Dec. 2, 1947. F. G. ALBIN 2,431,902

SELF REGULATING HIGH-FREQUENCY GENERATOR

Filed Dec. 28, 1943

Fig. 1.

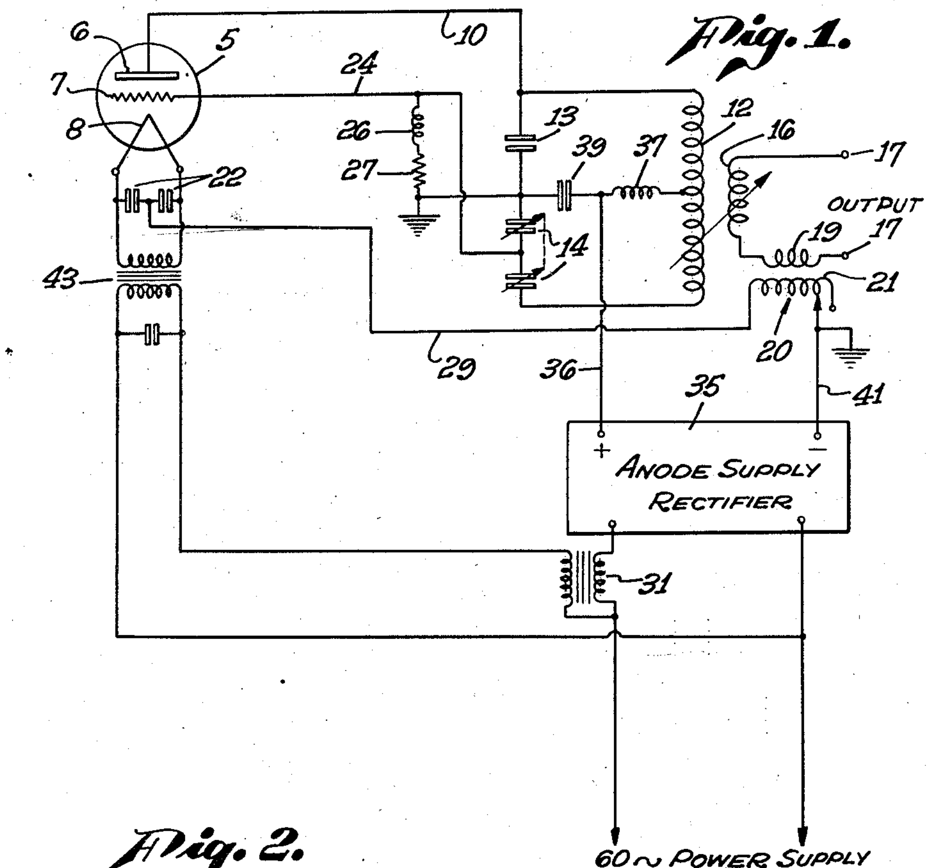
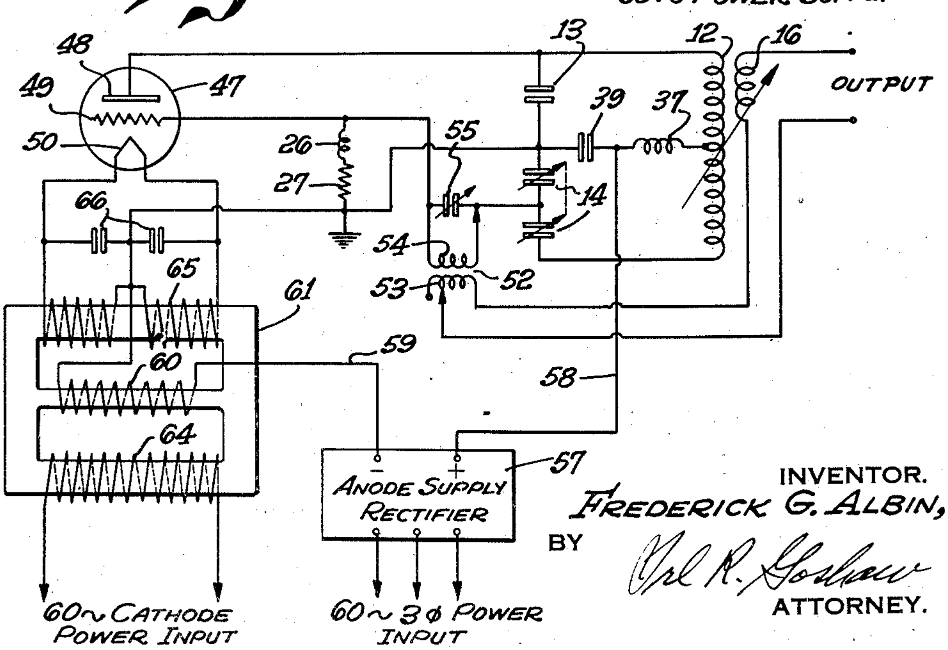


