June 5, 1945. E. E. SPITZER 2,377,456

HIGH FREQUENCY OSCILLATOR SYSTEM

Filed March 2, 1942 2 Sheets-Sheet 1

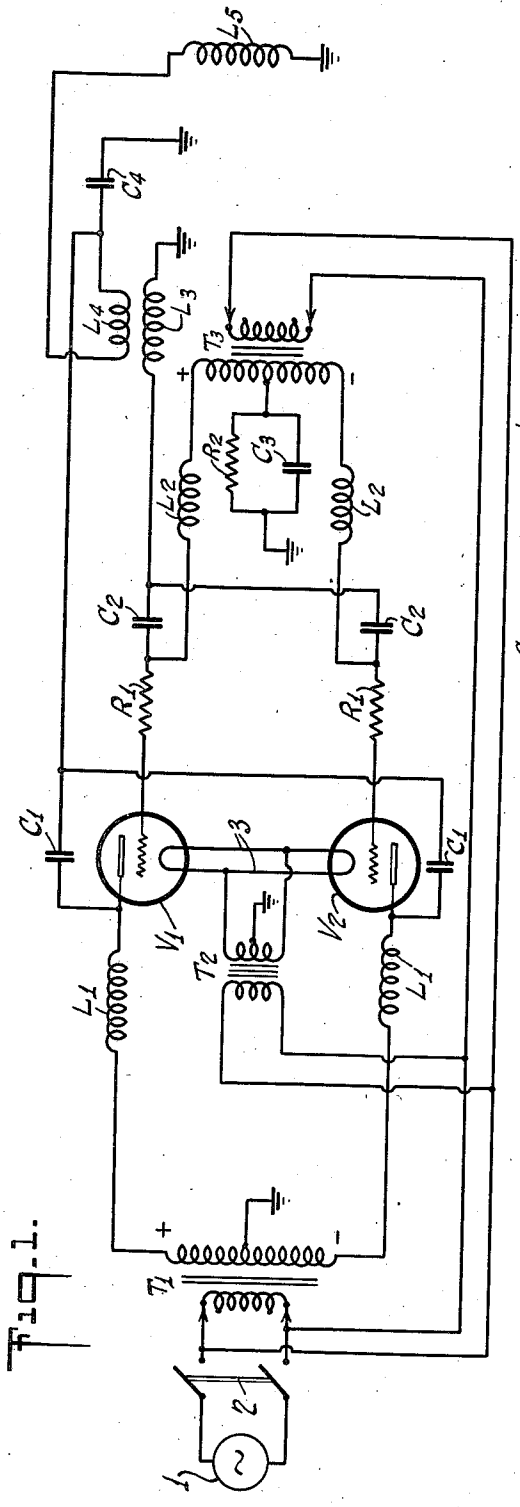


Fig. 1.

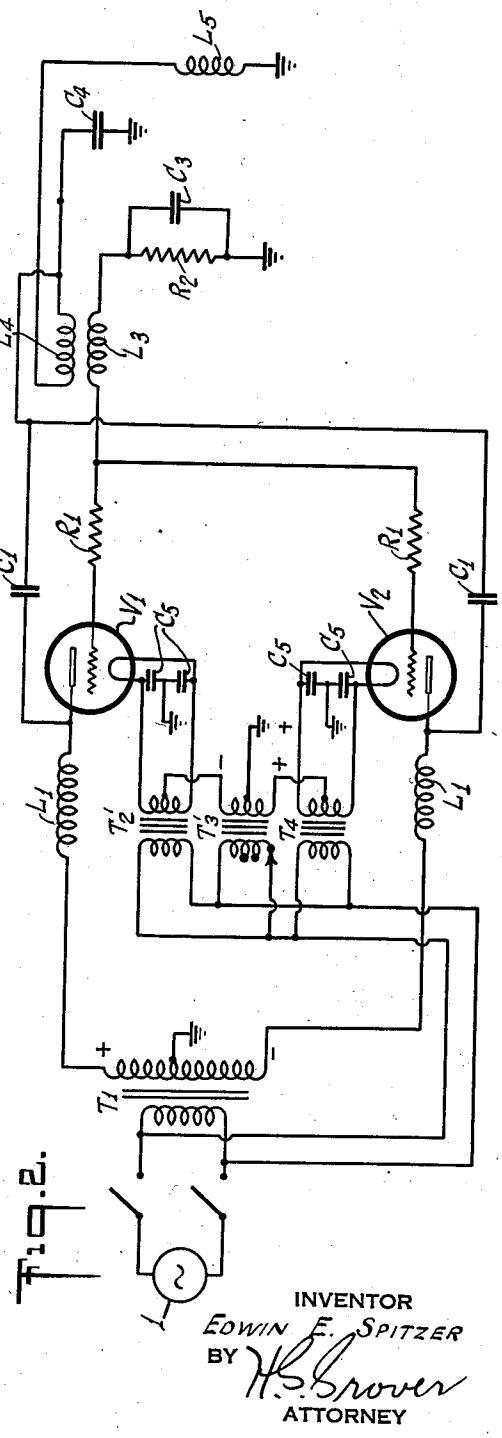


Fig. 2.

