

[54] ELECTROSURGERY INSTRUMENT
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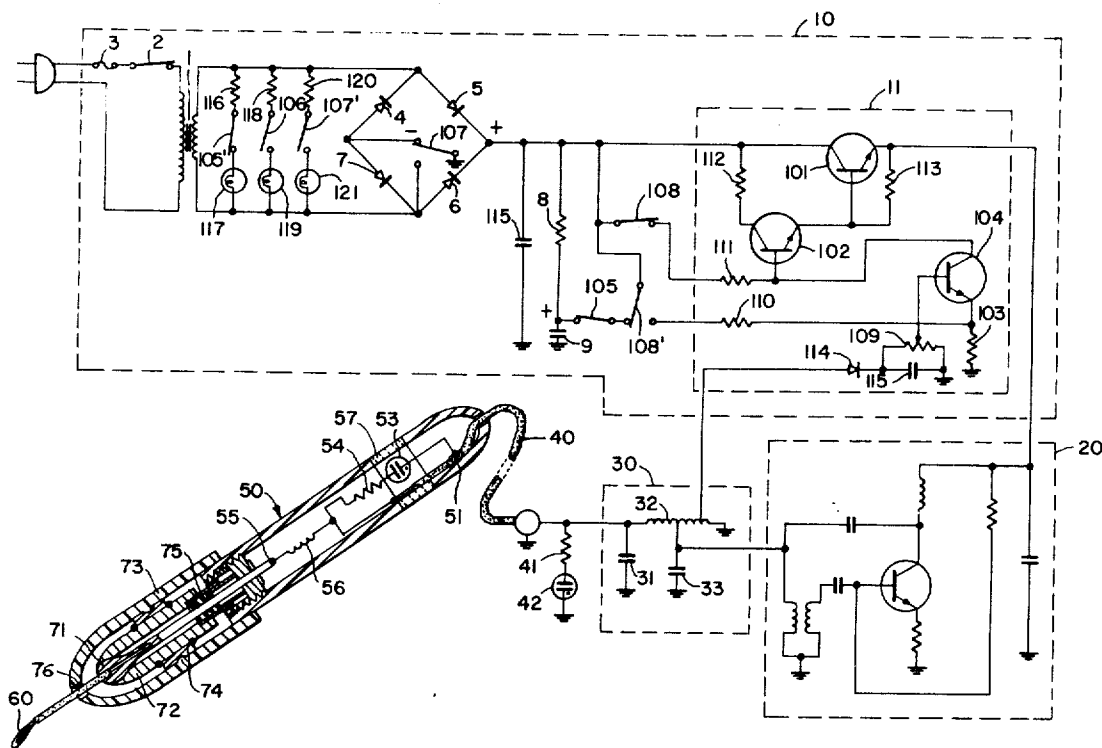
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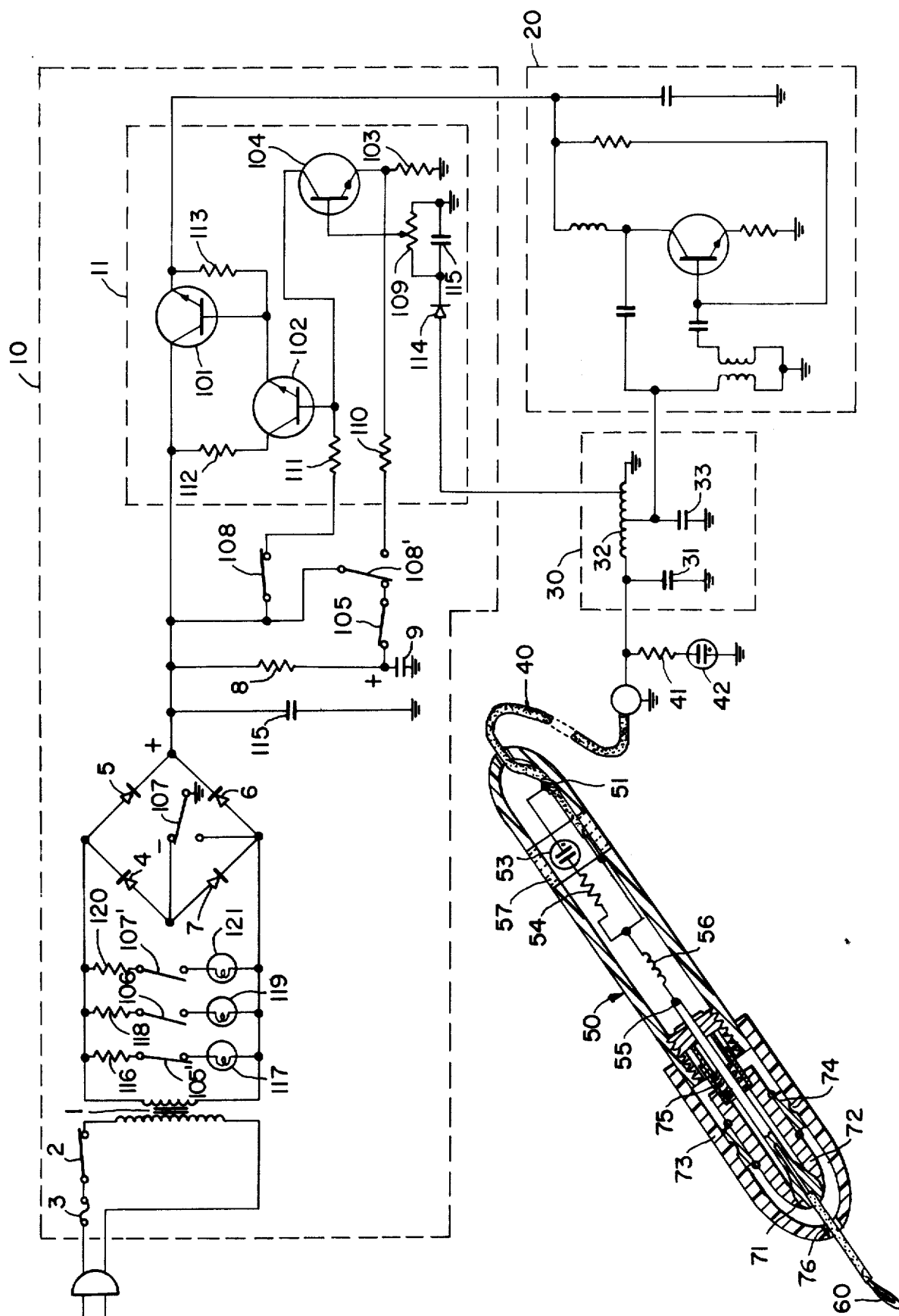
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[57] **ABSTRACT**

