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[54] ELECTROSURGICAL APPARATUS FOR DENTAL USE

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[51] **Int. Cl.**.....**A61b 17/38,** A61n 3/02

[58] **Field of Search**.....128/303.14, 303.17, 128/423

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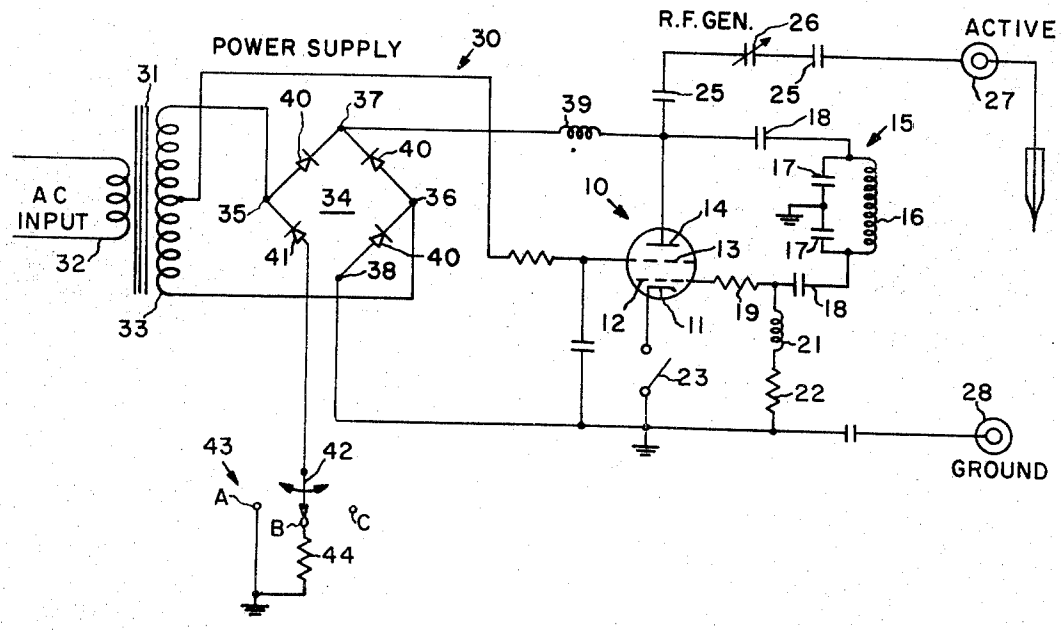
[57] **ABSTRACT**

Electrosurgical apparatus for dental use employing an electronic radio-frequency oscillator is described. The radio-frequency oscillator or R.F. generator is powered by an electronic power supply constructed to selectively deliver full-wave rectified voltage and current for excellent cutting with minimal hemostasis, half-wave rectified voltage and current providing moderate cutting with maximum hemostasis, and voltage and current between the full-wave rectified and half-wave rectified condition for combined good cutting and good hemostasis. A further variation makes selectively available filtered or unfiltered rectified voltage and current for further control over cutting and hemostasis.