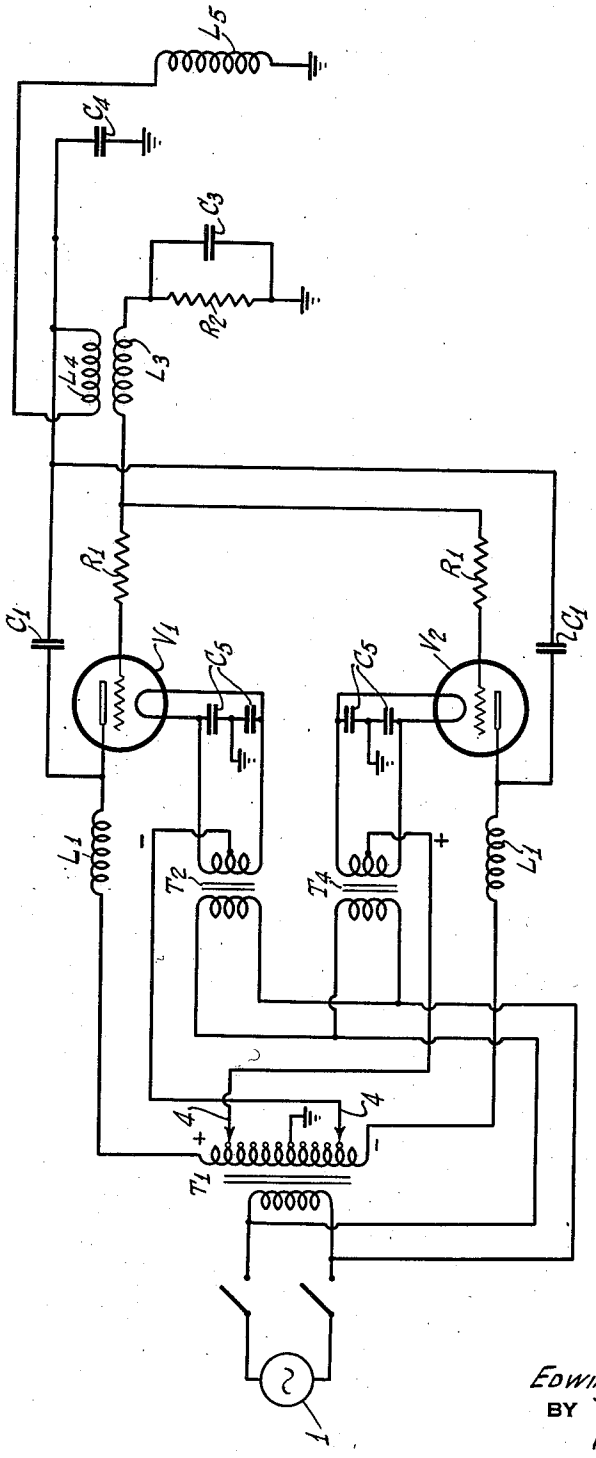
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Fig. 2.



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HIGH-FREQUENCY OSCILLATOR SYSTEM

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5 Claims. (Cl. 250—36)

This invention relates to improvements in electron discharge device circuits utilizing alternating currents for supplying power to the electrodes thereof, and more particularly to self rectifying vacuum tube oscillators.