An electrosurgery instrument having a radio frequency oscillator energized from a power supply controlled by a switching arrangement to produce either dc, full wave rectified ac, or half-wave rectified ac at its output, depending upon whether it is desired to operate in the cut, coagulate, or fulgurate modes, respectively. The level of output voltage of the power supply may be set to any value within a range and thereafter increased by a fixed percentage upon the operation of a remote control switch. The level of output voltage in any mode of operation, once set, is regulated by a feedback control circuit to minimize sparking at the electrode tip. The oscillator output is coupled to an operating probe through an impedance transformer and coaxial cable designed to deliver maximum radio frequency power to the patient without the use of a ground plate. An indicating lamp is connected to points of different potential in the cable and within the probe in order to give a positive indication of the presence of radio frequency power at the probe tip.

7 Claims, 1 Drawing Figure





ELECTROSURGERY INSTRUMENT

The present invention relates to electrosurgery instruments and, more particularly, to an electrosurgery instrument capable of efficiently delivering an adjustable quantity of radio frequency power for use in a selected one of three modes of operation.

For many years various types of surgical tools using electrical energy have been used to carry out various medical and dental operations. Early instruments utilized spark gap current to burn tissue and, while this was satisfactory for operations where the purpose was destruction of tissue, it was unsatisfactory where it was used to make an incision or for hemostasis with a minimum of necrosis and other undesirable histological changes in adjacent tissue.

