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HIGH-FREQUENCY DEVICE FOR DIELECTRIC HEATING

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2 Sheets-Sheet 1

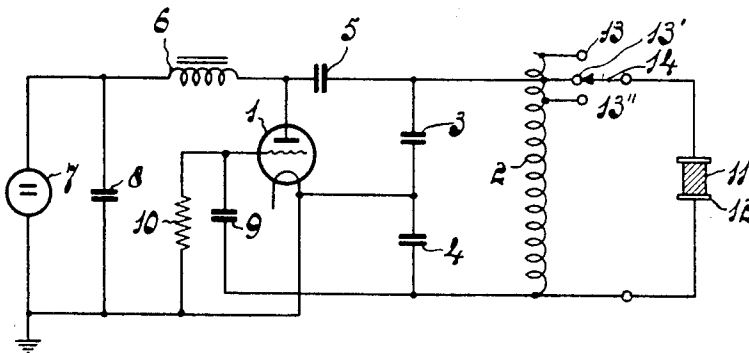


Fig. 1

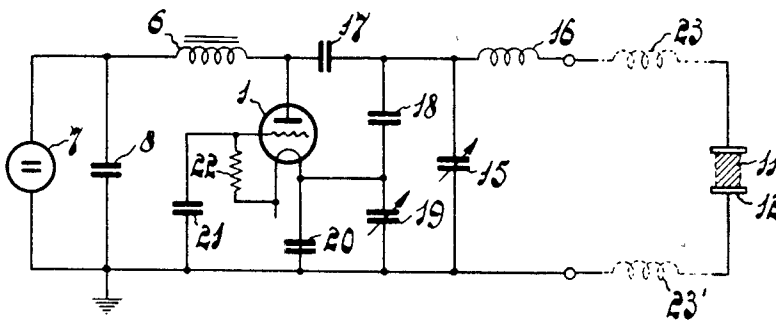


Fig. 2

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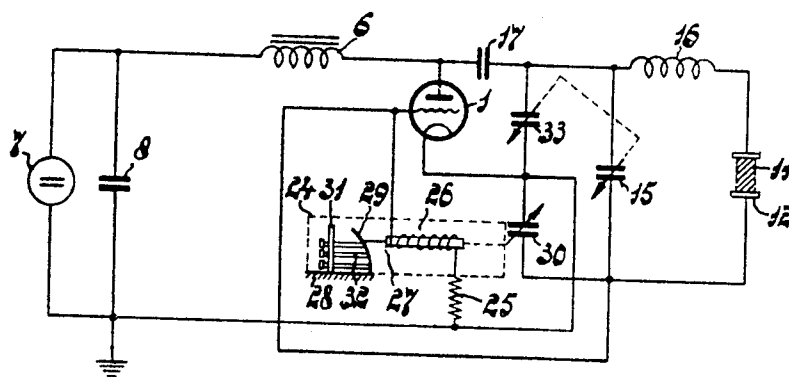


Fig. 3

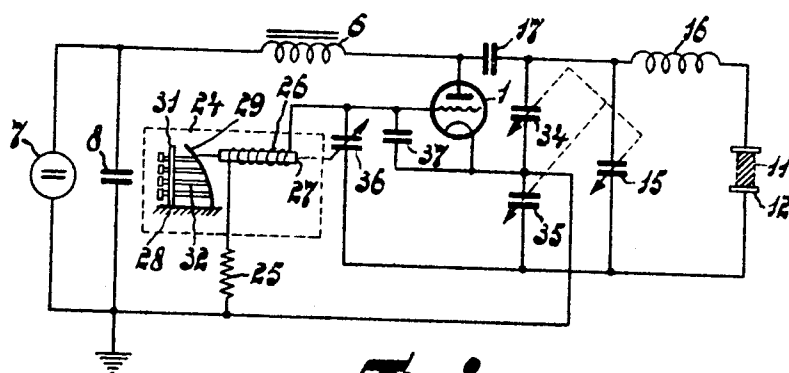


Fig. 4

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HIGH-FREQUENCY DEVICE FOR DIELECTRIC HEATING

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Claims priority, application Netherlands September 27, 1951

5 Claims. (Cl. 219—10.77)

This invention relates to high-frequency devices or circuit arrangements for dielectric heating wherein the high-frequency energy is produced by an electron tube feedback oscillator.