9 Claims, 9 Drawing Figures



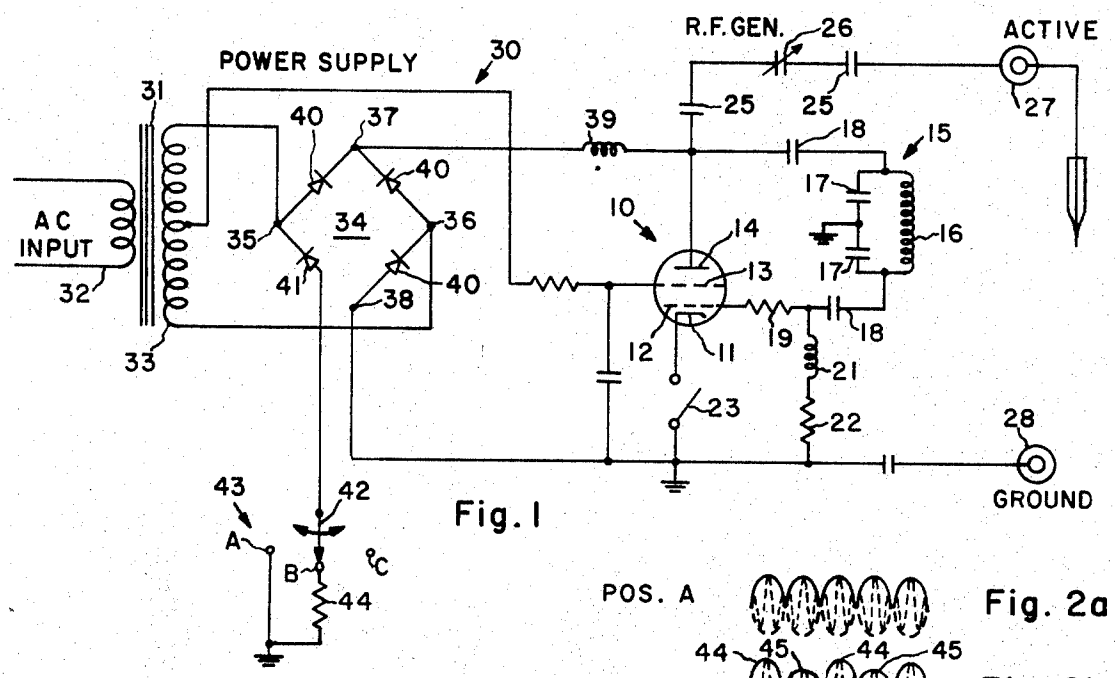


Fig. 1

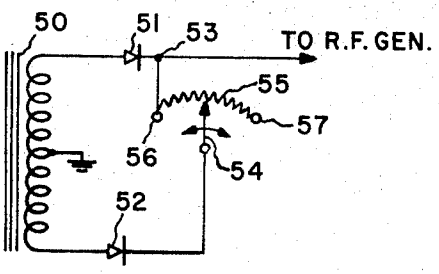


Fig. 3

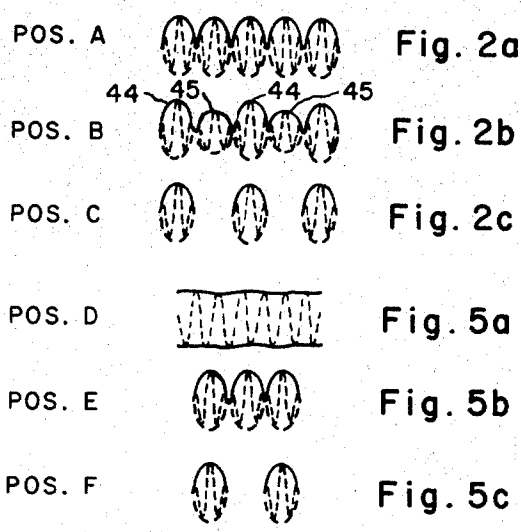


Fig. 2a

Fig. 2b

Fig. 2c

Fig. 5a

Fig. 5b

Fig. 5c

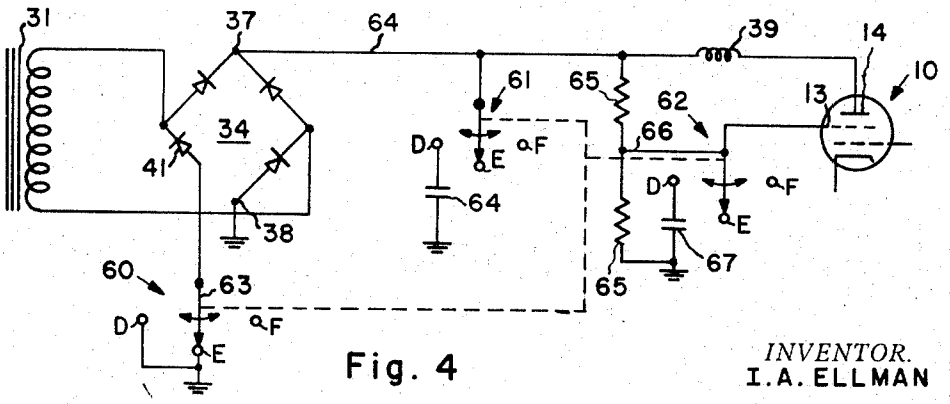


Fig. 4

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ELECTROSURGICAL APPARATUS FOR DENTAL USE

This invention relates to electrosurgical apparatus primarily for dental use.

