the ground connection 34. A resistor 38 is connected in series between the junction point 28 and the negative terminal of the bias source 40 and thus permits the application of the proper bias voltage between the emitter and the base of transistor 24. A control circuit is thus established which includes in series, connection 34, resistors 38, 26 and 22 respectively, control line 20, finger switch 14, inductance 12, electrode 13 and the patient who is conductively coupled to ground. The control circuit further includes transistor 24 and its associated connections. It further includes power transistor 44 whose base is connected to the collector of control transistor 24. The emitter of power transistor 44 is connected to the positive terminal of a direct voltage power source 42 whose negative terminal is tied to the ground connection 34, thus biasing the emitter base diode for conduction. The collector of transistor 44 is connected to a relay coil 46 whose other terminal is connected to ground. A diode 49 is connected in parallel with the relay coil 46. A relay armature 47 which is controlled by the relay coil 46, is mechanically coupled to the switch 48 in order to operate the latter.

In operation, a conductive connection is established between the electrode 13 and ground when the electrode is placed in contact with the patient's tissue. Even though contact is made by the surgical electrode, the control circuit 50 is not completed until the finger switch 14 is closed. The magnitudes of the resistors 32, 36 and 38 of the control circuit are chosen so that, until the finger switch is closed the voltage applied between the emitter and base of the transistor 24 by the bias source 40 causes the base of transistor 24 to be negative with respect to the emitter, thus cutting the transistor off. The absence of current flow through the collector of the control transistor 24 prevents base current, and therefore collector current, in transistor 44. The absence of current flow in the collector of the transistor 44 maintains the relay coil 46 in its unenergized condition. The relay armature 47 then remains in the position shown in FIG. 1 and the operating switch 48 remains open to prevent the application of radio frequency power to the surgical electrode 13.

If the finger switch 14 is closed while the surgical electrode 13 remains in contact with the patient's tissue, the control circuit is completed, and the base of the transistor 24 being grounded through resistor 22, by the closing of the switch rises in potential to a value slightly above the emitter voltage. Transistor 24 begins conducting. The voltage at the base of transistor 24 when the switch 14 is closed depends upon the relative values of resistors 22, 26 and 38. The absolute values of these resistors are chosen to limit the total current flowing in the control circuit to a very small value, e.g. 50 microamperes. This condition permits the emitter-base diode of transistor 44 to conduct in turn permitting current flow in the collector of transistor 44. Relay coil 46 is energized and relay armature 47 is actuated, closing the operating switch 48. With its control circuit 50 completed and

with the radio frequency circuit closed as long as the surgical electrode maintains contact, the generator 52 now supplies radio frequency energy to the surgical electrode 13.

Thereafter, if the surgeon wishes to interrupt the application of energy to the surgical electrode 13, he can do so either by opening finger switch 14 or by withdrawing the electrode from contact with the patient's tissue or both. Where the finger switch is opened, the control circuit is broken and the transistors 24 and 44 respectively are again cut-off. The operating switch 48 then resumes its normally open position and cuts off the radio frequency power source. When the electrode is withdrawn from contact with the tissue, both the radio frequency circuit as well as the control circuit are interrupted since both rely for their completion on a conductive coupling to ground through the patient.

As shown in FIG. 1, it might be considered possible for control line 20 to be grounded through the hand of the surgeon on the conductive finger switch 14, and thence through the surgeon's body, and his conducting shoes to grounded operating room floor. Thus it might be possible for the relay 46 to be operated even though switch 14 is not closed. However, the surgeon's hand is insulated from the switch 14 by the rubber or plastic gloves worn during most surgical procedures. Further, the portion of the switch 14 coming in contact with the surgeon's hand may be covered with an insulating coating if desired.

The function of the blocking condenser 56 is to prevent feedback of any direct currents from the control circuit in lead 20 to the generator 52. Similarly, the connection of the choke 12 between the surgical electrode 13 and the finger switch 14 provides a high impedance at radio frequencies while maintaining a conductive path for the direct control current. It will be noted, that terminal 17 of choke coil 12 represents the low radio frequency voltage terminal, since the voltage drop at the radio frequency takes place between terminals 15 and 17. Since the low voltage terminal 17 is connected to the finger switch 14, the surgeon's finger is in no danger of receiving shocks or burns.

