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W. D. KENDALL ET AL
THERAPEUTIC PULSE GENERATION, CONTROL AND
TRANSMISSION CIRCUIT

3,299,892

Filed July 15, 1963

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FIG. 1.

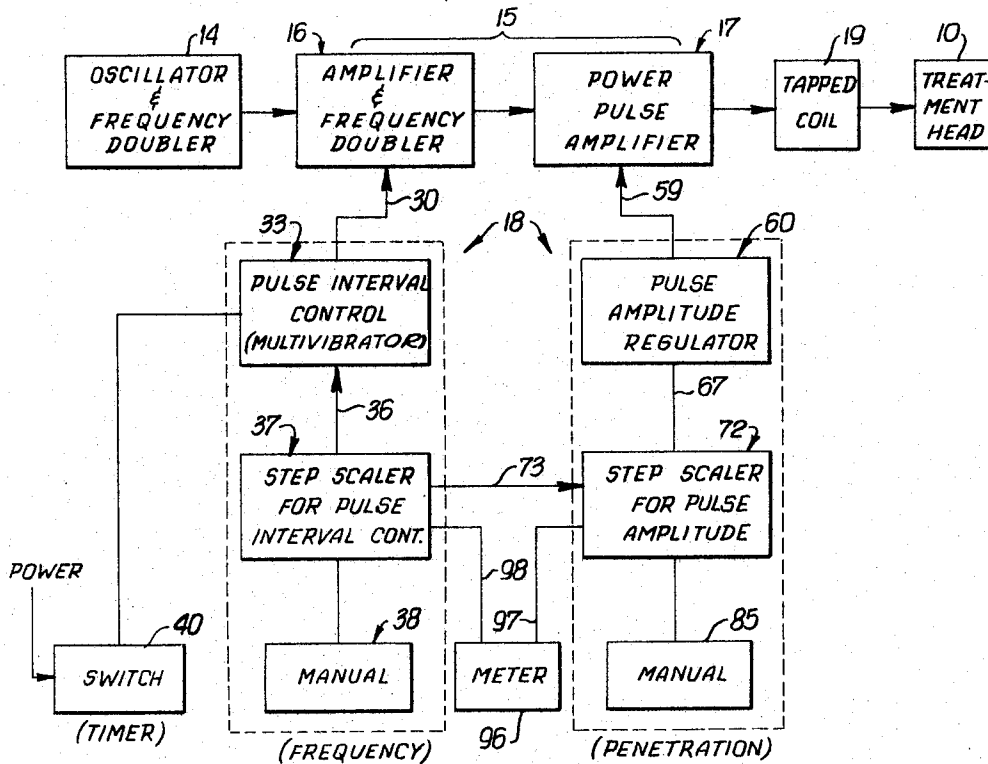
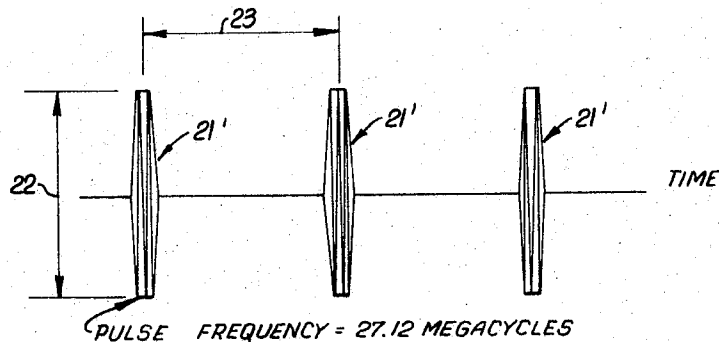


FIG. 2.



INVENTORS:
WILLIAM DENIS KENDALL
FRANK A. YARGER
BY *White & Keefliger*
ATTORNEYS.

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FIG. 3.