In high frequency induction heating equipment such as is commonly used in vacuum tube manufacture, diathermy treatment and elsewhere, the apparatus employs vacuum tubes connected to a radio frequency oscillating circuit. A high voltage low frequency transformer supplies the power to the anodes of the vacuum tubes. The high voltage from this transformer is usually applied directly to the vacuum tubes without using rectifier tubes and filter circuits in order to save the cost of this additional apparatus, and in order to increase the reliability of the equipment as a whole by eliminating as many components as possible. Now, since the vacuum tubes will produce oscillations only when their anodes are positive with respect to their cathodes, the vacuum tubes act as unilateral devices and thus rectify the alternating current anode voltage. The resultant rectified current would normally magnetize the core of the anode transformer, resulting in excessive iron loss and magnetizing current loss. This is commonly prevented by using vacuum tube oscillators in pairs, in conjunction with a center-tapped high-voltage anode transformer and so connected that the anodes of one or more oscillator tubes are fed from the high-voltage transformer tap on one side of the center tap while an equal number of oscillator tubes are fed from the opposite tap. In this way the rectified currents of the opposite tubes or pairs of tubes balance out in the high-voltage transformer secondary, so that the ill effects of magnetization are avoided. The oscillator tubes are then all effectively connected in parallel as far as high frequency currents are concerned. This is done by means of radio frequency coupling condensers and radio frequency chokes.

In the operation of such known apparatus, first the oscillator tubes connected to one side of the anode transformer oscillate. At this particular time the oscillator tubes connected to the opposite side of the anode transformer do not oscillate because their anode voltage is negative. However, the grids of these latter oscillator tubes have radio frequency voltage applied, because the tubes are all in parallel for radio frequency. This results in unnecessary heating of these grids and loss of radio frequency power. In practice, it has been found that as the power of such equipment is gradually increased, eventually the grid heating raises the grid temperature so much that the grids will emit electrons. This grid emission easily becomes cumulative due to the fact that it reduces the grid bias voltage on the tubes so that finally the anode current also increases due to loss of bias. This cumulative heating proceeds very rapidly so that either the high-voltage transformer protective fuses or relays trip out or the oscillator tubes are destroyed by overheating.

One of the objects of the present invention is to overcome the foregoing difficulties.

Another object is to prolong the life of self-rectifying vacuum tube oscillators employing alternating currents for supplying power to their anodes.

A further object is to enable the operation of electron discharge device apparatus of the type described above at a higher power than heretofore before limitation due to grid heating is encountered.

Briefly, the foregoing objects are achieved in accordance with the invention by obtaining from the source of anode voltage an additional alternating current bias voltage which is so connected that when the anode voltage of an oscillator tube goes negative, its grid also goes more negative by virtue of the additional alternating current bias. The magnitude of this bias is to be such that it overrides the radio frequency voltage applied to the grid, thus preventing the grid from becoming positive with respect to its filament. Putting it in other words, I supply sufficient alternating current bias to prevent a grid from drawing current when its anode is negative. In this manner, flow of grid current during the negative anode voltage cycle is entirely prevented, and consequently no unnecessary grid heating occurs.

A more detailed description of the invention follows in conjunction with the drawings, wherein Figs. 1, 2 and 3 illustrate three different embodiments of the invention.

In the figures of the drawings, the same parts are represented by the same reference characters.

Referring to Fig. 1 in more detail, there is shown one form of my improved high frequency induction heating equipment. The single phase alternating current power source is indicated at 1. This source may have any desired frequency such as 60 cycles per second. This source supplies the high voltage power transformer T_1, through double pole switch 2, of which the secondary has its midpoint grounded and its opposite terminals connected to the anodes of the respective oscillator electron discharge devices (vacuum tubes) V_1 and V_2 through radio frequency choke

coils L_1 and L_1. These choke coils are of proper inductance to block the passage of currents of the frequency generated by the tubes V_1, V_2, but to permit the currents from the source f to pass readily to the anodes.

The filaments of tubes V_1 and V_2 are connected together by leads 3, 3 and fed with heating current from step-down filament transformer T_2 whose primary winding is connected to the alternating current source f, and whose secondary winding is grounded at its center.

The grids of tubes V_1, V_2 are connected together through parasitic oscillation prevention resistors R_1, R_1 and radio frequency by-pass condensers C_2, C_2. The anodes of tubes V_1, V_2 are connected together through radio frequency by-pass condensers C_1, C_1. Thus, it will be seen that the inputs and outputs of the two vacuum tubes V_1 and V_2 are respectively connected in parallel relation from a radio frequency standpoint. Feedback between the anode and grid electrodes of the tubes, in order to sustain oscillations, is obtained by means of coupling coils L_4 and L_3 which are, respectively, grid excitation transformer primary and secondary coils. Condenser C_4 is the main oscillating circuit condenser and resonates with coils L_4 and L_5 in series. Coil L_5 is the output or load coil employed for inductively heating the object.