Fig. 2.



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SELF-REGULATING HIGH-FREQUENCY GENERATOR

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4 Claims. (Cl. 250—36)

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This invention relates to thermionic oscillators or electrical current generators, and particularly to control circuits for stabilizing or regulating the input energy to an oscillator tube with respect to the output energy therefrom.

In the industrial application of high frequency oscillators or generators, the load is varied between zero to maximum frequently, which is unlike conditions imposed upon such oscillators when used in radio broadcasting systems. Where the load is constant, it is only necessary to adjust the cathode and grid voltages or feedback voltage at the optimum values and the generators will operate satisfactorily over long periods. Where the load on such oscillators is frequently varied between zero and maximum, the cathode emission should always be ample for the maximum space current required and the cathode heater temperature should be minimum for optimum tube economy. Furthermore, for the highest efficiency, the grid voltage and current should be the maximum allowable when the oscillator is working into a full load. Normally, however, when the load is reduced, the grid voltage and current will rise above the allowable maximum which will reduce the life of the tube as well as cause possible damage by overheating.

The present invention is directed to automatic regulatory means to provide the optimum cathode heater current in accordance with the space current flowing, and also provides means for increasing the grid current to maximum during maximum load and to decrease the grid voltage and current as the load decreases. In this manner, it is unnecessary for the operator or his assistant to adjust the grid current and cathode heater current when changes are made in the oscillator load, which as mentioned above, occurs frequently where the oscillator output is used for industrial purposes such as wood gluing, heating of plastics, and similar uses.

The use of feedback circuits in which a portion of the output energy of the oscillator is rectified for varying the amount of energy supplied to the cathode is well-known, a system of this type being disclosed and claimed in G. E. Jones, Jr., Patent No. 2,175,694 of October 10, 1939. The Jones invention, however, is intended to maintain the high frequency output current constant, irrespective of load, by varying the filament power, whereas the present invention is for the purpose of varying the filament power in accordance with the variations in load, the load current being allowed to vary as required. A novel method and means for varying the cathode heater temperature with load changes as well as a means of controlling the grid voltage and current with load variations is provided.

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The principal object of the invention, therefore, is to facilitate the application of high frequency energy to varying loads over different time intervals.

Another object of the invention is to provide an improved high frequency generator for industrial uses.

A further object of the invention is to provide an improved regulatory system for high frequency oscillators wherein the grid voltage and current is varied in accordance with load variations.

A further object of the invention is to provide an improved regulatory system for high frequency oscillators wherein the cathode heater current is varied in accordance with load variations.

A still further object of the invention is to provide an improved high frequency oscillator or generator having a regulatory circuit for varying the grid feedback voltage and current and the cathode heater current in accordance with variations in the load on the oscillator.

