Feb. 6, 1951 T. U. FOLEY ET AL 2,540,613

HIGH-FREQUENCY VARIABLE POWER OUTPUT SYSTEM

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Fig. 1

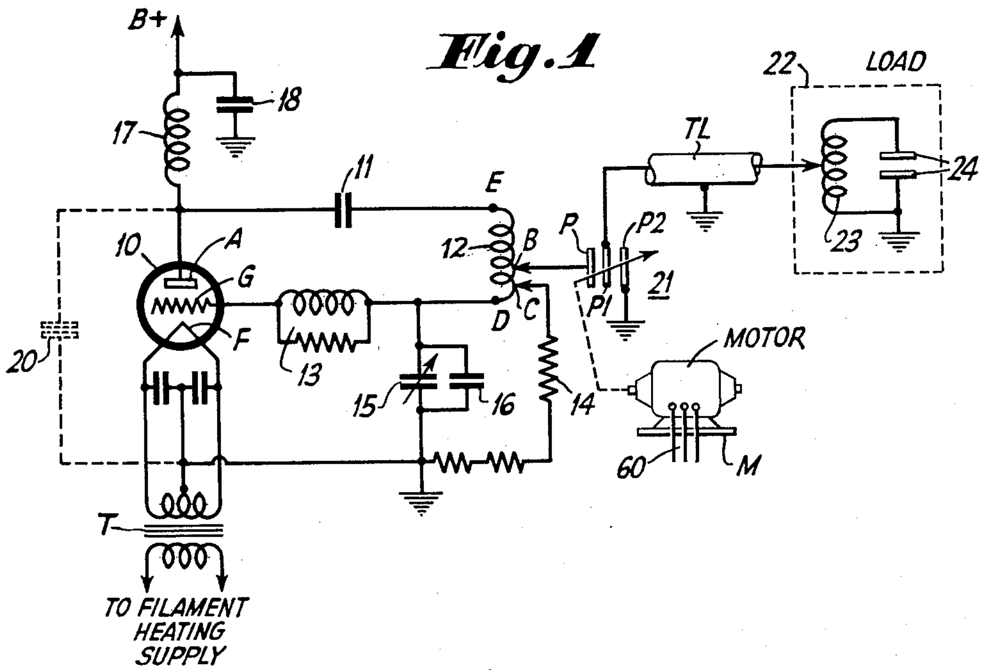

Fig. 2

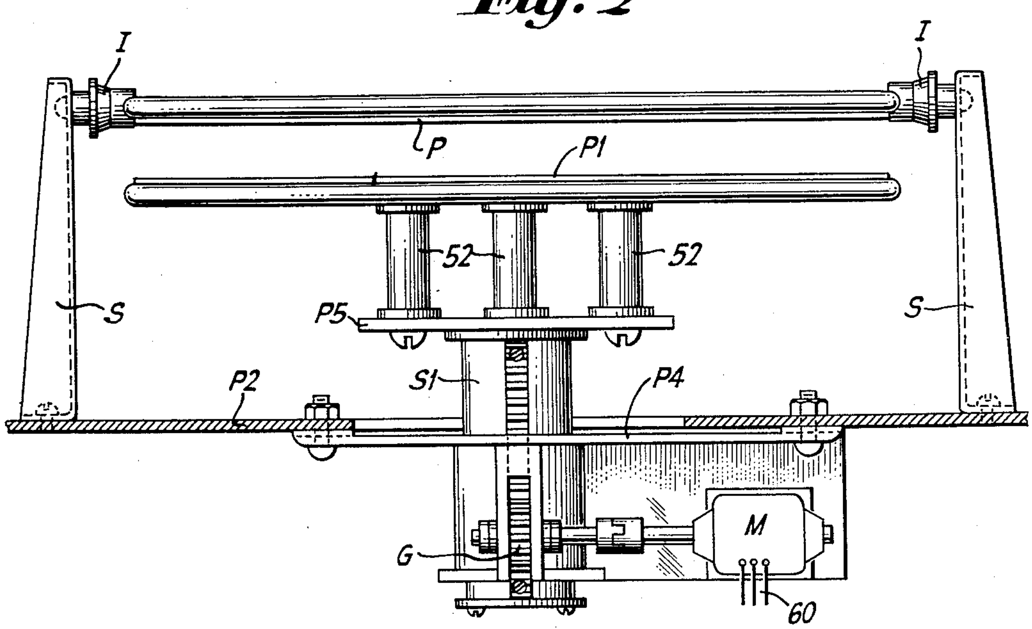

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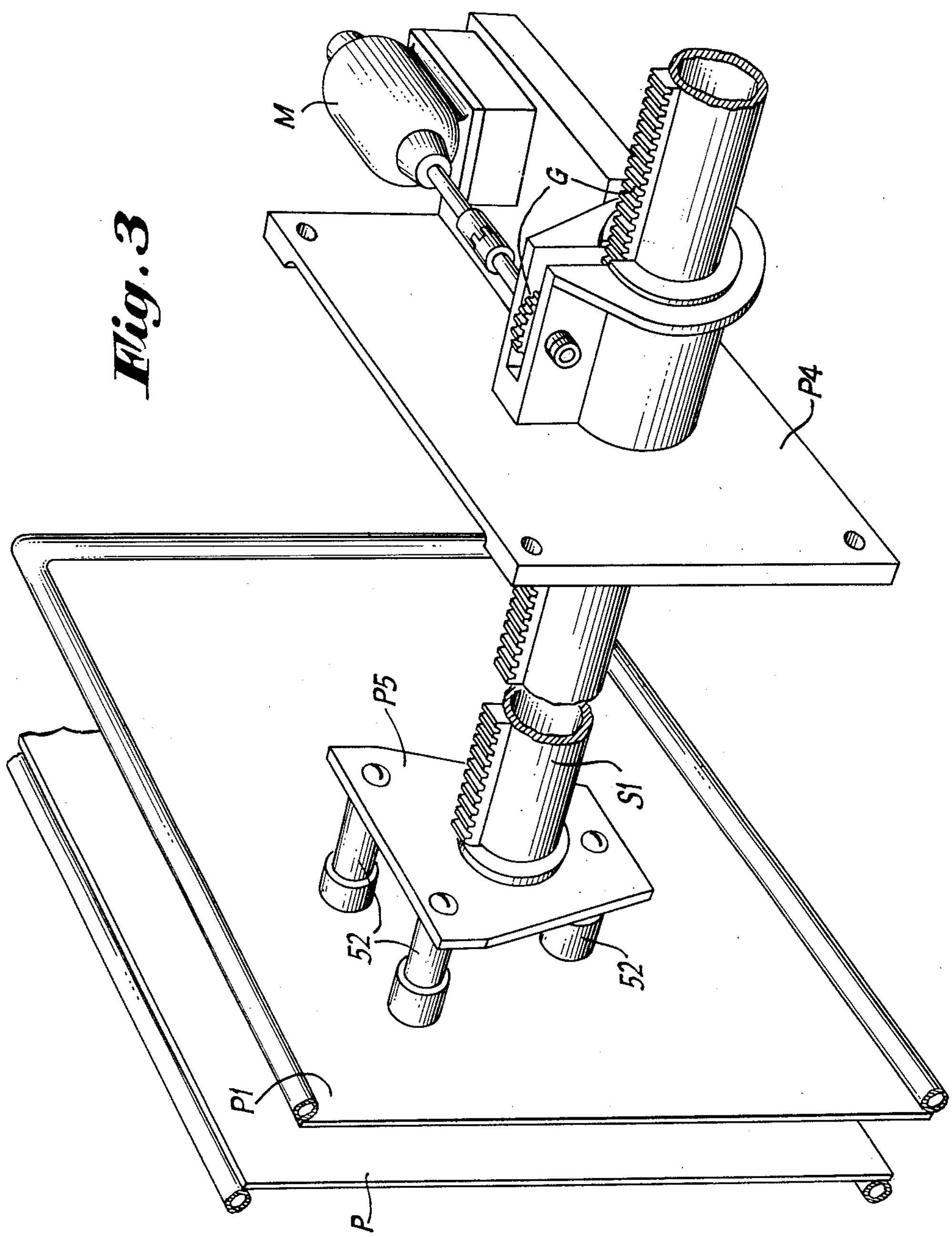
Fig. 3



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Patented Feb. 6, 1951 **2,540,613**

UNITED STATES PATENT OFFICE

2,540,613

HIGH-FREQUENCY VARIABLE POWER OUTPUT SYSTEM

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Application April 8, 1947, Serial No. 740,148

10 Claims. (Cl. 250—36)

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This invention relates to systems utilizing variable power outputs, such as high frequency dielectric heating systems, and particularly to a method of and apparatus for efficiently enabling the output of such a system to be varied over a very wide range in a continual and gradual manner.

