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SYSTEM FOR CONTROLLING OSCILLATOR GRID CURRENT

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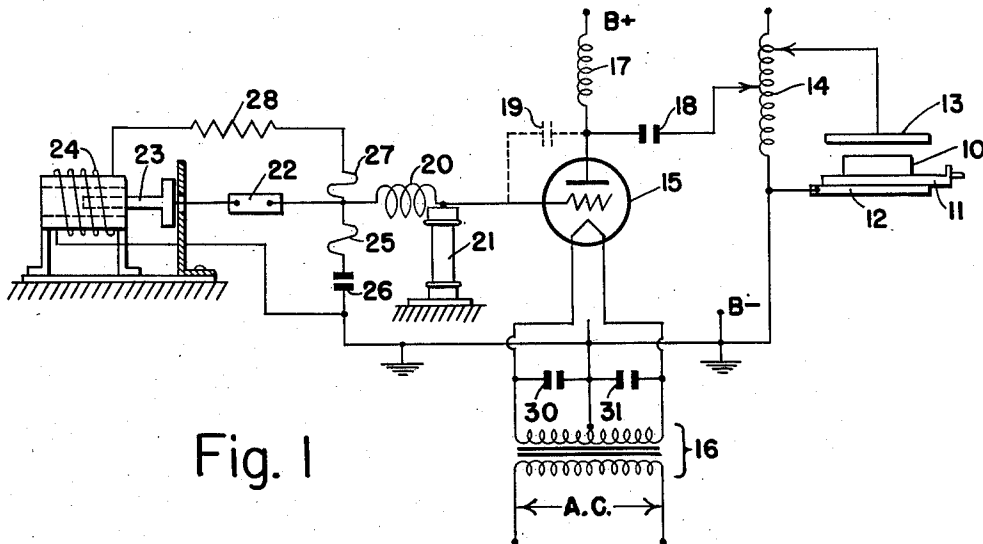


Fig. 1

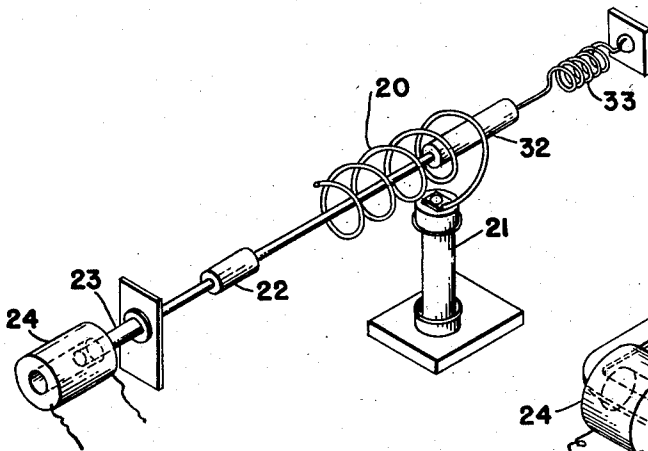


Fig. 2

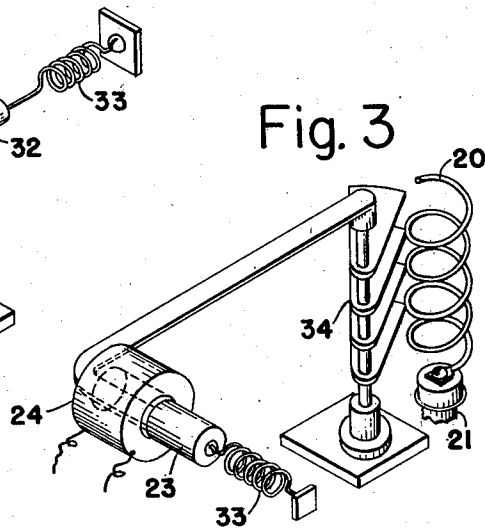


Fig. 3

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SYSTEM FOR CONTROLLING OSCILLATOR
GRID CURRENT

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This invention relates to high-frequency heating systems employing oscillators for generating the high-frequency energy and has for an object the provision of an improved grid-control system which assures increased efficiency of operation of the oscillator tube or tubes by maintaining the grid excitation more or less independent of the characteristics of the load presented to the oscillator.

In the more common types of oscillator circuits, grid excitation is often a function of frequency and more often varies with the power output in a manner which decreases the efficiency of the oscillator. In high-frequency systems used for raising the temperature of dielectric materials, such as plastic preforms and the like, the load characteristics vary substantially from the beginning to the end of the heating cycle, thus affecting the output and often the frequency of the oscillator. In the heating of a typical plastic preform load, for example, the oscillator plate current is usually initially adjusted somewhat below the full load rating so that the tube will not be overloaded toward the end of the heating cycle due to increase of the loss factor (power factor times dielectric constant) with increasing temperature: if the grid current be adjusted to optimum value at the beginning of the heating cycle, it will decrease to undesirably low value at the end of the heating cycle. Accordingly, the oscillator operates most inefficiently at the time of maximum power output, causing undue dissipation of energy at the anode of the oscillator tube. When, on the other hand, the dielectric material is one whose loss factor decreases with increasing temperature, the grid current must be adjusted below its optimum value at the beginning of the heating cycle, so that it will not rise beyond a safe value toward the end of the cycle.

