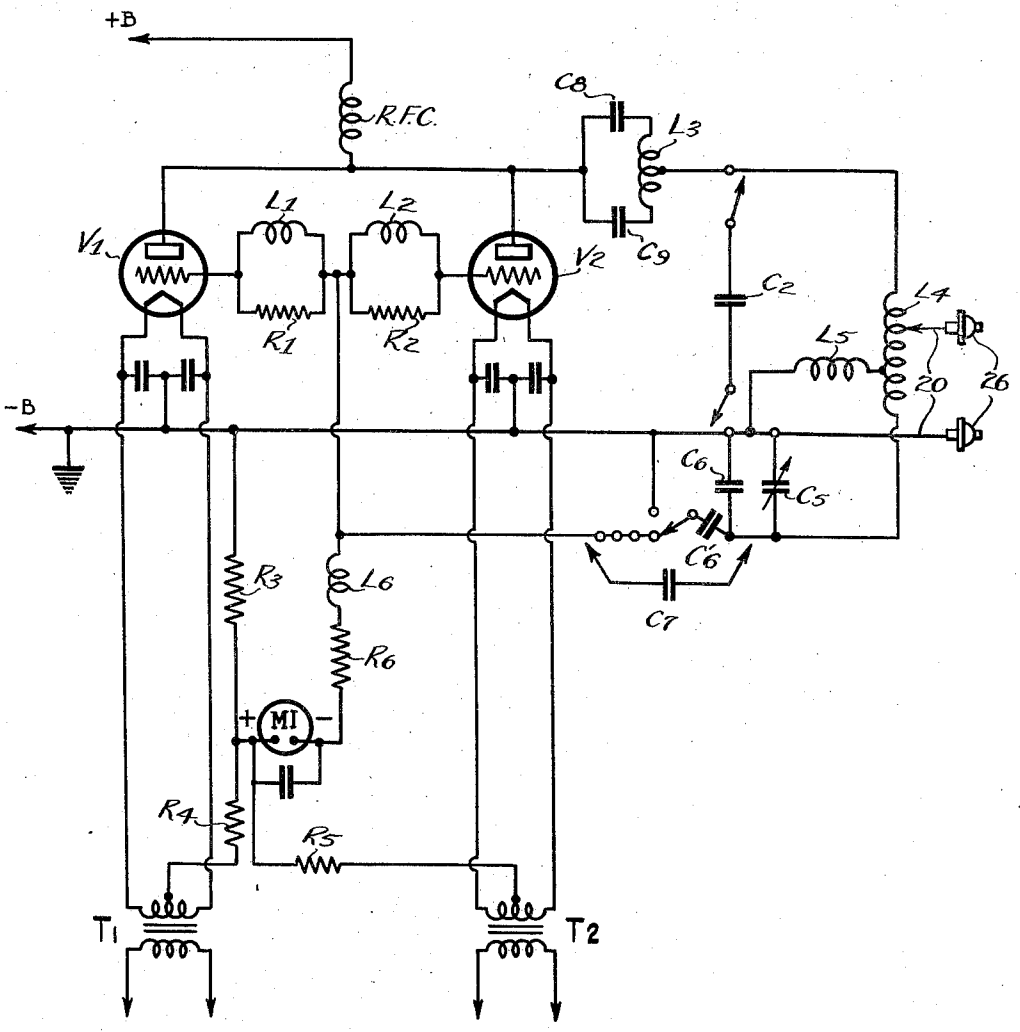
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ELECTRONIC POWER GENERATION

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INVENTORS
LESTER S. LAPPIN
& ROBERT F. HOLTZ
BY
H. B. Brower
ATTORNEY

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ELECTRONIC POWER GENERATION

Lester S. Lappin, Camden, and Robert F. Holtz, Merchantville, N. J., assignors to Radio Corporation of America, a corporation of Delaware

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This application discloses a new and improved means for generating high frequency power.

A general object of the present invention is to improve high frequency power generators for industrial and similar purposes.

A more particular broad object of the present invention is improved means of dielectric heating of non-conducting materials.

Power generators of the nature involved here known in the prior art include an electron discharge tube in a regenerative oscillation circuit. In many instances the regeneration circuit includes a tank circuit inductance through which the direct current for the tube anode flows. These power generators are satisfactory in many cases, but are of limited application for various reasons, many of which flow from the presence of the direct current and/or voltage in the tank inductance. For example, the tank circuit inductance in many cases is in or adjacent the load or material being worked on, so that the operator or operators are sufficiently near thereto to be endangered by the high voltage and/or currents involved.