FIGS. 2 and 3 illustrate in greater detail the improved probe which is used with the circuit of FIG. 1. A hollow, cylindrical barrel 60 made of an electrically nonconducting plastic material has an interior constriction 61 adjacent the front end of the barrel. Since the probe rests in the surgeon's hand during the operation, it is preferably of a diameter and weight convenient for such handling. An electrode clamp rod 58 is positioned concentrically within the barrel and is adapted to abut the interior barrel constriction 61. The electrode clamp rod includes a set of jaws 59 which hold the surgical electrode 13 when the clamp rod is forced against the interior constriction. The rod 58 is preferably of chrome-plated soft iron and is conductive throughout its length; it is adapted to supply radio frequency power to the surgical electrode 13.

The barrel 60 includes a number of circular grooves 62 in its exterior wall. As seen from FIG. 3, the grooves are spaced along the length of the barrel. A plurality of windings forming a choke coil 12 are positioned within the grooves formed in the barrel and surround the electrode clamp rod 58. The electrode clamp rod thus serves the additional function of a choke coil to increase the inductance of the choke at radio frequencies. The coils 63 are preferably embedded in an epoxy resin or the like. The terminal 15 of the choke coil 12 is connected to the electrode clamp rod 58 by the spring contact 15*a*. The other terminal 17 of the choke coil is connected to a ring contact 64 which surrounds the exterior of the barrel near the front end thereof. The ring contact 64 forms one part of the finger switch 14 while the other finger switch portion consists of an annular metal clip 67 which surrounds barrel 60. From FIGS. 4 and 5

it will be seen that the metal clip comprises four slots 66 which divide the left hand portion of the clip into four resilient metal leaves 69. The metal leaves are conductively connected together by means of the ring-like portion 71 which firmly engages the outside of barrel 60. Leaves 69 flare outwardly with respect to the barrel so as to be normally out of contact with ring contact 64. The pressure of the surgeon's finger on any one of resilient leaves 69 has the effect of closing switch 14 and completing the control circuit if the surgical electrode makes contact. The particular construction adopted herein enables the surgeon to turn the probe in any desired manner about the barrel axis without being forced to search for the finger switch.

A ring contact 72 (see FIG. 3) is disposed on the barrel near the rear end thereof and is connected to the metal clip 67 by means of an electrical conductor 68. The rear end of barrel 60 includes a threaded portion 80 which is hollow to permit the end 84 of the electrode clamp rod 58 to protrude beyond the barrel. A screw sleeve 74 fits over the rear end of the barrel 60 and has an interior threaded portion 78, the threads of which engage the threaded portion 80 of the barrel. The screw sleeve 74 further includes a sleeve contact 76 which is adapted to make electrical contact with the ring contact 72 when the screw sleeve 74 is in position on the rear end of the barrel. The opposite end of the screw sleeve includes a second sleeve contact 86 which is electrically connected to the sleeve contact 76 by means of a wire 88. A radio frequency contact 82 is disposed centrally of the screw sleeve 74 and is adapted to engage end 84 of the electrode clamp rod 58 when the screw sleeve is in position. The radio frequency line contact 82 not only forms an electrical connection with the electrode clamp rod, but also applies pressure on the clamp rod to force it against the interior constriction 61 causing jaws 59 to clamp electrode 13 in place. The right-hand end of the screw sleeve 74 (as seen in FIG. 3) contains an interior taper which extends to the radio frequency line contact 82. A cable connector 90 has a tapered portion 90*a* which engages the tapered interior 89 of the screw sleeve. The cable connector 90 is seen to receive cable 16 which contains the radio frequency line 18 and the control line 20. A ring contact 92 which is disposed on the tapered portion of the cable connector 90, is connected directly to the control line 20. The radio frequency line 18 is connected to a radio frequency line connector 87 whose swiveled end 85 is adapted to engage the radio frequency line contact 82 which is disposed in the screw sleeve 74.