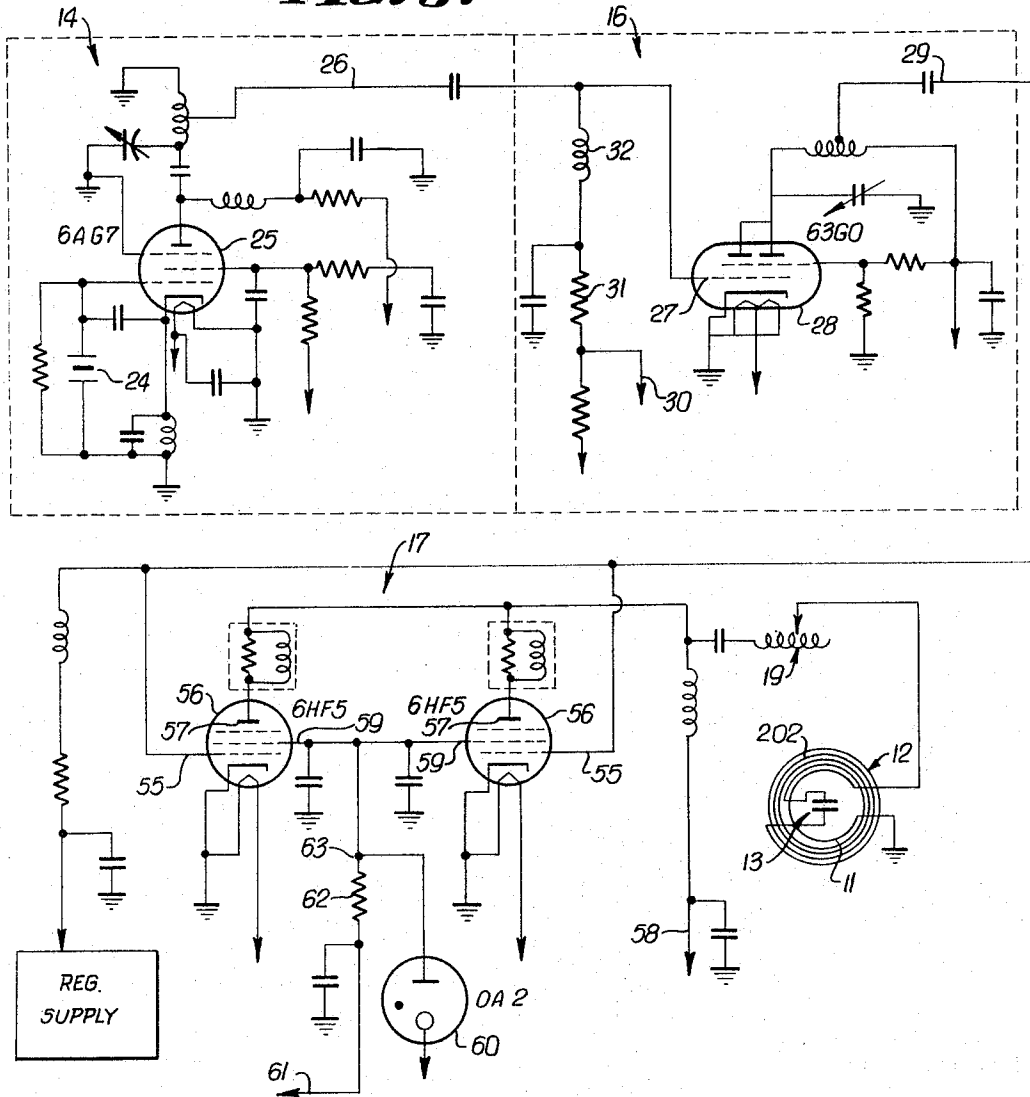
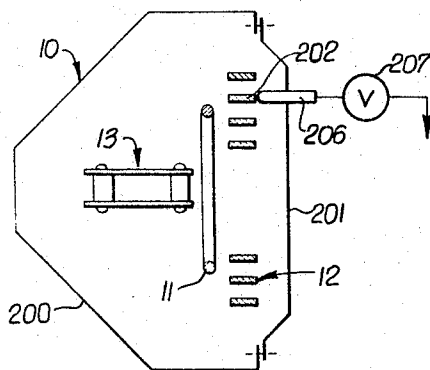


FIG. 5.



INVENTOR.
WILLIAM DENIS KENDALL
FRANK A. YARGER
BY *White & Haefliger*
ATTORNEYS.