Electrosurgical apparatus has come into wide use in dentistry because of its capability for making incisions in or cutting live gum tissue while minimizing bleeding, i.e., hemostasis. In its known form, the apparatus comprises a high-frequency oscillator or radio-frequency (R.F.) generator in the range, generally, of 2–4 MHz, which is usually a conventional Hartley or Colpitts oscillator employing a triode or tetrode electron tube capable of delivering from 25–100 watts of R.F. power. Such R.F. generators have been generally powered by single phase full-wave or half-wave rectifier circuits operated directly from the commonly available A.C. house supply and capable of supplying the high voltages and currents necessary to operate the R.F. generator. However, the R.F. output that is optimum for cutting is often not the optimum R.F. output for controlling bleeding. Prior art efforts to overcome these difficulties have followed generally along two different paths. In the first, two different kinds of R.F. generators have bee provided each to supply a different form of R.F. output for maximizing cutting or maximizing hemostasis. For example, a spark-gap generator is used for generating damped R.F. oscillations giving excellent coagulation, and an electron tube generator is employed for providing sustained undamped oscillations for excellent cutting. Apparatus has been developed following the second path employing special gating multivibrator or other pulsing circuits for enabling controlled bursts of short duration of the R.F. oscillations to be supplied to the tissue.

Both of these prior art paths have resulted in complicated, expensive apparatus that have not fulfilled a real need in the dental art for simple, inexpensive apparatus offering sufficient control over the waveform of the generated R.F. power output enabling the dentist to obtain optimum cutting, hemostasis, or combined cutting and hemostasis for satisfying the wide variation in operating conditions encountered in treating many dental patients.

The main object of the invention is improved electrosurgical apparatus capable of delivering controlled R.F. power to provide excellent cutting, excellent hemostasis, or both with remarkably simple and inexpensive circuitry.

These and other objects of the invention as will appear hereinafter are achieved in accordance with the invention by constructing the power supply that powers or activates the R.F. generator such that, in a manner selected by the dentist, it will provide to the R.F. generator fully-rectified D.C. power, half-wave rectified D.C. power, and forms of rectified D.C. power lying between these extremes. As a further feature of the invention, the power supply can be selectively controlled to provide filtered or unfiltered D.C. power to the R.F. generator providing still a further way of optimizing the cutting and coagulating capabilities of electrosurgery for dental use.

The foregoing and other objects of the invention will become more apparent from the following detailed description of several exemplary embodiments of the invention taken in conjunction with the accompanying drawing wherein: FIG. **1** is a circuit diagram of one form of electrosurgical apparatus in accordance with the invention employing a bridge rectifier circuit; FIGS. **2***a*, **2***b* and **2***c* illustrate the waveforms of the three D.C. output voltages derivable from the bridge rectifier embodiment of FIG. **1**; FIG. **3** is a circuit diagram of just the power supply of a second embodiment of the invention employing a center-tapped transformer; FIG. **4** is a circuit diagram of just the power supply of a third embodiment of the invention employing a filtered rectifier; FIGS. **5***a*, **5***b* and **5***c* illustrate the waveforms of the three D.C. output voltages derivable from the embodiment of FIG. **4**.

FIG. **1** illustrates a typical R.F. electron tube generator employing a Colpitts oscillator circuit. This is employed merely to illustrate one form of known oscillator, it being understood that other known forms of radio-frequency oscillators may also be used. Also, while a tetrode tube is shown, triodes or semiconductor devices can be used in place of the tetrode. The filament circuitry for the tube is not shown as it is well known, and similarly many of the known safety features of the circuit have been omitted as unnecessary to an understanding of the present invention.

The tetrode **10** contains the usual cathode **11**, control grid **12**, screen grid **13** and plate **14**. The usual tank circuit **15**, consisting of paralled connected coil **16** and capacitors **17** is coupled via capacitors **18** and grid resistor **19** between the control grid **12** and plate **14**. The connection between the tank capacitors **17** is grounded. The control grid **12** is also connected via an R.F. choke **21** and resistor **22** to ground. The cathode **12** is grounded via an on-off switch **23**, which can be a foot switch operable by the dentist for turning the R.F. generator on and off as desired. The R.F. power output is taken from the plate via several blocking capacitors **25**, one of which **26** is variable to control the output R.F. power. The power can be applied to the patient via terminals **27**, which is the hot or active terminal, and **28**, which is ground. As is well known, the patient is connected to the ground terminal **28**, and the usual cutting implement or electrode is connected to the active terminal **27** and then applied by the dentist to the patients tissue where cutting or coagulation is desired.