Improved instruments, utilizing radio frequency electromagnetic or diathermy energy, overcome some of these limitations but nevertheless suffer from certain disadvantages which have limited their utility. For example, a number of existing radio frequency electrosurgical devices utilize vacuum tubes with their concomitant bulk, delay for warm up time, excessive heat generation and poor reliability. Other such units are hazardous to the patient and operator in that they require ground plates to minimize the patient to ground impedance and to complete the radio frequency circuit, or they lack effective means for accurately indicating a "hot" electrode tip. Illustratively, units requiring a ground plate may not only hinder the operator and present a psychological deterrent to an already apprehensive patient, but they also suffer the disadvantage of subjecting the patient to the possibility of radio frequency burn where non uniform contact is made between the ground plate and the patient's skin, or where, by reason of an unsuspected intermittent break in the plate-connecting wire, the operator finds it necessary to increase the output power level only to find that the output increases still further when the break is reconnected. Still other radio frequency electro-surgery units lack effective means for giving a true indication that the tip is energized and thus give rise to the possibility of severe burns if the "hot" tip is inadvertently touched or wiped to remove tissue therefrom. Another significant disadvantage in existing electrosurgery units is the lack of versatility where there are but two output wave forms to choose from, for it is often desirable to have available an intermediate operational mode for coagulation as well as a cutting mode, designed for incision with a minimum of tissue destruction, and a fulguration mode, designed primarily for tissue destruction. Other such instruments fail to provide the operator with means enabling him to switch from one operational mode to another without taking his eyes from the site of surgery.

Accordingly, it is an object of my invention to provide a compact, efficient, reliable and versatile electrosurgery unit which utilizes radio frequency power and overcomes the shortcomings of the prior art.

It is still another object of my invention to provide a radio frequency electrosurgery instrument which operates efficiently without the need for a ground plate.

It is another object of my invention to provide a radio frequency electrosurgery instrument which affords the operator an opportunity to select from amongst three modes of operation designed primarily for cutting, coagulation, and fulguration, respectively.

It is still another object of my invention to provide a radio frequency electrosurgery instrument in which the operator may quickly switch from one mode of operation to another without diverting his attention from the site of surgery, or removing his hands from the electrode handpiece.

It is yet another object of my invention to provide an electrosurgery instrument in which there is a positive indication of a "hot" tip to prevent inadvertent injury to the patient, operator, or operator's assistant.

In most existing radio frequency electrosurgery instruments the operating voltage at the cutting tip varies markedly as contact is made and broken between the cutting tip and the tissue being cut. When this occurs sparking takes place, causing undesirable damage to the tissue.

Accordingly, it is another object of my invention to provide an electrosurgery instrument in which the radio frequency voltage applied to the cutting tip is kept constant, independent of the probe tip to ground impedance.

In accordance with the foregoing and other objects and features of the invention, I have provided an electrosurgery instrument in which a power supply connected to a radio frequency oscillator delivers power over a coaxial cable to a probe containing a surgical tip held in place by a spring loaded or other chuck. The instrument is designed to permit the operator to select from amongst three modes of operation by means of a switching arrangement that causes the power supply to deliver either a dc voltage, a full wave rectified ac, or a half-wave rectified ac as the supply voltage to an r.f. oscillator. The electrode tip coupled to the output of the oscillators is thus energized with a radio frequency voltage which is either unmodulated for operation in the cut mode, or modulated with a 60cps signal for operation in the coagulate mode, or modulated with a 120cps signal for operation in the fulgurate mode.

After the unit is turned on, the particular mode of operation is selected by first actuating a corresponding switch on a console control panel and thereafter enabling the first stage of a two position control switch remotely located from the console in the area of the patient. This switch may be foot operated or be mounted within the hand probe proximate to the cutting tip. The operator may, by increasing the pressure on the control switch, enable the second stage of the switch to increase the level of output voltage from the power supply and consequently the peak level of radio frequency output power. And when the instrument is being operated in the cut mode, engagement of the second stage of the control switch also causes operation to switch into the coagulation mode.