Jan. 24, 1967

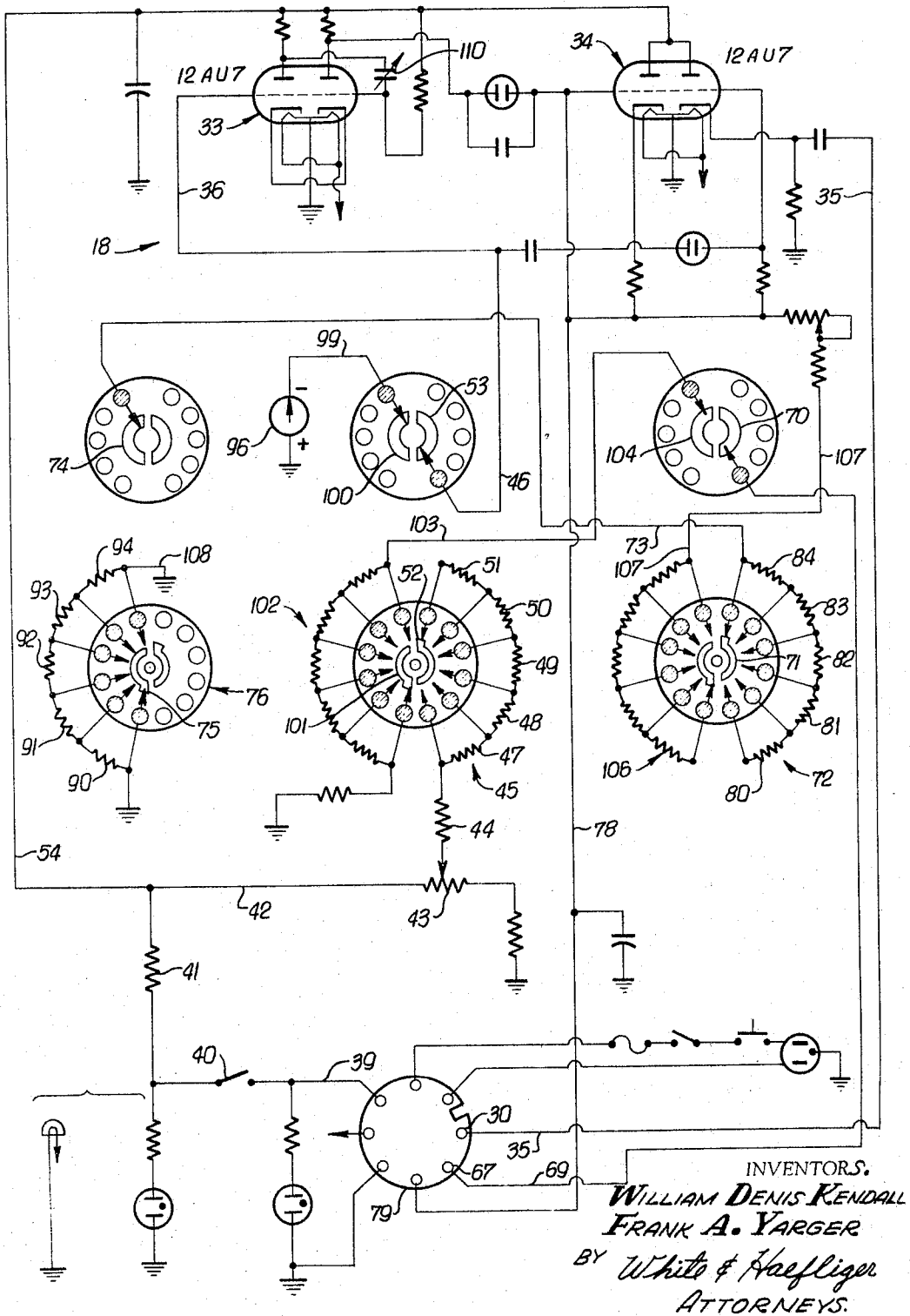
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FIG. 4.



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THERAPEUTIC PULSE GENERATION, CONTROL AND TRANSMISSION CIRCUIT

William Denis Kendall and Frank A. Yarger, Los Angeles, Calif., assignors to Dynapower Systems Corporation, Los Angeles, Calif., a corporation of Delaware

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2 Claims. (Cl. 128-421)

This invention relates generally to electrotherapeutic apparatus, and more particularly concerns the generation, control and transmission of electrical pulses of high frequency for application to a patient by means of a treatment head of particular construction, found highly suitable.