The high voltage for operating the R.F. generator is obtained from a power supply designated **30**. The power supply **30** comprises the usual high voltage transformer **31** having a primary winding **32** connected to the A.C. supply, usually 110 volts, 60 Hz, and a high voltage secondary winding **33** connected to opposite sides of a bridge rectifier **34** at points designated **35** and **36**. The remaining two points of the bridge designated **37** and **38**, are connected respectively to the tetrode plate **14** via an R.F. choke **39** and to ground. Three of the rectifiers, designated **40**, of the bridge are connected in the usual way as shown. However, in accordance with the invention, the fourth rectifier **41**, instead of being connected directly to point **38** as is usual, is connected to the movable arm **42** of a three-position rotary switch **43** having positions A, B, and C. Position A is directly grounded. Position B is grounded via a series resistor **44**, and Position C is unconnected or open.

FIG. **2** illustrates the voltage output waveforms from the point **37** to ground of the power supply **30** with switch **43** in the three positions as selected by the

dentist upon operating the switch 43. With switch 43 in position A, a normal bridge rectifier is obtained producing unfiltered full-wave rectification, as illustrated by the solid line curve in FIG. 2*a*. With switch 43 in position C, one leg of the bridge is disabled producing unfiltered half-wave rectification, as illustrated in FIG. 2C. With switch 43 in position B, one leg of the bridge has an additional resistance 44 in series causing a voltage drop across it with the result that while full-wave rectification is obtained, the output voltage level during the half cycle when the rectifier 41 is conducting is reduced, producing a full voltage half sine wave 44, as illustrated in FIG. 2*b*, and a partial voltage half sine wave 45.

Application of the voltages depicted in FIG. 2 to the R.F. generator will cause it to break into oscillation each time the rising voltage of each half sine wave reaches a level causing the tetrode to conduct, and the R.F. oscillations will terminate as the voltage reapproaches zero. Thus, the FIG. 2 solid line waveforms illustrate the top half of the modulation envelope of the R.F. power output which can be applied to the patient, the bottom half being a mirror image of the top half. This is illustrated by the dashed curves shown.

The R.F. power generated by the waveform depicted in FIG. 2*a* provides the hottest current and thus maximum cutting but with minimum hemostasis. The R.F. power corresponding to the waveform of FIG. 2*c* provides poorer cutting but excellent hemostasis because the R.F. energy is interrupted for a time substantially equal to the time of its application, thus allowing the tissue to cool between the R.F. pulses. The waveform of FIG. 2*b* provides an operating condition roughly halfway between that of FIGS. 2*a* and 2*c*, that is, the cutting is better than with the waveform of FIG. 2*c*, and the hemostasis is more effective than with the waveform of FIG. 2*a* because of the smaller power pulses 45, allowing some tissue cooling, alternating with the larger power pulses 44.

Thus, by simple switching of one of the legs of the bridge rectifier in and out of the circuit, or in series with a resistor, a very simple circuit results for controlling the output R.F. power waveforms in a stepped manner for optimizing, at the will of the operating dentist, the apparatus for cutting, for hemostasis, and for combined cutting and hemostasis.

FIG. 3 is a circuit of a modified power supply providing an even greater flexibility of operation. A full-wave rectifier circuit is illustrated, this time with a center-tapped transformer 50, of which only the secondary is shown. The usual two rectifiers 51 and 52 are shown. In the usual full-wave rectified circuit, the anode of the rectifier 52 would be connected directly to the point 53, with the result that the output wave-form would appear as depicted in FIG. 2*a*. In accordance with the invention however, the rectifier anode is connected to the movable arm 54 of a rheostat 55 one end 56 of whose resistor is connected to the point 53, and the other end 57 of which is unconnected or open. With the arm 54 full counterclockwise at point 56, then the full-wave output of FIG. 2*a* is obtained. With the arm 54 full clockwise at point 57, then, with a sufficiently high resistance, say 50,000 ohms, the rectifier 52 is effectively open-circuited producing the half-wave voltage depicted in FIG. 2*c*. With arm 54 in intermediate positions, then waveforms similar to that of FIG. 2*b* are obtained, with the amplitude of the smaller voltage 45 being controllable in a continuous manner between the full level shown in FIG. 2*a* and the zero level shown in FIG. 2*c*. This provides the practicing dentist with a greater degree of control over the output power for most efficient cutting, hemostasis or both. It is understood that the rheostat 55 of FIG. 3 can be employed as a substitute for the three-position switch 43 to provide the same advantages in a bridge rectifier.