Although the novel features which are believed to be characteristic of this invention will be pointed out with particularity in the appended claims, the manner of its organization and the mode of its operation will be better understood by referring to the following description read in conjunction with the accompanying drawings forming a part hereof, in which:

Fig. 1 is a schematic circuit diagram of a high frequency oscillator or generator embodying the grid voltage and current regulatory circuit and cathode heating current regulatory means of the invention, and

Fig. 2 is a schematic circuit diagram of a high frequency oscillator embodying alternative means for regulating both the grid voltage and current and the cathode heater power of the invention.

Referring now to Fig. 1, a triode vacuum tube 5 is shown with an anode 6, a grid 7, and a cathode 8. The anode circuit is connected over conductor 10 to the tuning or tank inductance 12 shunted by fixed tuning or tank condenser 13 and variable tuning and feedback condensers 14 as described in detail in my copending application, Ser. No. 492,248, filed June 25, 1943. The tank or tuning coil 12 is variably coupled to an output pickup coil 16 to vary the load adapted to be connected across terminals 17. A primary winding 19 of a feedback transformer 20 having a secondary 21 is shown connected in the load circuit.

The normal grid circuit of the oscillator tube 5 is over conductor 24 to the mid-point between variable condensers 14. The radio frequency circuit from grid to cathode includes in order, conductor 24, the grounded half of variable condenser 14, ground, radio frequency transformer secondary 21, conductor 29, and the filament by-pass capacitors 22. A path for the direct current discharge of condenser 14 is provided through radio frequency choke coil 26 and resistor 27 to ground. Anode potential for the tube 5 is supplied from the rectifier 35 over conductor 36, choke coil 37 and the upper portion of tuning coil 12, a by-pass condenser 39 being connected to ground and the end of coil 37. The negative terminal of the rectifier 35 is connected over conductor 41 to ground. The cathode heating energy is obtained from any suitable power supply over transformer 31 and transformer 43, which power supply is also connected to the rectifier 35.

The adjustment of the secondary 21 of transformer 20 is such that with the radio frequency output power from the generator equal to the maximum rating for the apparatus, the optimum grid potential, current, and phase relative to the plate potential are obtained, and consequently the maximum efficiency is realized.

The phasing of the winding 21 is so determined that the potential across its terminals as a result of the load current through primary winding 19 adds to the potential obtained from condenser 14. Thus, the total grid-cathode potential is equal to the sum of these two voltages.

Under conditions of reduced output power, the potential of winding 21 is reduced, thereby reducing the potential of grid-to-cathode. Due to regulation of the anode circuit, when the load is reduced, the potential of condenser 14 will rise, but the amount of this rise is substantially less than the decrease of potential of winding 21. Thus, the net effect of the reduction of the load current is a reduction of grid-cathode potential.

Simultaneous with the above action, the large line current into the anode supply rectifier 35 induces a potential in the secondary circuit of the current transformer 31 adding to the potential obtained from the line to supply the transformer 43. Under conditions of maximum load, the filament potential and current are also maximum and ample for the space current of the tube 5. The reduction of output power causes a reduction in the anode supply rectifier line current, and consequently a reduction of filament power. This regulatory means is particularly applicable to tubes having pure tungsten filaments. It is also desirable for stable operation that the filament emission be above the saturation point for all load conditions. In other words, the filament emission must not be reduced to the condition where the tube output power is impaired due to lack of sufficient emission. The regulatory means lessens the filament power above the saturation point.

Referring now to Fig. 2 in which a similar oscillator generator is shown, the tube 47 has an anode 48, grid 49, and cathode 50. The other elements of the tuning circuits, such as the coils 12, 16, and 37 and condensers 13, 14, and 39, correspond to the same numbered elements in Fig. 1. In the embodiment shown in Fig. 2, the grid voltage regulating circuit includes a feedback transformer 52 with its variable primary winding 53 and its secondary winding 54. The winding 54 is shunted by a variable condenser 55 for adjusting the phase of the feedback voltage across winding 54 with respect to the feedback voltage across the grounded feedback condenser 14. This regulating feedback circuit operates in the same manner as the modification shown in Fig. 1 and maintains the grid voltage at a constant ratio with respect to the anode current during variations in the load current.