An object of the invention is to provide a high frequency dielectric heating system whose power output obtained from the tank circuit can be varied anywhere in the range of 400 watts to 15 kilowatts gradually and continuously, without introducing arc-over complications.

Another object of the invention is to provide a capacity coupling arrangement between the output tank circuit of an electron discharge device system and a load, by means of which the output power available to the load can be continuously and gradually varied over an extremely wide range.

A feature of the invention lies in the use of a capacity potentiometer comprising, in effect, three physically parallel plates, the outer two plates of which are stationary and the center plate of which is coupled to the load and movable in a direction at right angles to the outer plates.

Other objects and features of the invention will appear from a reading of the following description, in conjunction with a drawing, wherein:

Fig. 1 illustrates an embodiment of the invention used in a high frequency dielectric heating system; and

Figs. 2 and 3 are different views of the details of the variable capacity coupling feature of the invention.

Throughout the figures of the drawing, the same parts are indicated by the same reference numerals.

In Fig. 1 there is shown a high frequency dielectric heating system comprising a vacuum tube **10** connected as a Colpitts type oscillator. This vacuum tube has an anode A, a grid G and a filament F. The anode A is connected through blocking condenser **11** to one terminal E of the tank inductance **12**. The grid G is connected through a parasitic suppressor circuit **13** to the other terminal D of the tank inductance **12**. The filament is connected to ground and through a grid leak resistor **14** to a point C of zero radio frequency potential on the tank inductance **12**. A grid excitation capacitor **15** is connected between the grid and the filament as shown. This capacitor **15** is shunted by a fixed capacitor **16**

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such that there is obtained a vernier adjustment in the operation of the variable capacitor **15**. Heating current for the filament is supplied through iron-core transformer T. Anode polarizing potential from the positive terminal B+ of a source of unidirectional supply is fed to the anode A through a radio frequency choke coil **17**. A radio frequency bypass condenser **18** is connected between the B+ supply lead and ground for assuring substantially complete filtering of the radio frequency energy. The anode to cathode interelectrode capacity and the external stray capacity is represented by the dash line capacitor **20** shown connected between the anode and ground.

It will be seen that the electron tube circuit is, in effect, a self-excited Colpitts oscillator, with the capacitor portion of the tank circuit comprising the grid excitation capacitor **15** in series with the effective anode to ground capacities represented by the dash line capacitor **20**.

Output energy from the tank circuit is taken from terminal B on the tank inductor **12**. This terminal B is at a point of low radio frequency potential and low impedance in order to facilitate loading, reduce harmonics and also reduce reaction of the load on the tank. This terminal B is coupled to one outer plate of a three-plate motor driven capacity potentiometer **21**. The capacity potentiometer **21** is independent of the oscillator per se, and is not depended upon to cause oscillations to occur in the tank circuit. This potentiometer **21** comprises three metallic plates, P, P1 and P2 which are physically parallel to one another. The outer plates P and P2 are respectively connected to the tank inductor **12** and to ground. The central plate P1 is connected through a transmission line TL to the load or applicator unit **22**. In effect, this load comprises a coil **23** which tunes with the effective load capacity across the electrodes **24**. The dielectric or non-metallic batch of material to be heated is adapted to be placed between the plates **24** in the applicator unit **22**.

In using the dielectric unit circuit of Fig. 1, it will be evident that different materials to be heated between the electrodes **24** in the load will require different output power from the oscillator. It is therefore necessary to provide an arrangement for enabling the output from the Colpitts oscillator to vary over a wide range. The capacity potentiometer **21** of the invention achieves this desired result in a gradual and continual manner over a very wide power output range.

In effect, the plates P, P1 and P2 have relatively wide surface areas. The outer plates P and P2 are stationary, while the center plate P1 is movable in an axial direction toward or away from P2. When the plate P1 is moved toward P2 and away from plate P, there will be a reduction in the power output to the load. Conversely, when the plate P1 moves away from the ground plate P2 and toward the plate P which is connected to the tank inductor, the power output to the load will increase.

In one embodiment of the invention, the circuit of Fig. 1 was used to produce 15 kilowatts maximum power output at 40 megacycles. The tank inductor 12 was in the form of a U-shaped flat plate linear stub arrangement with a shorting bar to adjust the frequency to certain specified values. Thus, with no shunt capacity directly connected across the terminals E and D of the tank inductor 12, it was possible to obtain power output at a frequency of the order of 40 megacycles, whereas with the addition of certain values of capacities across the terminals E and D of the tank inductor, it was possible to obtain power output at frequencies of 13 megacycles and 27 megacycles depending upon the values of the added capacitors. When the oscillator was used to produce output power at a radio frequency of the order of 13 megacycles and 27 megacycles, the tank inductor was changed and shunted with suitable capacities, and the values of the anode choke coil 17 and the parasitic suppressor 13 were also changed to suitable values. The oscillator was able to supply full power at any one of these three frequencies, 13 megacycles, 27 megacycles and 40 megacycles.