In order to prevent unnecessary heating of the grids, there is provided a transformer T_3 whose primary winding is connected to the alternating current source f and whose secondary winding is connected to the grids of the tubes through radio frequency choke coils L_2, L_2 and the resistors R_1, R_1. A common grid leak resistor R_2 shunted by radio frequency by-pass condenser C_3 is connected between ground and the center point of the secondary of transformer T_3. This arrangement enables me to supply the grid of that tube whose anode momentarily goes negative with an additional negative alternating current bias, the magnitude of which is such that it overrides the radio frequency voltage applied to the same grid. The peak voltage delivered by transformer T_3 from its center tap to either outside leg is adjusted so as to be equal or greater than the difference between the peak radio frequency voltage across coil L_3 less the peak voltage across grid leak resistor R_2. In this way the grid of tube V_2 will not go positive with respect to its filament during the time its anode is negative, nor will the grid of tube V_1 go positive with respect to its filament during the time its anode is negative. The positive (+) and negative (—) signs indicate the polarities for the instantaneous condition when the anode of tube V_1 goes positive and the anode of tube V_2 goes negative.

The taps on the primary windings of transformers T_1 and T_3 show how, if desired, power can be controlled and the auxiliary bias adjusted. Alternatively, the secondary winding of transformer T_3 can be wound on the core of transformer T_1, in which case the periodic bias would vary in optimum manner as the power is varied by varying the connections to the taps on the primary of T_1. In this last case, the T_3 secondary should be provided with taps for the initial adjustment of the periodic bias.

Fig. 2 shows another circuit embodiment of the invention and differs from Fig. 1 in the manner in which the additional alternating current bias is supplied to the grids. In Fig. 2, the additional bias is supplied by a transformer T'_3 in the cathode circuit of the oscillator tubes V_1, V_2. The filaments of tubes V_1 and V_2 are supplied with heating currents from individual step-down transformers T'_2 and T_4, respectively. Across the legs of each filament are a pair of radio frequency by-pass condensers C_5, C_5 to whose junction point is a connection to ground. The midpoints of the secondary windings of transformers T'_2 and T_4 are connected to opposite terminals of the secondary winding of transformer T'_3. The midpoint of the secondary winding T'_3 is grounded. The tap on the primary winding of transformer T'_3 provides a degree of adjustability of the voltage transfer to the secondary winding.

The common grid leak resistor R_2 with its shunt connected by-pass condenser C_3 is now connected between ground and one terminal of grid excitation coil L_3.

The polarity symbols in Fig. 2 indicate the instantaneous potentials applied to the circuit elements, and an inspection thereof will show that when the anode of a tube goes negative its grid will also go negative, relative to the filament of the same tube.

In Fig. 2, if desired, a variable transformer may be used between the primary of transformer T_1 and the power source f. As an alternative to the arrangement shown in Fig. 2, the secondary of transformer T_3' can be wound on the core of transformer T_1, in which case this secondary should be provided with two sets of taps for the initial adjustment of the periodic bias.

Fig. 3 is a preferred embodiment of the present invention. Additional bias is here supplied to the grids by means of taps 4, 4 suitably positioned on the secondary winding of power transformer T_1. By adjusting the taps 4, 4 to obtain the desired magnitude of bias for the grids, no further adjustment is needed as the voltage on the primary of transformer T_1 is adjusted for various power levels. In this way, the additional bias varies in optimum manner as the anode voltage is adjusted for the desired output. This can be more readily appreciated from the following: If the system is operating with peak anode supply voltage of tube V_1, and the peak radio frequency grid voltage is E_g and the peak bias across the grid leak is E_c, then a periodic bias of $V_3 \geq E_g - E_c$ volts is needed. Now such oscillators are quite linear, i. e., if V_1 is doubled, E_g and E_c also double, thus requiring V_3 also to double. This end is obtained very simply by having V_3 and V_1 supplied from the core of one transformer so that they always bear a constant ratio to each other.

Although the three figures of the drawings show one particular type of radio frequency oscillatory circuit, it should be understood that the invention is not limited thereto since any suitable radio frequency oscillatory circuit could be used, such as the Colpitts or Hartley circuits.

What is claimed is:

1. In combination, a pair of high frequency electron discharge device oscillators each having an anode, a filament and a grid, connections between corresponding electrodes of said oscillator devices for coupling them in electrically parallel relationship for high frequency energy, a source of low frequency alternating current, a power transformer having a primary winding connected to said source and a secondary winding connected at opposite terminals to said anodes, a connection from the midpoint of said secondary winding to ground, whereby opposite instantaneous energizing potentials are supplied to the anodes of said pair of oscillators, separate filament transformers coupling the filaments of said os-

cillators to said source for supplying heating current to said filaments, and means coupling said source to the midpoints of the secondary windings of said filament transformers for applying a periodic bias to each grid of such magnitude and sense to bias the grid negatively relative to its associated filament during the time the anode of the same tube is also supplied with a negative potential relative to its associated filament, whereby said negatively biased grid is prevented from drawing current when its associated anode is negative relative to its filament.