The instrument also incorporates an impedance transformer, for matching the oscillator low output impedance to the higher patient to ground impedance for the efficient transmission of power without the need of a ground plate, and an indicating lamp, connected within the probe to give positive, reliable indications of a "hot" tip.

These and other objectives and features of my invention will be better understood if reference is had to the following detailed description and accompanying drawing depicting a schematic circuit and probe construction used in my invention.

Referring now to the drawing, the electrosurgery instrument includes a power supply 10 driving an oscilla-

tor 20 which is coupled by means of an impedance transformer 30 to a coaxial cable 40 terminated in a surgical probe 50 containing a cutting tip 60.

The basic components of power supply 10 include a step down transformer, a bridge rectifier and filter and a voltage regulator circuit. Also connected to control the power supply is a remote control two stage switch 108 and 108'.

Step down transformer 1 is arranged so that its primary winding is connected through a normally open switch 2 and a fuse 3 to the 110 volt source of power. The secondary of transformer 1 is connected to a full wave bridge rectifier comprising diodes 4, 5, 6 and 7. A filter circuit, consisting of resistor 8 and electrolytic capacitor 9, is connected between the positive output terminal of the bridge circuit and ground. An output voltage regulating circuit 11 is connected between the positive output terminal of the bridge circuit and the output of the power supply.

Power supply 10, oscillator 20 and impedance transformer 30 may all be included within a console containing on-off switch 2 and mode switches 105, 105', 106, 107 and 107' as well as indicating lamps 117, 119 and 121. Switches 105 and 105' are mechanically coupled as are 107 and 107', and switches 105, 106 and 107 are mechanically interlocked so that only one may be actuated at a time. A two stage spring loaded control switch 108 and 108', remotely situated from the console in the area of the patient, also forms part of the circuit for the electrosurgical instrument.

The drawing depicts the circuit as it exists when line power is applied to the instrument, the cut mode of operation is selected at the console and the first stage only of the control switch is actuated. Under these circumstances on-off switch 2 is closed, cut switch contacts 105' are closed to deliver ac power from the secondary of transformer 1 through limiting resistor 116 to lamp 117 located under the cut mode switch button, the normally open contacts 108 in the first stage of the control switch are closed and the single pole double throw contacts of switch 108' are as shown to connect resistor 111 through the closed contacts of switches 108, 108' and 105 to the positive terminal of capacitor 9. At the same time resistor 8 is shorted through switches 108' and 105.

When the pressure on the control switch is increased sufficiently to actuate the second stage of the control switch, contacts 108 remain closed and the position of contacts 108' are changed to remove the short across resistor 8 and connect the emitter of transistor 104 through resistor 110 to the positive output terminal of the bridge rectifier circuit. Now resistor 8 is connected in series between the positive terminal of the bridge rectifier and capacitor 9. Resistor 111 remains connected to the positive terminal of the bridge rectifier.

When normally open switch 105 is actuated for the cut mode of operation, the contacts of coagulate mode switch 106 are open and the contacts of the fulgurate mode switch 107 and 107' are as shown with ground connected to the negative output terminal of the bridge circuit. With the first stage of the control switch actuated as shown, a full wave rectified ac voltage is produced at the output terminals of the bridge circuit and thereafter filtered to deliver dc power to the input of the oscillator which in turn produces an unmodulated radio frequency signal at its output. The filter circuit consists of capacitor 9 connected directly across the

output terminals of the bridge circuit inasmuch as resistor 8 is shorted through the contacts of switches 105 and 108'. Capacitor 9 must be large enough to provide a relatively smooth, ripple free dc voltage across its terminals.

A feedback circuit is provided to regulate the voltage at the cutting tip in order to keep it constant at a selected value in the face of varying load impedance. A portion of the radio frequency voltage at the output of oscillator 20 -- e.g., the voltage drop between the input and first tap in inductance 32 of impedance transformer 30 -- is rectified by diode 114 and thereafter filtered by capacitor 115 connected in parallel with potentiometer 109. A portion of this rectified and filtered voltage is picked off by the wiper of potentiometer 109 and impressed upon the base of transistor 104 which is connected as an inverting amplifier. Transistors 102 and 101 connected as Darlington emitter followers are connected between the collector-output of transistor 104 and the output of power supply 10. The emitter voltage of transistor 101 follows the base voltage of transistor 102. Since the collector of transistor 104 is connected to the base of transistor 102, the emitter voltage of transistor 101, which is the dc supply voltage for oscillator 20, follows the collector voltage of transistor 104.