The invention has for its principal object to provide a particularly suitable high-frequency device permitting the supplied power to be varied within wide limits with satisfactory efficiency, such as is desirable, for example, for the dielectric heating of workpieces of different nature and size.

According to the invention the electron tube feedback oscillator of the high-frequency device comprises a tuned circuit which is provided between the anode and the control grid circuit and includes a coil connected in series with a load circuit-capacitor, an adjustable circuit-capacitor being placed between anode and control grid for controlling the supplied power. The feedback voltage for the electron tube oscillator is taken from a variable capacitive voltage divider which is connected in parallel with the circuit capacitor and whose tapping point is connected to the tube cathode, the voltage division ratio for stabilization of the grid excitation being controlled in accordance with the grid direct current.

In order that the control range of the power control may be further widened, the capacitive voltage divider comprises a variable capacitor mechanically coupled to the adjustable circuit capacitor in a manner such that on adjusting the supplied power the mechanically coupled capacitors vary in the same sense whereas another branch of the capacitive voltage divider comprises a voltage divider capacitor controlled by the grid current.

In order that the invention may be more readily carried into effect it will now be explained in greater detail with reference to the accompanying drawings, given by way of example, in which:

Fig. 1 is a schematic diagram of a known high-frequency device;

Fig. 2 is a schematic diagram of an embodiment of the high-frequency device according to the invention;

Fig. 3 is a schematic diagram of another embodiment of the high-frequency device according to the invention; and

Fig. 4 is a modification of the embodiment of Fig. 3.

In the prior art circuit-arrangement shown in Fig. 1 the high-frequency heating energy is taken from a grid-controlled electron tube oscillator comprising a triode 1. The tuned anode circuit of the tube oscillator, which is a Colpitts circuit, comprises an oscillator circuit, connected between anode and control grid and provided with a coil 2 and a capacitive voltage divider consisting of capacitors 3 and 4, the junction point of the capacitors being connected to the grounded cathode of the tube. The anode of the tube is coupled by way of a coupling capacitor 5 to the anode circuit 2, 3, 4 and connected through a choke 6 to a source of direct anode voltage 7 shunted by a smoothing capacitor 8. The control grid of the tube is connected by way of a grid capacitor 9 to that end of the anode circuit which is remote from

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the anode, a grid leak-resistor 10 being connected between grid and ground.

The high-frequency oscillations produced in the anode circuit upon oscillations of the circuit-arrangement are utilized for dielectric heating of a load 11 provided between the electrodes of a charge capacitor 12 connected to the anode circuit. In order to match the oscillator to the load to be heated the coil 2 may be provided with tapings 13, 13', 13'' which can be chosen at will by operating a selector switch 14.

It has been found that with this known power control by means of an adjustable tapping point on the coil, the control range is greatly limited by the stray self-induction of the coil acting as an autotransformer. Furthermore, this power control is adversely affected by an abrupt leap from the oscillator frequency to a parasitic frequency, which is due to the self-induction that is no longer negligible at high-frequencies, of the lead between anode circuit and load. This has a capacitive nature in respect to the oscillator frequency and acts as a self-induction in respect to high-frequencies, said self-induction together with the anode circuit capacity being chiefly instrumental in determining the parasitic oscillator frequency.

The use of the high-frequency device according to the invention as shown in Fig. 2 permits the control range of the power control to be appreciably widened with a satisfactory efficiency.