Circuits developed in the past to generate and transmit electrical pulses for electrotherapeutic treatment have suffered certain disadvantages. Among these have been undesirable complexity and low efficiency, high manufacturing cost, and inability to control the generated pulses in the manner described herein, such control increasing the utility and therapeutic value of the apparatus. Whereas in the past it has been thought desirable to adjust the impedance of the apparatus as by placing a light bulb in the zone forward of the head, observing the brightness of bulb lighting while adjusting capacitors in an impedance matching network, and stopping the adjustment when the brightness of the bulb is maximized, it has been found that this method results in undesirable loss of power transmitting efficiency. One reason for this condition is the difference between the impedance of such a light bulb and the impedance of a patient to which the head is applied during treatment, the loss of energy transmitting efficiency of the apparatus being characterized by reflection of power from the head back to the input circuit.

Accordingly, it is a major object of the invention to provide novel electrotherapeutic apparatus capable of overcoming the disadvantages mentioned above, as well as others found in prior equipment.

Broadly considered, the apparatus comprises a power radiating head including power elements electrically interconnected for interaction when the head is applied to treat a patient, and input circuit means for said head including oscillator, amplifier and control means for creating and transmitting to the head a sequence of high frequency pulses and for controlling the selected amplitude of the pulses and the time intervals therebetween. The power elements include a power radiating coil having multiple turns in a spiral, and said elements and the input circuit means are characterized in that the coil has a region localized at a substantial distance from opposite ends of the coil and which remains at an approximately null voltage condition over a range of said selected pulse amplitudes and time intervals. As a result, the efficiency of the apparatus in terms of transmission and radiation of energy is optimized for increasing the therapeutic performance and value of the apparatus.

More specifically, it is now possible to overcome the undesirable loss of efficiency mentioned above through the provision of head power elements typically including a primary coil, a power radiating secondary coil having multiple turns in a spiral, and a condenser, and in particular the elements and input circuit are characterized in that the secondary coil has a region localized substantially half-way along the spiral length of the coil and which remains at an approximately null voltage condition over a selected range of pulse amplitudes and time intervals. Further, the capacitor network described above is eliminated and inductance such as a tapped coil is

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provided to transmit power pulses to the head, the coil being located and sized or adjusted to optimize the null voltage condition as determined at the head, whereby substantially all of the energy transmitted to the head is radiated by the secondary coil.

Other features and advantages of the improved electrotherapeutic apparatus include the provision of a regulator connected in series between pulse amplitude control means and power amplifier means from which pulses are transmitted to the head, the regulator maintaining substantially constant each selected value of pulse amplitude transmitted to the head. In this connection, the pulse amplitude control includes a voltage divider network having a scaler to provide stepwise selection of pulse amplitude, the power amplifier includes a power tube having a screen grid the voltage input of which is controlled by said voltage divider network and scaler, and the regulator typically comprises a gas tube to maintain substantially constant the scaler-selected value of voltage input to the screen grid.

These and other objects and advantages of the invention as well as the details of an illustrative embodiment will be more fully understood from the following detailed description of the drawings, in which:

FIG. 1 shows a block diagram of the overall system;
FIG. 2 shows the wave form transmitted to the power head;

FIG. 3 shows a schematic diagram of part of the circuit;

FIG. 4 shows a schematic diagram of another part of the circuit; and

FIG. 5 shows a diagram of the power radiating head.

Referring first to FIGS. 1, 3 and 5 the treatment head is indicated at 10 and is shown to comprise loop primary and spiral secondary coils 11 and 12 respectively, and having a typical turns ratio of about 1 to 4. A fixed capacitor or condenser is shown at 13 as connected with the secondary coil to provide a tank circuit and all of these power elements are enclosed within a head shell 200 the front plate 201 of which is applied to or near a patient undergoing treatment. As mentioned above, the secondary coil 12 has a region 202 localized at a substantial distance from opposite ends of the coil, and typically about half-way therebetween along the spiral length of the coil, said region remaining at an approximately null voltage condition over a selected range of pulse amplitudes and time intervals therebetween.

The portion of FIG. 1 to the left of the treatment head comprises the input circuit means for the head and includes an oscillator 14 typically having a frequency doubling function, amplifier means 15 including a first amplifier 16 and a power amplifier 17 connected in series sequence with the oscillator, and control means generally designated at 18 below the amplifier means. These same general elements are indicated in FIG. 3 by the same numerals. The input circuit means also includes a tapped coil 19 located to transmit the power pulses to the head and tap-adjusted to substantially optimize the null voltage condition at region 202 of coil 12, and so that substantially all of the energy transmitted to the head is radiated by the coil 12. This may be assured by adjusting the coil 19 while probing the coil 12 seen in FIG. 5 with a lead 206 connected to a voltmeter 207, the probe-lead being applied to the region 202 of the coil 12 when the apparatus is energized.