Thus, if the wiper of potentiometer 109 is set closer to its grounded end, a smaller voltage is applied to the base of transistor 104 causing its collector voltage to increase. This, in turn, causes the emitter voltage at transistor 101, and thus the output voltage of power supply 10, to increase. Since the output voltage of rf oscillator 20 is proportional to its dc input voltage, it is controlled by the dc voltage at the emitter of transistor 101. Accordingly, the rf output voltage at the tip of probe 60 is adjusted by moving the wiper of potentiometer 109 -- the closer the wiper is to ground, the higher the output rf voltage applied to cutting tip 60.

As is well known in the art, the tip to ground impedance varies considerably during operation. Thus, for example, tip to ground impedance when the tip is not in contact with the patient's tissue is substantially greater than when contact is made. Unless this variation in impedance is compensated for, the rf voltage at the probe tip will vary during operation, producing a high voltage when the tip is separated from the tissue being cut and a much lower voltage when the tip is in contact with the tissue. And when the voltage increases as described, sparking occurs between the tip and the tissue being cut, causing undesirable tissue damage. It is a prevent this, as well as to make the output independent of power line variations, that I have provided the voltage regulating circuit 11.

By means of the negative feedback arrangement described, any rf voltage increase at the tip of the probe above the level set by potentiometer 109, is detected by diode 114. After passing through the wiper of potentiometer 109 and transistor inverting amplifier 104, the probe tip voltage increase causes a voltage decrease at the collector of transistor 104. This, in turn, causes the dc supply voltage to the oscillator to decrease and thus produces a decrease in the oscillator output voltage applied to the cutting tip. In this fashion the rf voltage at cutting tip 60, selected by the position of the slide on potentiometer 109, is maintained at a relatively constant level despite variations in load impedance seen by the cutting tip.

Also shown in the drawing are three lamp circuits connected in parallel across the secondary of transformer 1 to provide an indication of the mode of operation selected. As described above, when switch 105 is actuated for operation in the cut mode, normally open switch contacts 105' are closed to deliver ac power from the secondary of transformer 1 through limiting resistor 116 to lamp 117 located under the cut mode switch button. Similar arrangements are provided for the coagulate mode and the fulgurate mode in the form of switches 106 and 107', respectively.

If, while in the cut mode of operation, the operator desires to switch to the coagulate mode, he will increase his pressure on the control switch and thereby actuate the second stage contacts 108' to simultaneously remove the short across resistor 8 and connect resistor 110 between the emitter of transistor 104 and the output of the bridge circuit. This puts resistor 8 in series with capacitor 9, and since resistor 8 is substantially larger than the bridge circuit impedance, a substantially unfiltered full wave rectified ac appears across the positive output terminal of the bridge circuit and thus across resistor 110 in series with resistor 103. Resistor 110 and resistor 103 form a voltage divider with the portion of the unfiltered full wave ac voltage across resistor 103 applied to emitter of transistor 104 to increase its collector voltage by a fixed amount. This, of course, also increases the rf output voltage of the oscillator by a fixed amount. The voltage regulating circuit 11 continues to function as before, only now a full wave rectified ac voltage is produced at the output of power supply 10 and connected to oscillator 20 as a modulating signal. It can be shown histologically that by selecting a value for resistor 110 which permits an increase of approximately 50 percent in the ratio of peak to average output voltage, more effective in vivo operation in the coagulate mode results.

It can be seen that the two stage switch circuit arrangement produces certain desirable advantages. Often, during operation in the cut mode, the operator wishes to quickly and effectively coagulate blood without removing his eyes from the surgical site. He may do this by actuating the second stage of the control switch. If, thereafter, he reduces his pressure on the control switch, the second stage will disengage and operation in the cut mode is resumed. When this is done switch contacts 108' return to their original state to again short out resistor 8 and disconnect resistor 110 from the emitter of transistor 104.