Moreover, in many of these known systems inductive coupling between the tank circuit and the load is used, and in many cases these arrangements operate unsatisfactorily because this sort of coupling to the load causes trouble of various natures. For example, a phenomenon known as frequency skip is often encountered. By this it is meant that the oscillation generator might operate intermittently at its operating frequency and shift erratically to other frequencies not satisfactory for the use at hand. Furthermore, where inductive coupling is used on loads of certain material full power output is unattainable. This may occur where the dielectric load is of low power factor or where loads of high impedance are being worked on or big masses are adjacent the output bushings or terminals of the system. Thus in many known systems the operators are exposed to the high direct current potentials and voltages of the tank circuit. Furthermore, since the operation is limited or restricted by loads of certain type the uses to which the known power generators may be put is limited.

An object of the present invention is to provide a power generator including an improved tank

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circuit arrangement wherein the direct current is eliminated, thereby reducing the danger to which the operator is exposed. To attain this object, we provided a regenerative generator of the Colpitt's type with two tubes and a tank circuit wherein blocking and coupling capacity is used between the anodes of the generator tubes and the tank circuit to keep direct current and voltage out of the tank circuit.

A further object of the invention is to provide a radio frequency power generator suitable for wide use in the industrial heating art, and one wherein operation at optimum power is assured irrespective of the nature of the material or load being worked on. To attain this object we provided a direct coupling or shunt feed from the tank to the load to eliminate frequency skip and other operational defects of the nature mentioned above.

The blocking capacities available for coupling the anodes to the tank circuit blow up or burn out because of capacity limitations at high frequency. In other words, there are not available condensers which will carry the load involved satisfactorily. To overcome this limitation we use two condensers in parallel as blocking condensers between the anodes of the tube and the tank circuit.

Then due to lack of uniformity in condenser manufacturing we found that the division of current and power through the blocking condenser would become unequal and again one of the condensers would fail throwing the entire load on the remaining condenser which would also fail. This unequal distribution or division of current in the condensers takes place and is believed to be due to variations in the condenser characteristics and structure, some of which variations are as follows. One condenser may have more capacity reactance than the other so that there is a tendency for one condenser to carry more than its share of the load. Another cause may result from the fact that in one condenser the inductive reactance may almost equal the capacitive reactance so that this condenser is of substantially zero impedance to the high frequency power being supplied to the tank and this condenser assumes more of the load than the other, and since its arrangement and dimensions are in general the same as the other it heats up or fails otherwise,

To overcome the above defects we include in series with the two blocking condensers inductive reactance which is large as compared to the reactance of the condensers. This inductive reactance then provides such a large part of the total reactance of the parallel connections that any inequalities in the reactances of the two condensers are swamped out and are ineffective to cause one of the condensers to assume more than its share of the load.

The power generator of the present invention is to operate at various frequencies. In the embodiment tested and found highly satisfactory the generator operates at 2, 5 and 10 megacycles. To facilitate this operation a novel arrangement of tank circuit tuning condensers has been provided which permits ready adjustment of the tank circuit tuning to the several frequencies at which it is desired to operate.

Although it is believed that our invention will be understood from the description given above, a detailed description of the manner in which our objects are attained and the advantages derived therefrom will now be given. In this description, reference will be made to the attached drawings wherein the single figure illustrates the essential elements of a power generator arranged in accordance with our invention. The circuit diagram of the drawings is basic and it will be obvious to those skilled in the art that the practical embodiment which we found highly satisfactory includes many refinements and operating circuit elements not shown, being not a part of the subject matter claimed. For example, in the drawings the metering circuits, control circuits, electrode supply rectifier circuits, and filament heating circuits, or portions thereof at least, are omitted.

In the drawings two electron discharge devices V1 and V2 have their control grids and anodes coupled in a parallel circuit of the Colpitt type for the production of radio frequency power by regenerative generation of oscillations. The grids of the two tubes are coupled together by parasitic damping impedances including inductances L1 and L2 shunted by resistors R1 and R2. The anodes are tied together and connected by the blocking condensers C8 and C9 to the terminals of an inductance L3, a point of which is connected to one end of the tank circuit inductance L4. The other end of the inductance L4 is coupled (in the switch position shown) by condensers C'6 to a point intermediate parasitic damping inductances and resistances L1R1, L2R2. A point on the tank inductance L4 is coupled by a choking inductance L5 to ground, thus preventing the accumulation of a static charge in the tank coil, providing additional protection to the operator.