Generally speaking, the elements of the circuit are interconnected as described and as to be described, in such manner as to create and transmit to the treatment head a sequence of high frequency pulses, and also to control the selected amplitude of the pulses and the intervals therebetween in predetermined relation. As an il-

illustration of this, reference is made to FIG. 2 showing the sequence of like pulses 21', each of which is made up of a high frequency signal burst having a selected amplitude 22, and having intervals 23 therebetween, these having predetermined relationship. Typically, the pulse of the signal frequency will be 27.12 megacycles, and the interval 23 will be variable, preferably in stepwise relation. Also the amplitude equal to one-half the dimension 22 will be variable in stepwise relation as will be described. Thus, the time interval 23 may be varied in four or five steps within the range 1.6 milliseconds to 12.5 milliseconds, in order to increase or decrease the intensity of treatment given the patient.

Referring again to FIG. 3, the oscillator means 14 is shown to include a crystal 24 for establishing a desired high frequency oscillation say 6.780 megacycles. This frequency is applied to the tube 25 and doubled in the oscillator to the value 13.56 megacycles for transmission at 26 to the amplifier doubler 16, and in particular to the grid 27 of the tube 28. One function of the amplifier-doubler 16 is to double the frequency to the value 27.12 megacycles which is transmitted at 29 to the power amplifier 17. An additional function is to transmit the high frequency in pulses, as established by the switching pulse input at 30 which is coupled to the lead 26 through the resistor 31 and coil 32.

The switching pulse input is obtained from the output of the multivibrator 33 shown in FIG. 4 which is coupled to the cathode follower stage 34 shown in the same figure. The output from the cathode follower is obtained at 35 and transmitted at 36, as previously described. The multivibrator 33 has a grid input shown at 36, the voltage of which is variable and preferably stepwise variable to provide selection of pulse interval over the previously described predetermined range. FIG. 1 shows the step control 37 for the multivibrator 33 as having a manual control 38 in order to provide the selection of pulse interval.

A highly desirable step control for the multivibrator is illustrated in FIG. 4 to comprise a circuit which includes the B+ voltage lead 39, timer switch 40, resistor 41, lead 42, calibration potentiometer 43, resistor 44, step resistance selector 45 providing voltage scaler or divider means, and lead 46 connected to the grid input 36. As shown in FIG. 4, the device 45 includes a series of resistances 47 through 51 which are connected in series and are tapped as illustrated for selective connection to the rotatable terminal 52. The latter is connected through the device 45 with the terminal 53 on the back side, the latter being connected to the lead 46. Accordingly, as the terminal 52 is rotated, different resistors are connected in series to provide a selective voltage application to the grid of the multivibrator 33 for pulse interval control. In this connection, the plates of the multivibrator are suitably supplied with voltage by means of the lead 54.

Turning back to FIGS. 1 and 3, the output from the amplifier-doubler 16 is transmitted at 29 to the grids 55 of the power amplifier tubes 56, for pulse power amplification. In this connection, the plates 57 of the tubes 56 are suitably supplied with high voltage, for example 2000 volts D.C. from the point 58. FIG. 1 shows the amplifier 17 as having an input at 59 from what may be described as a pulse amplitude regulator 60. The input points 59 shown in FIG. 3 at the screen grids of amplifier 17 are kept at a potential controlled by pulse amplitude controlling network and scaler 72, to which positive voltage is supplied from source 61. From that source, direct current flows through resistor 62, regulator 60, to point 67 and then to the network and scaler circuit described below. Regulator tube 60 operates to maintain point 63 and points 59 (screen grids) at regulated scaler-selected potential, in order to maintain substantially constant each selected value of pulse amplitude transmitted to the head.

This simple control obviates any necessity for complex feed-back circuitry to control pulse amplitude.