2. In combination, a pair of high frequency electron discharge device oscillators each having an anode, a filament and a grid, connections between corresponding electrodes of said oscillator devices for coupling them in electrically parallel relationship for high frequency energy, a source of low frequency alternating current, a power transformer having a primary winding connected to said source and a secondary winding connected at opposite terminals to said anodes, a connection from the midpoint of said secondary winding to ground, whereby opposite instantaneous energizing potentials are supplied to the anodes of said pair of oscillators, a grid bias resistor connected in common to the grids of said devices, separate filament transformers coupling the filaments of said oscillators to said source for supplying heating current to said filaments, another transformer having a primary winding coupled to said source and a secondary winding whose opposite terminals are connected to the midpoints of different secondary windings of said filament transformers, a connection from ground to the midpoint of the secondary winding of said other transformer, said other transformer being so constructed and arranged that the peak voltage measured from the center of its secondary winding to either terminal is equal to or greater than the difference between the peak high frequency voltage applied to the grids of the devices less the peak voltage across the common grid leak resistor.

3. In combination, a pair of high frequency electron discharge device oscillators each having an anode, a filament and a grid, connections between corresponding electrodes of said oscillator devices for coupling them in electrically parallel relationship for high frequency energy, a source of low frequency alternating current, a power transformer having a primary winding connected to said source and a secondary winding connected at opposite terminals to said anodes, a connection from the midpoint of said secondary winding to ground, whereby opposite instantaneous energizing potentials are supplied to the anodes of said pair of oscillators, separate filament transformers coupling the filaments of said oscillators to said source for supplying heating current to said filaments, connections from points on opposite sides of the midpoint of the secondary winding of said power transformer to the midpoints of the secondary windings of the filament transformers and so arranged that the application of a positive potential from said power transformer to the anode of one oscillator will simultaneously apply a positive potential to the filament of the other oscillator, said last connections being so positioned on the secondary winding of the power transformer that the grid of each tube is supplied with a periodic negative bias relative to its filament of such magnitude as to prevent this grid from drawing current when its anode is negative relative to the same filament.

4. In combination, a pair of high frequency electron discharge device oscillators each having an anode, a filament and a grid, connections between corresponding electrodes of said oscillator devices for coupling them in electrically parallel relationship for high frequency energy, a source of low frequency alternating current, a power transformer having a primary winding connected to said source and a secondary winding connected at opposite terminals to said anodes, a connection from the midpoint of said secondary winding to ground, whereby opposite instantaneous energizing potentials are supplied to the anodes of said pair of oscillators, separate filament transformers coupling the filaments of said oscillators to said source for supplying heating current to said filaments, a common grid leak resistor for said oscillators, a by-pass condenser arrangement across the legs of each filament and with the electrical center thereof grounded, connections from points on opposite sides of the midpoint of the secondary winding of said power transformer to the midpoints of the secondary windings of the filament transformers and so arranged that the application of a positive potential from said power transformer to the anode of one oscillator will simultaneously apply a positive potential to the filament of the other oscillator, said last connections being so positioned on the secondary winding of the power transformer that the grid of each tube is supplied with a periodic negative bias relative to its filament of such magnitude as to prevent this grid from drawing current when its anode is negative relative to the same filament.

5. In combination, a pair of high frequency electron discharge device oscillators each having an anode, a filament and a grid, connections between corresponding electrodes of said oscillator devices for coupling them in electrically parallel relationship for high frequency energy, a source of low frequency alternating current, a power transformer having a primary winding connected to said source and a secondary winding connected at opposite terminals to said anodes, a connection from the midpoint of said secondary winding to ground, whereby opposite instantaneous energizing potentials are supplied to the anodes of said pair of oscillators, an oscillatory circuit in common to said devices comprising the series connection of a pair of separated coils and a condenser, one of said coils being the output coil, a feed back coil for said input electrodes coupled to said other coil of said pair, separate filament transformers coupling the filaments of said oscillators to said source for supplying heating current to said filaments, and means coupling said source to the midpoints of the secondary windings of said filament transformers for applying a periodic bias to each grid of such magnitude and sense as to bias the grid negatively relative to its associated filament during the time the anode of the same tube is also supplied with a negative potential relative to its associated filament, whereby said negatively biased grid is prevented from drawing current when its associated anode is negative relative to its filament.

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