The high-frequency device shown in Fig. 2 according to the invention, comprises, similarly to the circuit-arrangement shown in Fig. 1, a triode 1 connected through a supply choke 6 to a source of direct voltage 7 comprising a smoothing capacitor 8. The anode circuit of the tube oscillator (Colpitt's circuit) comprises a variable capacitor 15, a coil 16 connected in series with the load circuit including a load capacitor 12, and a capacitive voltage divider provided between anode and control grid. The voltage divider consists of a capacitor 18, connected to the anode through a blocking capacitor 17, in series with the parallel-connection of a variable capacitor 19 and a fixed capacitor 20. The tapping point of the voltage divider is connected to the cathode of the tube. Those ends of the voltage divider capacitors 19 and 20, which are remote from the tapping, are grounded and connected by way of grid capacitor 21 to the control grid connected to the cathode by way of a leak resistor 22.

In this circuit-arrangement, the power supplied to the load is variable within wide limits (control range 1:10 for example) by varying the circuit capacitor 15. In the present case, in contradistinction to the circuit-arrangement shown in Fig. 1, the control range is not adversely affected by the stray self-induction of the coil, which is an autotransformer, and the self-induction of the leads between anode-circuit and load. Thus, for example, this circuit-arrangement permits the load capacitor 12 to be placed without adverse effects at a few meters from the high-frequency device. The inductances 23 and 23' introduced by the leads do not practically affect the power control.

In order that the control grid excitation of the oscillator tube may be stabilized throughout the range of power control, so that this oscillator consistently operates under optimum operating conditions, the voltage distribution ratio of the capacitive voltage divider 18, 19 is automatically controlled in accordance with the grid-direct current, for example, in the manner set out in the copending U. S. patent application, Serial No. 281,642, filed April 10, 1952. To this end the voltage divider capacitor 19 is variable in the present embodiment. Alternatively, capacitor 18 instead of capacitor 19 may be variable.

In a practical embodiment of the high-frequency device shown in Fig. 2, comprising as an oscillator tube

a Philips triode of the type TBL 6/6000, the inductance of coil 16 was approximately 1 microhenry, the capacity variation of capacitor 15 being about 50 to 450 micro-microfarads, the capacitors 18 and 19 being 25 and 100 micro-microfarads respectively; the capacitor 20 having a capacity of 50 micro-microfarads, and the overall wiring and zero capacity of the said capacitors being approximately 120 micro-microfarads, the control range of the capacitor then being well over 1:3 corresponding to a power control of about 1:10.

In accordance with the nature of the load to be heated the capacity of the load capacitor 12 has a value of from 40 to 2000 micro-microfarads.

When heating, for example, a rod-shaped workpiece, the spacing between the electrode of the load capacitor 12 then being considerable so that the load capacitor is small, the oscillator frequency (in the frequency-range of from 6 to 22 megacycles per second) is comparatively high and in this case, moreover, the voltage across the load capacitor is comparatively high as compared with the circuit voltage. Both factors insure that a reasonable power is dissipated in the load even under these operating conditions.

Fig. 3 shows a high-frequency device according to the invention, which, in comparison with the circuit-arrangement shown in Fig. 2, permits further widening of the control range of power control. In Fig. 3, corresponding elements have the same reference numerals as in Fig. 2.

In Fig. 3, the control grid excitation is stabilized by means of a device 24 provided in the control grid circuit and of the type set out in the above-identified co-pending patent application. This device comprises a magnet coil 26 connected in series with a leak resistor 25 and having a movable regulating member 27 which upon excitation of the magnet coil 26 by the grid direct current is movable against the force exerted by a spring 29 clamped unilaterally in mounting plate 28, thus varying the degree of feedback by adjustment of a capacitor 30 coupled to the regulating member.