Although the grid voltage regulation circuit is as shown in Fig. 1, a modification of the cathode heater current regulating circuit of Fig. 1 is shown in Fig. 2. It will be noted that the rectifier 57 supplying anode voltage for the tube 47 over conductor 58 and conductor 59, includes a winding 60 on the center leg of the cathode transformer core 61. The cathode heating current is obtained from any suitable alternating current power source and impressed on primary winding 64 and then impressed on the cathode 50 from secondary winding 65 on core 61, the winding 65 being shunted by alternating current circuit condensers 66. Since the plate current flowing through winding 60 varies the coupling between windings 64 and 65, the heating of cathode 50 is controlled by the load on the oscillator. That is, the higher the anode current, the greater the magnetic saturation of the core 61. Thus, as the load increases and the space current increases, the greater the saturation of the core 61 which reduces the reactance in the transformer and permits a greater transmission of energy from the primary winding 64 to the secondary winding 65. This provides greater emission from the cathode and adequately accommodates the increased load. As the load is reduced, the plate current decreases and the reactance of the transformer increases to decrease the cathode heating current. In this manner, the optimum operating efficiency and economy is provided for the tube 47.

With the above regulatory circuits embodied in an oscillator or generator system, the output of the system may be varied between zero and maximum without overheating the system due to increased grid current, while maintaining maximum efficiency of the system at all times. Since the secondary winding of filament transformer 43 in Fig. 1 has a high radio frequency potential above ground determined by the voltage across winding 21, the circuit of Fig. 2 is preferred. Furthermore, the saturable transformer system of Fig. 2 is particularly suitable to an anode supply rectifier employing a three-phase supply line, although the modification of Fig. 1 could also be used with a three-phase supply source.

I claim as my invention:

1. An oscillator system comprising a thermionic vacuum tube having an anode, grid, and cathode, an anode-cathode circuit including a tuning inductance, a tuning condenser connected in shunt to a portion of said inductance, and a rectifier, a load circuit including the primary of a feedback transformer, and a grid-cathode circuit including a feedback condenser and the secondary of said feedback transformer, said feedback condenser being connected in shunt to a portion of said tuning inductance and said secondary of said feedback transformer being connected in series with said feedback condenser between said grid and cathode, the total grid-cathode potential being the sum of the feedback condenser voltage and the feedback transformer voltage.

2. An oscillator system in accordance with claim 1, in which means are provided to decrease the feedback transformer voltage with an increase in the feedback condenser voltage, said means

causing said feedback transformer voltage to decrease at a higher rate than the feedback condenser voltage.

3. An oscillator system comprising a thermionic vacuum tube having an anode, grid, and cathode, a tank circuit including a truning inductance, a tuning condenser, and a feedback condenser, a load circuit coupled to said tuning inductance, said tuning condenser being connected across a portion of said inductance and said feedback condenser being connected across another portion of said inductance a feed back transformer having a primary winding in said load circuit, an anode-cathode circuit including said tuning condenser and said tuning inductance and a grid-cathode circuit including said feedback condenser and the secondary winding of said feedback transformer, the grid-cathode potential being the sum of the voltage across said feedback condenser and the voltage across the secondary of said feedback transformer, the decreases in the voltage in said load transformer being greater than the increases in voltage across said feedback condenser during variations in the output of said vacuum tube.

4. An oscillator system in accordance with claim 3, in which a cathode heating circuit is provided, said circuit including a transformer having

a core, said anode-cathode circuit of said vacuum tube also including a winding on said core, variations in the feedback voltage across said feedback transformer varying the current in said transformer core winding to vary the current fed to said cathode.

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