Direct current for the anode circuits of the tubes V1 and V2 is supplied from a source not shown by way of a radio frequency choke RFC connecting the anodes to a positive terminal on the source, the negative terminal of which is connected to ground and to the cathode of tube V1 by resistor R3 and resistor R4 and to the cathode of V2 by resistor R3 and R5. The direct current grid circuit includes radio frequency choke L6, resistance R6 and a branch R4 to the cathode of tube V1 and a branch R5 to the cathode of tube V2. The bias results from tube current through the grid resistance R6. A meter M1 denotes the grid current intensity. The cathodes may be heated by alternating current supplied through transformers T2 and T1. Oscillations are generated by virtue of the fact that the tank circuit terminals connected to the anodes and grids operate at opposed high frequency voltages and oscillatory energy is fed back from the tank circuit to the grids of a phase opposite to the phase of the oscillatory energy on the anodes of the tubes to provide regeneration.

As stated above, the blocking condensers C8 and C9 in parallel have in series therewith portions of the balance coil L3, which is used to equalize the currents through C8 and C9 by swamping out inequalities in reactance thereof. At a frequency of 10 megacycles the capacitive reactance of C8 and C9 in an embodiment which proves satisfactory, is 8 ohms and the inductive reactances (external and internal) are comparable to the capacitive reactance resulting in an extremely low net reactance. If the stray inductive reactances of the two capacitors are not equal the net unbalance may be relatively great resulting in a considerable current unbalance and overheating of C8 or C9. The balance coil L3 is connected in series with each capacitor and the mutual inductance thereof is of such a magnitude that its reactance in each branch is large as compared to the stray inductive reactances and variations in the stray reactances have relatively small effect with respect to unbalancing the currents through the two condensers.

The load or output circuit including the leads 25 and the output plugs 26, is directly coupled to the tank inductance L4 so that frequency instability (frequency skip or jumping) is held to a minimum in all cases including the case where the output works on a load of low power factor.

As stated above the power generator is to operate at several frequencies, in the embodiment developed at frequencies of 2, 5 and 10 megacycles. To permit such operation an improved tank circuit is provided. The tank circuit comprises in addition to the capacity within the tubes between the plate and cathode, etc., and between the plates and ground, the inductance L4 and condenser C2, the condensers C5, C6 and C'6.

For high frequency operation (10 megacycles in the present embodiment) the plate end of the tank circuit is tuned by the tube internal capacity and the stray capacitive between plates and ground, etc., and L4. For low and medium frequency operation condenser C2 is added by connecting the same between the plates and cathode. The grid capacity for the high frequency operation (10 megacycles) includes in addition to the capacity in the tube between the grid and cathode the variable condenser C5 and the fixed condenser C6. Then the condenser C'6 is the grid blocking (coupling) condenser through which the feedback takes place. For the low and medium frequency operation condenser C'6 is put in shunt with C6 and C5 and condenser C7 is switched in as the grid coupling condenser. The choke coils RFC and L6 are changed to a value appropriate for each operating frequency. The condenser C5 is such that with C6 connected in parallel thereto and C2 out of the circuit the tank may be tuned to the highest frequency, i.e., 10 megacycles, with C2 included in the plate end of the circuit and C'6 in shunt with C6 and C5, with C7 acting as the coupling condenser the tank circuit may be tuned to the medium or low operating frequencies, i.e., 2 or 5 megacycles. Although it will be readily understood that the circuit element dimensions and values depend on the operating frequencies and that my invention is not limited to particular circuit element dimensions and values, in one embodiment which operated very satisfactorily the circuit elements were as follows:

The tubes V1 and V2 are type RCA892R.

R1=100 ohms
R2=100 ohms
R3=0.2 ohm
R4=0.2 ohm
R5=0.2 ohm
R6=2560 ohms
L1=1 turn 2'' dia. at 10 mc., 2 turns 2'' dia. at 2 and 5 mc.
L2=1 turn 2'' dia. at 10 mc., 2 turns 2'' dia. at 2 and 5 mc.
L3=5 turns 1½'' dia. approx.
L4=to tune to appropriate frequency with given capacity
L6=self-resonant at approx. operating frequency
C2=.0004 microfarads approx.
C5=.00056 microfarads
C6=500 microfarads approx.
C'6=625 microfarads approx.
C7=.003 microfarad
C8=.002 microfarad
C9=.002 microfarad

What is claimed is:

1. In apparatus for electronically generating oscillatory power for industrial and like purposes, an electron discharge device having an anode, a cathode and a control grid, coupled in regenerative circuit including inductive reactance and capacitive reactance in parallel, the parallel reactances being coupled at one end to the anode of the device and at the other end by feedback coupling to the control grid of the device, direct current blocking condensers connected in parallel in the coupling between the anode of the device and said one end of said parallel reactances, and means for equalizing the current through the said blocking condensers comprising conductors coupled by mutual inductance in series with the parallel blocking condensers.