Secured to a mounting plate 28 is a corner stay 31 carrying a number of adjusting screws 32 extending in a direction transversely of the spring and successively engaged by spring 29 when the regulating member moves to the left. In this device the adjusting screws are so set that the characteristic of the spring force acting on the regulating member is a laterally inverted image of the characteristic of the magnetic attractive force exerted, the desired, as the case may be, maximum permissible excitation of the oscillator, on the regulating member 27 relative to the axis on which the displacement of the regulating member is plotted. Owing to the action of the regulating device 24 the same favorable, as the case may be, maximum permissible excitation voltage is set up at the control grid of the oscillator throughout the range of power control. In other words, the oscillator consistently operates under optimum operating conditions.

In the circuit-arrangement so far described, the limits of the control range of power control are mainly determined by the maximum and minimum circuit capacity. For a large control range it is therefore advantageous to so construct the high-frequency device that the minimum circuit capacity (zero capacity) is exceedingly low.

Applicant has found that reduction of the voltage divider capacitors in the circuit-arrangement shown in Fig. 2 to widen the control range results in a considerable decrease in efficiency of this circuit-arrangement, notably at high capacity values of the variable capacitor 15, i. e. at low oscillator frequencies. This effect is to be attributed to grid-current limitation of the positive peaks of grid excitation, because the capacitive voltage divider has a considerable impedance towards these low oscillator frequencies.

Widening of the power control without detracting from

the efficiency is obtained by making the voltage capacitor divider 33 adjustable and coupling it mechanically to capacitor 15 in a manner such that on adjusting the supplied power the mechanically coupled capacitors 15 and 33 vary accordingly.

In this circuit-arrangement, upon adjusting the capacitor 15 to a low value, hence at a comparatively high oscillator frequency, the voltage divider capacitor 33 mechanically coupled to capacitor 15, will also be set to a low value. The distribution ratio of the capacitive voltage divider capacitor 30, 33 is then so readjusted by the device 24 as to produce the desired excitation voltage at the control grid of the oscillator tube. In other words the voltage divider capacitor 30 controlled by the grid direct current follows the decrease of the voltage divider capacitor 33.

In comparison with the circuit-arrangement shown in Fig. 2 the overall capacity of capacitive voltage divider 30, 33 in the circuit-arrangement of Fig. 3 decreases towards the high oscillator frequencies and consequently also the minimum circuit capacity (zero capacity). In practice, it has been found that the capacitive voltage divider following the oscillator frequency does not adversely affect the efficiency.

In this manner the circuit-arrangement described permits the control range to be widened appreciably, for example, by a factor 3 to 5, without adversely affecting the efficiency.

Experimental tests have shown that the voltage divider capacitor 30 controlled by the grid current should be able to vary within wide limits, say 60 to 600 micro-microfarads.

Alternatively, the voltage divider capacitor 30 connected between cathode and control grid may be mechanically coupled to the variable capacitor 15, the voltage divider capacitor 33 connected between anode and cathode then being controlled in accordance with the direct grid current.

High-frequency devices according to the present invention have the further important advantage that the supplied power depends to a lesser degree upon any variations arising in the supply source voltage. Upon the occurrence of a supply source voltage variation the circuit voltage will vary, and without excitation control the excitation voltage will vary as well. In practice, it has been found that in the last-mentioned case a decrease of 5% in supply source voltage involves a decrease of 12% in supplied power, whereas in a device according to the invention a power loss of only 5% occurs, as a result of the grid excitation being maintained constant.

Fig. 4 is a modification of the embodiment of the high-frequency device of Fig. 3, corresponding elements bearing the same reference numerals.

In the circuit-arrangement shown in Fig. 4, capacitor 15 is mechanically coupled to capacitors 34 and 35 of the capacitive voltage divider, which capacitors are included in the anode circuit and in the control-grid circuit, in a manner such that the capacitors 15, 34, 35 vary accordingly. The capacitor 36 controlled in accordance with the grid current is included in a branch connected in parallel with voltage divider capacitor 35, and constituted by a capacitive voltage divider 36, 37, one tapping point of which is connected to the control grid of tube 1.

The operation of the circuit-arrangement of Fig. 4 is substantially similar to that of Fig. 3 and is in accordance with what has been said with reference to Fig. 3 and needs no further explanation.