The point 67 is also shown in FIG. 4 as being connected with the series circuit that includes the leads 69 of rotary terminal 70, rotary terminal 71 of the scaler or voltage divider device 72, lead 73, rotary terminals 74 and 75 of the auxiliary scaler or voltage divider device 76, and to ground at 108. Lead 78 and point 79 are suitably supplied with negative D.C. voltage. Device 72 is like device 45 in that it is provided with a series of resistors 80 through 84 connected in series and provided with intermediate taps which are selectively connectible with the rotary terminal 71 upon manual turning thereof as by the control shown at 85 in FIG. 1. Accordingly, a selected voltage is applied to the input point 67 of the pulse amplitude regulator 60 and therefore the output 59 of the regulator are stepwise variable to control the voltage applied to the screen elements of the power amplifier tubes 56, giving the desired step control of pulse amplitude.

Turning now to FIGS. 1 and 4, the connection as shown at 73 functions to interconnect the step controls or scalers 72 and 76 as previously described. The scaler 76 is operated simultaneously with the scaler 45, as by mounting on a common shaft, turnable by the manual control 38. Accordingly, an adjustment in the step controller scaler 45 to change the pulse interval simultaneously changes the pulse amplitude by virtue of a change in the resistance of the step control circuit for the pulse amplitude regulator. The purpose of this cross over connection is to provide resistance to substantial increase in the selected pulse amplitude in response to a selected change in the pulse interval. In other words, in the absence of such cross over interconnection 73 with its associated scaler 76, the pulse amplitude would change to an undesirable extent in response to a selected change in the pulse interval, so that this problem is solved by means of the described cross over control. The scaler device 76 is similar to those previously described in that it includes a series of resistors 90 through 95 which are tapped at intermediate points for selective connection to the rotary terminal 75, placing a desired number of the resistors in series in the circuit.

Finally, reference to FIG. 1 shows a meter 96 connected at 97 and 98 to both the step control 37 comprised of the devices 45 and 76, and also to the step control device 72. The purpose for such dual connection is to cause the meter to sense the changes in both of these controls. A desirable connection serving this purpose is shown in FIG. 4 with the meter 96 connected with the scaler 45 as by means of a series circuit including the lead 99, rotary terminals 100 and 101, scaler or voltage divider 102, lead 103, rotary terminals 104 and 105 of the scaler or voltage divider 106, and voltage supply lead 107. In this regard, the scaler 102 is made responsive to adjustment in the scaler 45 by mounting on a common shaft, whereas the scaler 106 is made responsive to adjustment of the scaler 72. Accordingly, adjustment of either of the scalers 45 and 72 will effect adjustment of one or the other of scalers 102 and 103 thereby to effect the reading of the meter 96, to show that the pulse interval and pulse amplitude controls are working.

Referring back to the multivibrator 33 in FIG. 4, a variable capacitor is shown at 110 in the plate circuit of the tube to control the width of the pulses 21' seen in FIG. 2. Typically, the capacitor is adjusted to produce an approximately 65 microsecond pulse width for all values of pulse amplitude and interval set by adjustment of scalers 37 and 72.

We claim:

1. In electrotherapeutic apparatus, a power radiating head including a primary coil, a power radiating secondary coil having multiple turns connected in a spiral, and a condenser electrically connected across the secondary

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coil, and input circuit means connected to transmit power pulses to said primary coil, said input circuit means including oscillator, amplifier and control means for creating and transmitting to the head a sequence of high frequency pulses and for controlling the selected amplitude of said pulses and the intervals therebetween, said oscillator means providing a high frequency signal, said amplifier means including first amplifier means and power amplifier means connected in series sequence with said oscillator means, said control means including pulse interval control means connected with said first amplifier means to intermittently interrupt transmission of said signal to said power amplifier means, said control means also including pulse amplitude control means connected with said power amplifier means to provide amplitude selection of power pulses transmitted to said head, said input circuit means including a coil having an adjustable tap connected in series between the power amplifier means and one end terminal of the primary coil and adjusted to effect maximum energy transfer to the head for radiation by the secondary coil accompanied by a null voltage remaining localized substantially half way along the spiral length of the secondary coil and for different selected pulse intervals and amplitudes.

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2. The apparatus of claim 1 in which said power amplifier means includes a power tube having a grid, said pulse amplitude control means includes a voltage divider network having a scaler to provide stepwise selection of pulse amplitude and a gas regulator tube to maintain substantially constant the scaler selected value of voltage input to said grid, said gas tube being connected in series in said voltage divider network and between said scaler and said grid.

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RICHARD A. GAUDET, *Primary Examiner.*

W. E. KAMM, *Assistant Examiner.*