When the operator selects the coagulate mode of operation by actuating switch 106 at the console, switch 105 opens to remove the short from across resistor 8 which is then connected in series between the positive output terminal of the bridge circuit and capacitor 9. When the first stage of the control switch is actuated, contacts 108 are closed and the resistor 111 is connected to the positive output terminal of the bridge rectifier circuit to energize transistor 104. As before a full wave rectified ac voltage is produced at the output of power supply 10. If, now, the operator wishes to momentarily actuate the second stage of the control switch -- i.e., contacts 108' -- resistor 110 is connected to the emitter of transistor 104 to increase the peak to average output voltage as before.

If it is desired to operate the instrument in the fulgurate mode, the operator actuates switch 107, which, by reason of its mechanical interconnection, causes

switches 105 and 106 to open. When this occurs the ground is removed from the negative terminal of the bridge circuit and applied instead to one side of the secondary winding of transformer 1. Of course, switch 105 is opened and the short is removed from across resistor 8. The effect of this is to convert the full-wave bridge rectifier circuit into a half-wave rectifier circuit, utilizing only rectifier 5 to produce a half-wave rectified ac voltage at the positive terminal of the bridge circuit. And since resistor 8 is now connected in series with capacitor 9, the half wave output voltage, in substantially unfiltered form, is applied to the collector of transistor 104 through resistor 111 and the terminals of contacts 108 of the first stage of the foot switch. As before, the unfiltered voltage appears at the output of power supply 10. Once again, if the operator desires to momentarily increase the output power, he will engage the second stage of the control switch and actuate contacts 108' to connect resistor 110 between the emitter of transistor 104 and the positive terminal of the rectifier circuit to deliver an increased peak to average voltage at the output of power supply 10.

In each mode of operation the power supply produces the direct current power to operate and modulate oscillator 20. While a common emitter feedback type oscillator circuit is shown, it has been found that any oscillator producing a radio frequency in the range of 1 to 4 megacycles will enable the instrument to perform satisfactorily.

Typically, the collector impedance of transistor power oscillators such as oscillator 20 is small compared to the impedance between the cutting tip and ground -- e.g., the power oscillator collector impedance is resistive and on the order of 5 ohms, while the tip to ground impedance, consisting of the patient body resistance in series with the patient to ground capacitance, can be as high as 1,500 ohms. In conventional electro-surgery instruments this mismatch is compensated for by reducing the tip to ground impedance with a ground plate with its concomitant disadvantage.

In my invention, I have eliminated the need for a ground plate and simultaneously avoided the problems of radiation interference and the possibility of radio frequency burns (where insulation becomes defective) associated with the common usage of an insulated conductor connecting the oscillator to the probe.

In my invention, coaxial cable 40 is connected between the probe 50 and an impedance transformer 30 to match the load impedance to the oscillator output impedance for efficient and safe power transfer. By choosing a length for cable 40 which is less than one quarter wavelength, the impedance seen looking into the cable at the junction with impedance transformer 30 is approximately the capacitance of cable 40 in parallel with the patient-body impedance. As will be understood by those versed in the art, the cable capacitance adds to the capacitance of capacitor 31 in impedance transformer 30, and this augmented capacitance is connected in a π network, including capacitor 33 and the portion of inductor 32 between capacitor 31 and capacitor 33, to transform the high patient impedance into a lower impedance approximating the output impedance of oscillator 20.

An inductance 56 may be connected between the end of the cable 40 and a terminal post 55 that is electrically connected to a chuck fitted within the hollow of probe 50, which may be fashioned from cylindrically

shaped insulation material. The inductance will then be in series with the patient to ground circuit. This inductance 56 is selected to have a value so that its positive reactance equals the negative reactance of an average patient to ground capacitance to further increase the effective rf power delivered to the cutting site.