In the circuit-arrangement of Fig. 4, the capacitor 36 controlled by the grid current carries only the excitation current. As compared with the grid-current controlled capacitor 30 in the circuit-arrangement of Fig. 3, which is moreover loaded by part of the circuit current, the capacitor 36 may be of a smaller size which, in practice, may be advantageous under certain conditions.

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Finally it is to be noted that for stabilizing the grid excitation the voltage divider capacitor 37 in place of capacitor 36 may be made variable. If desired, the capacitors 36 and 37 may be controlled in opposite sense by the grid current in the manner of a differential capacitor.

It is to be understood that the invention is not limited to the details disclosed but includes all such variations and modifications as fall within the spirit of the invention and the scope of the appended claims.

What I claim is:

1. High-frequency apparatus for the dielectric heating of a load; said apparatus comprising an electron discharge tube having a cathode, a grid and an anode, a coil, electrodes forming a load capacitance and connected in series with said coil, means for varying the power supplied to said load capacitance comprising an adjustable condenser connected across said series-connected coil and capacitance and forming therewith a tuned circuit, means coupling said condenser between said anode and said grid, a variable capacitive voltage divider connected across said condenser and having a tap connected to said cathode, means to apply an operating potential between said anode and said cathode whereby high-frequency oscillations are produced in said tuned circuit, and means coupled to said grid and responsive to direct-current grid flow to vary the voltage division ratio of said divider to effect stabilization of grid excitation.

2. Apparatus, as set forth in claim 1, wherein said divider is constituted by two series-connected variable capacitors whose junction constitutes the tap connected to said cathode, and further including means mechanically ganging one of said capacitors to said adjustable condenser to effect variation thereof in the same sense, the other of said capacitors being controlled in accordance with grid current flow.

3. High-frequency apparatus for the dielectric heating of a load; said apparatus comprising an electron discharge tube having a cathode, a grid and an anode, a coil, electrodes forming a load capacitance and connected in series with said coil, means for varying the power supplied to said load capacitance comprising an adjustable condenser connected across said series-connected coil and capacitance and forming therewith a tuned circuit, means coupling said condenser between said anode and said grid, a variable capacitive voltage divider coupled between said anode and said grid and constituted by two series-connected variable capacitors, the junction of said capacitors being connected to said cathode, means to apply an operating potential between said anode and said cathode whereby high-frequency oscillations are produced in said

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tuned circuit, means mechanically ganging that capacitor of said divider which is coupled between said anode and said cathode to said adjustable condenser to effect variation thereof in the same sense, and means coupled to said grid and responsive to direct-current grid flow to adjust the other capacitor of said divider so as to effect stabilization of grid excitation.

4. Apparatus, as set forth in claim 3, wherein said last-named means includes a magnet coil connected between said grid and said cathode, said coil being provided with a movable member coupled to said other capacitor to vary same in accordance with grid current flow in said magnet coil.

5. High-frequency apparatus for the dielectric heating of a load; said apparatus comprising an electron discharge tube having a cathode, a grid and an anode, a coil, electrodes forming a load capacitance and connected in series with said coil, means for varying the power supplied to said load capacitance comprising an adjustable condenser connected across said series-connected coil and capacitance and forming therewith a tuned circuit, means coupling said condenser between said anode and said grid, a variable capacitive voltage divider coupled between said anode and said grid and constituted by two series-connected variable capacitors, the junction of said capacitors being connected to said cathode, means to apply an operating potential between said anode and said cathode whereby high-frequency oscillations are produced in said tuned circuit, means mechanically ganging the two capacitors of said divider to said adjustable condenser to effect variation thereof in the same sense, a second capacitive voltage divider formed by third and fourth capacitors, said third capacitor being variable and being interposed between said grid and the first divider said fourth capacitor being connected between said grid and cathode, and means coupled to said grid and responsive to grid current flow to adjust said third capacitor in accordance therewith to effect stabilization of grid excitation.

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