2. In apparatus for electronically generating oscillatory power for industrial and like purposes, an electron discharge device having an anode, a cathode and a control grid, coupled in regenerative circuit including inductive reactance and capacitive reactance in parallel, the parallel reactances being coupled at one end to the anode of the device and at the other end by feedback coupling to the control grid of the device, direct current blocking condensers connected in parallel in the coupling between the anode of the device and said one end of said parallel reactances, and means for equalizing the current through the said blocking condensers comprising a winding in series with each of said blocking condensers.

3. In apparatus for electronically generating oscillatory power for industrial and like purposes, a plurality of electron discharge tubes each having an anode, a cathode and a control grid parallel coupled in a regenerative circuit including a tank circuit having inductive reactance and capacitive reactance in parallel, the parallel reactances being coupled at one end to the anodes of the tubes and at the other end by feedback coupling to the control grids of the tubes, direct current blocking condensers connected in parallel in the coupling between the anodes of the tubes and said one end of said parallel reactances, and means for equalizing the current through the said blocking condensers including a winding in series between adjacent ends of the parallel blocking condensers so that each blocking condenser has a portion of said inductance in series therewith in the parallel connection.

4. In apparatus for generating oscillatory power for industrial purposes, an electron discharge device having an anode, a cathode, and a control grid, coupled in a Colpitt's circuit including parallel inductance and capacity coupled at one end to the anode and at the other end by feedback connection to the control grid, direct current blocking condensers in the connection between the anode and said one end of said tank circuit, and means for equalizing the current through the said condensers comprising a balancing inductance coupling the tank end terminals of said condensers together with a point on the balancing inductance connected to said one end of said tank circuit.

5. In apparatus for generating power for industrial purposes, an oscillation generator of the Colpitt's type comprising at least one electron discharge tube having an anode, a cathode and a control grid, a tank circuit connected by parallel blocking condensers to the anode of said tube and by a feedback condenser to the control grid of said tube, the purpose of said blocking condensers being to prevent direct current from flowing in said tank circuit and to feed oscillatory power from the tube to the tank circuit, and means for preventing unbalanced reactance of the parallel condensers from causing failure of one thereof including inductance in parallel between the tank terminal ends of said blocking condensers and said tank circuit.

6. Apparatus for generating oscillatory power for industrial and like purposes, at least one electron discharge tube having an anode, a cathode, and a control grid, a parallel tank circuit comprising inductance and at least the capacity inherent between the tube electrodes, a connection between a point on the inductance of said tank circuit and the cathode of said tube, a connection between one terminal of the tank circuit and the anode of the tube, a feedback coupling between the other terminal of the tank circuit and the control grid of the tube whereby oscillatory energy is developed in the tube when the electrodes thereof are energized, means for blocking the flow of direct current in said tank circuit when the electrodes are energized including a pair of condensers each having a terminal tied together and to the anodes of said tubes, and a blocking condenser reactance balancing inductance connected at its terminals to the other terminals of said blocking condensers and at a point intermediate its terminals to the said one end of tank circuit.

7. In an oscillatory power generator, an electron discharge device having an anode, a cathode and a control grid, coupled in regenerative circuit including inductive reactance and capacitive reactance in parallel, the parallel reactances being coupled at one end to the anode of the device and at the other end by feedback coupling to the control grid of the device, direct current blocking condensers connected in parallel in the coupling between the anode of the device and said one end of said parallel reactances, and means for equalizing the current through the said blocking condensers comprising conductors coupled by mutual inductance in series with the parallel blocking condensers.

8. In combination, a pair of condensers of substantially equal capacity, a connection directly connecting a pair of terminals of said condensers together, a coil connected to and between the other terminals of said condensers, and conductors connected to said direct connection and to the midpoint of said coil whereby alternating

current fed from one conductor to the other does not produce harmful unequal current flow through said condensers.

9. In apparatus for generating power for industrial purposes, an electron discharge device having an anode, a cathode and a control grid, circuits including a tank circuit coupling the anode, cathode and control grid of said device in a regenerative oscillation generating circuit, said tank circuit comprising in parallel an inductor and a capacitor including at least the inherent capacity between device electrodes, a source of direct current potential connected between the anode and cathode of said device, and means for preventing direct current potential from appearing in said tank circuit including, in the couplings between the anode of said device and said tank circuit, a pair of capacitors, said capacitors each having a terminal tied to the anode of said device and a second inductor connected between the

other terminals of said last named capacitors and a coupling between a point intermediate the terminals of said second inductor and said tank circuit.

LESTER S. LAPPIN.
ROBERT F. HOLTZ.

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