With the surgical apparatus described above, the surgeon is free to concentrate on his work without having to give any attention to the operation of the probe. The probe may be freely handled by the surgeon due to its swiveled rear end cable connection and because the finger switch is equally accessible in any desired position. The electrode clamp rod serves the dual purpose of holding the surgical electrode and of increasing the inductance of the choke at radio frequencies. Owing to the high inductance which results from this construction, a high voltage drop occurs across the choke at radio frequencies which permits the surgeon to contact the finger switch without the danger of receiving any shock or burn.

The specific embodiment of the invention disclosed in the foregoing specification and drawings, is for the purpose of illustration only. Numerous modifications, departures and equivalents may now occur to those skilled in the art, all of which fall within the true spirit and scope of the invention.

I claim:

1. Surgical apparatus for operating on tissue which is conductively coupled to a point of reference potential, comprising a probe including a surgical electrode protruding therefrom, means for applying high frequency energy between said electrode and said reference point, conductive coupling means connected to said electrode, said coupling means presenting a high impedance at said high frequency, control means including a relay, having a coil and at least one set of contacts, a relay control circuit and a voltage source, both said relay control circuit and said voltage source being connected to said point of reference potential, switching means having a pair of contacts disposed on said probe, means connecting one contact of said switching means to said coupling means and means connecting the other contact of said switching means to said relay control circuit, the contacts of said relay being normally open and being connected so as to interrupt the application of high frequency energy to said electrode when said relay contacts are open, means connecting said relay control circuit between the coil of said relay and said voltage source, said control circuit causing energization of said relay coil when said switching means is closed and said electrode is in contact with said tissue.

2. The apparatus of claim 1 wherein said probe further comprises a conductive electrode clamp rod adapted to hold said electrode, said conductive coupling means comprising a choke coil surrounding said clamp rod.

3. The apparatus of claim 1 wherein said switching means comprises an annular metal clip surrounding said probe, said clip having a plurality of resilient outwardly flaring leaves encircling said probe, said leaves being conductively joined together at one end, a conductive ring encircling said probe, said resilient leaves being normally out of contact with said ring, any one of said leaves being adapted to establish electrical contact with said ring.

4. The apparatus of claim 1 wherein said relay control circuit comprises a first transistor having its base coupled to said switching means by means of a first resistor, a second resistor connected between a junction point and said transistor base, a third resistor connected between said reference point and the emitter of said first transistor, a fourth resistor connected between said transistor emitter and said junction point, a second direct voltage source providing bias for said transistors, said second source having one terminal connected to said reference point, a fifth resistor being connected between the other bias source terminal and said junction point, a second transistor having its base coupled to the collector of said first transistor, said direct voltage power source being connected between said reference point and the emitter of said second transistor, said relay coil being connected between the collector of said second transistor and said reference point, a diode shunted across said relay coil, said resistors being chosen to reduce the normally cut-off biasing voltage applied between the emitter and base of said first transistor when said switching means is closed and said surgical electrode is in contact with said tissue.

5. Surgical apparatus for operating on a body which is conductively coupled to a point of reference potential comprising, in combination, a source of high frequency energy having a pair of output terminals and a pair of control terminals, means connecting a first of said output terminals to said point of reference potential, a surgical electrode, means connecting a second of said output terminals to said electrode, a relay having a coil and at least one set of contacts, means connecting the contacts of said relay to the control terminals of said high frequency source whereby upon energization of said relay, said source will energize said electrode, a finger operated switch having at least one pair of opposing contacts, a high frequency choke coil connecting one of said finger operated switch contacts to said electrode, a source of direct voltage having two terminals, one terminal of said voltage source being connected to said reference potential source, a relay control circuit, means connecting said relay control circuit between the other terminal of said direct voltage source and the coil of said relay, means connecting the other of said switch contacts to said control circuit, said control circuit being connected to said source of reference potential the reference potential ap-

plied to said control circuit upon closure of said finger switch when said electrode is touching said body causing operation of said relay and energization of said surgical electrode by said high frequency energy source.

6. The combination defined in claim 5 in which the means connecting the second output terminal of said high frequency energy source to said surgical electrode includes means for blocking the flow of direct current.

References Cited in the file of this patent

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