The voltage developed across the terminals E and D in the embodiment actually tried out in practice, was about 6700 volts R. M. S. The voltage between the terminals E and C was 5430 volts R. M. S. The voltage between terminals B and C was 1800 volts R. M. S., while the voltage between terminals C and D was 1270 volts R. M. S.

Suitable cooling fluid for cooling vacuum tube was supplied by a blower circuit. Although air-cooling was actually employed, it will be evident that a water tube can be employed. The vacuum tube actually was an RCA 889R–A power triode which was employed in parallel with another similar power triode, in order to obtain greater power output than can be supplied with one such tube alone.

The details of the capacity potentiometer 21 are shown more clearly in Figs. 2 and 3. The outer plate P and the middle plate P1 had dimensions of the order of 12 inches by 20 inches, while the other outer plate P2 formed part of the metallic housing for the apparatus. The plate P was supported at both ends through insulators I mounted on support S, S, in turn, fastened to the metallic grounded housing plate P2. The housing plate P2 is provided with an aperture at its center across which is bridged a metal plate P4 attached to P2. Attached to plate P4 is a rack and gear mechanism G which is linked to a reversible motor M. The rack and gear mechanism is linked to the central plate P1 through a shaft S1, in turn, secured to a plate P5 mounted on three insulators 52.

The motor M is controlled by power supplied to connections 60. This motor can revolve in either of two directions depending upon the operation of either of a pair of switches. These switches are preferably push-buttons. (Motor control could also be accomplished with an automatic sensing device.)

In the operation of the system of Fig. 1, the parasitic frequencies have been largely suppressed by the use of the parasitic grid suppressor 13 and by the elimination of inductance in the grid return. Harmonics were reduced to a low value by tapping the output feed line to the terminal B which is close to the zero potential point on the tank inductor 12, and by the use of high-Q tank inductance. The capacities used for the grid excitation control, for anode blocking, for filament bypassing purposes, and for stabilizing the tank were of the low self-inductance and high current-carrying capacity kind. The tank stabilizing capacitors, not shown, which were used across the tank inductor 12 for obtaining a change in frequency to 13 megacycles or 27 megacycles, were of the vacuum type.

Suitable interlocking, control and rectifier circuits of the conventional type were employed, and the entire system was metallically enclosed. Low pass radio frequency filters were used to prevent power line radiation.

By means of the capacity potentiometer of the arrangement, it has been possible to obtain a power output variation from 15 kilowatts maximum down to 300 to 400 watts in a gradual and continuous manner, and without introducing arcing complications. It should be understood that this range of output power by means of the capacity potentiometer is merely given by way of example only, and that other ranges of power output variation may be obtained by the use of our particular type of capacity potentiometer.

The term "ground" used in the appended claims is not limited to an actual earthed connection, and is deemed to include the chassis for the apparatus.

What is claimed is:

1. In a dielectric heating system, an electron discharge device oscillation generator having an oscillatory output circuit, a load to be heated, and a coupling circuit between said load and output circuit, said coupling circuit forming no integral part of said oscillatory circuit and including a capacitor having three spaced electrodes one of said electrodes being movable relative to the other two electrodes, said other two electrodes being stationary, a connection from said one movable electrode to said load, and connections from said other two electrodes to said output circuit and ground respectively.

2. In a dielectric heating system, an electron discharge device oscillation generator having a cathode and a tank circuit, a load to be heated, and a capacitor arrangement coupling said tank circuit to said load, said capacitor arrangement being independent of said tank circuit and comprising three physically spaced and parallel metallic plates, a connection from one outer plate to said tank circuit, a connection from said other outer plate to said cathode, a connection from the middle plate to said load, and means for moving the middle plate in a direction toward or away from one of said outer plates while maintaining parallelism with both of said outer plates.