FIG. 4 shows a further modified power supply affording still greater control of the output R.F. power. As in FIG. 1, a bridge rectifier is depicted, the same numbers referencing the same elements, except in this modification a three-ganged three-position switch 60, 61, 62 is employed. The movable arm 63 of switch 60 connects the rectifier 41 to ground in two positions D and E, and leaves it unconnected in the third position F. The switch 61 of the three-ganged switch connects the power supply output lead 64 to a filter capacitor in switch position D, and remains unconnected in positions E and F. The switch 62, similarly to switch 61, connects a lower voltage point from a voltage divider 65 via lead 66 to a filter capacitor 67 in position D, and remains unconnected in positions E and F.

The results on the D.C. output from the supply rectifier circuit is depicted in FIG. 5. In position D, FIG. 5*a*, a normal full-wave condensor filter rectification is obtained that is applied to the tetrode plate 14, while similarly the voltage applied to the screen 13 of the tetrode is additionally filtered by capacitor 67, providing a high degree of cutting action due to the continuous R.F. power generation, as illustrated by the dashed waveforms. In position E, FIG. 5*b*, a full-wave unfiltered rectified output is obtained, similar to that of FIG. 2*a*. In position F, FIG. 5*c*, half-wave unfiltered rectified output is obtained, similar to that of FIG. 2*c*. Of course, this combination with filtering can also be combined with the resistor 44 or rheostat 55 of FIGS. 1 and 3 respectively, providing additional possibilities of control over the R.F. power output as desired by the dentist.

As before, the filtered fully rectified supply voltage will afford the hottest current and cleanest cutting with minimal hemostasis whereas the unfiltered half-wave rectified supply voltage will afford poorer cutting but maximum coagulation, and the unfiltered full-wave rectified supply voltage an inbetween condition.

In a typical example for the FIG. 1 embodiment, the plate voltage will be, for example, 600 volts, the screen voltage about 300 volts, and the resistor 44 may be about 7,500 ohms.

While my invention has been described and illustrated in several specific embodiments, it will be understood they are merely exemplary, and that various changes and modifications may be made in the circuitry disclosed without departing from the principles of the invention herein described.

What is claimed is:

1. Electrosurgical apparatus for dental use providing controlled cutting and coagulation comprising a radio-frequency oscillator circuit for generating at its output radio-frequency oscillating currents when activated by voltage at its input, means coupled to the output of said radio-frequency oscillator for applying said radio-

frequency oscillating currents to a dental patient, a voltage supply circuit for receiving A.C. voltage and converting same to a rectified D.C. output voltage capable of activating said radio-frequency oscillator when applied to the oscillator input, means for applying the said output voltage of the supply circuit to the input of the radio-frequency oscillator, and means connected to said voltage supply circuit for selectively changing the waveform of its output voltage and thereby selectively modifying the radio-frequency oscillating currents generated by the oscillator when activated by said output voltage, said voltage supply circuit comprising a single-phase full-wave rectifier circuit comprising plural rectifiers capable of producing a fully-rectified output voltage, and the selective changing means comprising means connected to the rectifier circuit for producing a half-wave rectified output voltage.

2. Electrosurgical apparatus as set forth in claim 1 wherein the selective changing means comprises means for introducing resistance in series with at least one of the rectifiers to produce a rectified output voltage wherein the peak voltage is different for alternate half cycles.

3. Electrosurgical apparatus as set forth in claim 1 wherein the selective changing means comprises means for connecting one of the rectifiers to the bridge circuit, means for disconnecting one of the rectifiers from the bridge circuit, and means for connecting one of the rectifiers in series with a fixed resistor in the bridge circuit.

4. Electrosurgical apparatus as set forth in claim 1 wherein the selective changing means includes a variable resistance, and means for selectively connecting the variable resistance into the voltage supply circuit.

5. Electrosurgical apparatus as set forth in claim 1 wherein the voltage supply circuit comprises a single phase full-wave bridge rectifier circuit and the selective changing means includes means for disabling at least one of the rectifiers.

6. Electrosurgical apparatus as set forth in claim 1 wherein the rectifier circuit comprises a center-tapped transformer and two rectifiers, and the selective changing means comprises means for disconnecting one of the two rectifiers.

7. Electrosurgical apparatus as set forth in claim 6 wherein the selective changing means comprises means for introducing a resistance in series with one of the two rectifiers.

8. Electrosurgical apparatus as set forth in claim 1 wherein the voltage supply circuit comprises filtering means, and the selective changing means comprises means for selectively connecting the filtering means to the voltage supply circuit.

9. Electrosurgical apparatus as set forth in claim 8 wherein the selective changing means comprises a three-position switch for connecting the filtering means in one switch position and for disabling part of the rectifying circuit in another switch position.

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