The shield of coaxial cable 40 is grounded at a jack terminal at the impedance transformer 30 within the console. Insulation is stripped away from a portion of cable 40 within probe 50 some distance from terminal post 55 to expose a shield segment 51. A series circuit consisting of resistor 54 and lamp 53 is connected between the end of the center conductor of cable 40 and the exposed shield segment 51 to provide a means for indicating when radio frequency power is present at the cutting tip 60. Probe 50 is constructed with a translucent circumferential band forming a window 57 that permits the light from lamp 53 to be seen over a 360° viewing angle.

A series circuit consisting of resistor 41 and a lamp 42 may be connected at the console between the output of impedance transformer 30 and ground to indicate when oscillator 20 is energized. Lamps 53 and 42 may be neon bulbs or any other indicators that can be energized directly by rf voltage.

Finally, the chuck may be any of a variety of convenient devices which enable cutting tip 60 to be inserted and removed with facility. Thus, for example, the chuck may be a friction device or, as shown in the drawing and as more fully described in U.S. Pat. No. 2,801,613, a device having 3 or 4 normally open jaws 71 made from spring brass or other conductive metal which are closed by a spring loaded collar 72. Cap 73 is press fitted over a retainer bushing 74 fitted over collar 72, which in turn acts against spring 75. Jaws 71 are fitted within collar 72 so that their shaft extends through spring 75 into a tapped portion of terminal post 55 so an electrical connection is made therebetween. When cap 73 is pushed to compress spring 75, the jaws of the chuck extend from collar 72 to expand and permit the insertion or removal of cutting tip 60. This extension of jaws 71 takes place entirely within cap 73, which has a small opening 76 at its end to admit tip 60. With this arrangement, the chuck is made to accept various diameter cutting tips.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What I claim is:

1. An electrosurgery instrument connected to a source of ac power comprising a power supply including a switching means for selectively producing a full wave rectified output voltage, a half wave rectified output voltage and a substantially ripple-free dc output voltage from said source of ac power; and ac oscillator having input terminals and output terminals; an operating probe containing a cutting tip, means for coupling

said oscillator output terminals to said cutting tip; and regulator means for connecting a selected one of said output voltages to said oscillator input terminals including feedback means connected to said coupling means for maintaining a substantially constant voltage at said oscillator output terminals independent of variations in load impedance and power line voltage.

2. An electrosurgery instrument in accordance with claim 1 wherein said regulator means includes means for selectively adjusting the magnitude of output voltage from said power supply independent from said switching means.

3. An electrosurgery instrument in accordance with claim 2 wherein said regulator means further includes a feedback circuit comprising a rectifier connected to a portion of said oscillator output voltage, a filter network including a potentiometer connected to said rectifier, an inverting amplifier connected to the slide of said potentiometer and amplifier means controlled by said inverting amplifier for connecting a selected one of said power supply output voltages to said oscillator input terminals.

4. An electrosurgery instrument in accordance with claim 1 wherein said switching means includes a primary switch for selectively producing one of said output voltages at the output of said power supply and a remotely situated control switch having a first stage for energizing said oscillator input terminals with a selected one of said power supply output voltages and a second stage for simultaneously increasing the magnitude of said selected output voltage and for overriding said primary switch to produce said full wave rectified voltage at said output of said power supply when said primary switching means is arranged to select said ripple-free dc output voltage for application to said output of said power supply.

5. An electrosurgery instrument in accordance with claim 4 wherein said oscillator produces a voltage having a frequency in the range of 1 to 4 megacycles.

6. An electrosurgery instrument in accordance with claim 1 wherein said means for coupling said oscillator to said cutting tip includes an impedance transformer to effect a substantial match between the operating impedance seen by said cutting tip and the output impedance of said oscillator, a coaxial cable having a length less than one-quarter the wave length of said oscillator voltage connected between said cutting tip and said impedance transformer and an inductance having a magnitude in the range of 10-40 microhenrys serially connected between the terminal of said cable within said probe and said cutting tip.

7. An electrosurgery instrument in accordance with claim 1 wherein said operating probe comprises a hollow tubular housing fabricated from an electrical insulator material having a translucent band running circumferentially over a portion of its length and an interior lamp adjacent to said band having two terminals connected to points of different potential on said cable.

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