3. In a dielectric heating system, an electron discharge device oscillator having a cathode and a tank circuit, a load to be heated, and a capacitor arrangement coupling said tank circuit to said load, said capacitor arrangement being independent of said tank circuit and comprising three physically spaced and parallel metallic plates, the outer plates being stationary and the middle plate being movable relative to the outer plates, a connection from one outer plate to said

tank circuit, a connection from said other outer plate to said cathode, a connection from the middle plate to said load, and means for moving the middle plate in a direction toward or away from one of said outer plates while maintaining parallelism with both of said outer plates.

4. An electron discharge device dielectric heating system capable of supplying a wide range of output power to a load to be heated, comprising a vacuum tube having a tank circuit including a tank inductor, a capacitor arrangement independent of said tank circuit and having three physically parallel metallic plates, the two outer ones of which are stationary, a connection from one outer plate to said tank inductor, a connection from the other outer plate to ground, and a connection from the middle plate to said load, and means for moving the middle plate in a gradual manner relative to the outer plates while maintaining substantial parallelism between said plates, to thereby vary the amount of output power supplied to said load.

5. A high frequency heating system comprising an electron discharge device generator having a tank circuit including a tank inductor and a cathode electrode coupled to a point of zero radio frequency potential on said inductor, a transmission line adapted to be coupled to the material to be heated, a capacitor arrangement independent of said tank circuit and comprising three physically parallel plates, a connection from one outer plate to a point on said inductor relatively close to the point of zero radio frequency potential, a connection from the other outer plate to ground, a connection from the middle plate to said transmission line, and means for moving said middle plate relative to said outer plates while maintaining parallelism therebetween.

6. A high frequency heating system comprising an electron discharge device generator having a tank circuit including a tank inductor and a cathode electrode coupled to a point of zero radio frequency potential on said inductor, a transmission line adapted to be coupled to the material to be heated, a capacitor arrangement independent of said tank circuit and comprising three physically parallel plates, the outer two plates of which are stationary, a connection from one outer plate to a point on said inductor relatively close to the point of zero radio frequency potential, a connection from the other outer plate to ground, a connection from the middle plate to said transmission line, and means for moving said middle plate relative to said outer plates in a direction perpendicular to the planes of said plates while maintaining parallelism therebetween.

7. An electron discharge device heating system capable of supplying a wide range of output power to a load adapted to be heated, comprising a vacuum tube having a tank circuit including a tank inductor, a capacitor arrangement independent of said tank circuit and having three physically parallel plates the two outer ones of which are stationary, a connection from one outer plate to said tank inductor, a connection from the other outer plate to ground, and a connection from the middle plate to said load, and a reversible motor for moving the middle plate in a gradual manner relative to the outer plates in a direction at right angles to said plates while maintaining substantial parallelism between said plates, to thereby vary the amount of output power supplied to said load.

8. A high frequency dielectric heating system

comprising a Colpitts type vacuum tube oscillator having a tube including anode, cathode and grid electrodes, a tank circuit for said oscillator including a tank inductor of distributed constants, a connection from one end of said tank inductor to said anode, a connection including a parasitic suppressor from the other end of said tank inductor to said grid, a connection from said cathode to a point of zero radio frequency potential on said tank inductor, a connection from said cathode to ground, a load adapted to be heated, and a variable capacitor arrangement independent of said tank circuit and coupling said load to said tank inductor, said capacitor arrangement including three physically parallel metallic plates, the outer two plates being stationary, a connection from one outer plate to a point of relatively low radio frequency potential on said tank inductor, a connection from the other outer plate to ground, and a reversible motor linked to the middle plate for moving the same in a direction at right angles to said plates so as to vary the amount of output energy to said load while maintaining parallelism of said plates.

9. In a high frequency heating system, in combination, a source of alternating current power, a load to be heated, and a variable capacitor arrangement for varying the amount of power fed from said source to said load, said capacitor arrangement being independent of said source and comprising three physically parallel plates, a connection from one outer plate to said source, a connection from the other outer plate to ground, a connection from the middle plate to said load, means for moving said middle plate in a direction at right angles to the planes of all three plates while maintaining the physically parallel relationship, and means for supporting said outer two plates in fixed spacial relation to each other.

10. In a high frequency heating system, an electron discharge device oscillation generator having a cathode and a tank circuit, a load to be heated, and a capacitor arrangement coupling said tank circuit to said load, said capacitor arrangement being independent of said tank circuit and comprising three physically spaced and parallel metallic electrodes one of which is positioned bteween the other two, a connection from an outer electrode to said tank circuit, a connection from the oppositely disposed electrode to said cathode, a connection from the middle electrode to said load, and means for moving the middle electrode relative to said other electrodes while maintaining parallelism with both of said other electrodes.

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