In accordance with the present invention, there is provided in the grid circuit of the oscillator a reactance whose effective magnitude is automatically varied during the heating cycle in response to change in the grid excitation and in a sense and extent to maintain the grid excitation at its predetermined optimum value. In one form of the invention, the reactance may be a coil which is mechanically elongated or shortened by a solenoid, or equivalent device, in response to changes in magnitude of the grid excitation so to change the grid-circuit inductance and thus control the grid excitation. In other forms of the invention, the grid coil may be of fixed mechanical dimensions and its inductive

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reactance varied by movement of a core or vane structure actuated by a solenoid or similar electromagnetic device responsive to changes in the grid current.

For a more detailed understanding of the invention and for illustration of various forms thereof, reference may be had to the following description taken in conjunction with the accompanying drawings, in which:

Fig. 1 diagrammatically shows a dielectric heating system including one electro-mechanical arrangement for varying the grid-circuit reactance; and

Figs. 2 and 3 are isometric views of other electro-mechanical arrangements of varying the reactance of the grid circuit.

Referring to Fig. 1 of the drawings, the invention in one form has been shown as applied to a high-frequency heating system utilized for elevating the temperature of plastic preforms 10 supported on a tray 11 conductively supported by a stationary plate 12. Above the preform 10 or other dielectric load is a second plate or electrode 13 which may be adjustable or preset to provide an air space between it and the plastic preform 10. The electrode 13 may be adjustably connected to an output coil 14 of an oscillator. The oscillator tube 15 may be connected to the usual filament transformer 16 and to a source of anode current whose positive and negative terminals have been identified respectively as B+ and B-. A radio-frequency choke-coil 17 is included in the direct-current anode circuit and the high-frequency output of the tube 15 is fed by way of the coupling capacitor 18 to the load circuit. The inductance of the coil 14, together with the capacitance between the electrodes 11 and 13, forms a tuned anode or resonant frequency-determining circuit for the oscillator. The grid circuit of the tube 15 receives its excitation through the anode-grid capacitance indicated by the dotted line connection including the coupling capacitor 19. Where this interelectrode capacitance is not adequate, a capacitor of the desired size may be connected in shunt thereto.

The grid circuit includes an adjustable reactance shown in the form of inductance coil 20 anchored at one end to a supporting insulator 21. The free end of coil 20 is mechanically connected by an insulator 22 to the movable core 23 of a solenoid 24. So far as the high-frequency currents are concerned, the grid circuit comprises the inductance 20, flexible lead 25 and by-pass condenser 26, all in series between the

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grid and cathode of tube 15. The direct-current component of the current in the grid circuit flows through the inductance 20, and thence through flexible lead 27, resistor 28 and the winding of the solenoid 24 to the grounded cathode of tube 15. Conventional by-pass capacitors 30 and 31 are included in the filament circuit to provide a low impedance path for the high-frequency currents to ground.

In operation, to elevate the temperature of the plastic preform 19, or other suitable dielectric load, it will be assumed that the electrodes 11 and 13 have their proper spacing and that the adjustable connections to the output coil 14 are in proper positions for optimum operation of the oscillator at a predetermined frequency which may be of the order of from 1 to 50 megacycles, 10 to 25 megacycles being the usual operation of high-frequency systems of this character. It will be further assumed that the D. C. component of the grid current has the proper value for producing the optimum bias on the grid of the tube 15. This may be accomplished by proper selection of the value of the resistor 28 and of the initial setting of the inductance 20. With the oscillator adjusted for optimum efficiency of operation, the temperature of the plastic preforms 19 will be rapidly increased. However, during the heating of such dielectric materials, the dielectric constant and the power factor may rise, thereby decreasing the frequency and increasing the power absorbed by such dielectric material. Both the decreased frequency and the increased power output cause the grid drive or grid excitation to be decreased, thereby decreasing the D. C. component of the grid current. The increased power absorption by the load causes a decrease in the radio-frequency voltage of the tank circuit including the output coil 14 and the capacitance between electrodes 11 and 13. Thus, the decreased high-frequency voltage of the tank circuit results in a decrease in the high-frequency voltage or feed back applied through the capacitor 19 to the grid circuit. Because of decreased excitation of the grid circuit, less high-frequency voltage will be rectified and thus the direct-current component will decrease. The cumulative result of the foregoing is that the direct-current biasing voltage of the grid decreases and the plate dissipation of the tube rises, with consequent inefficient operation of the oscillator. The foregoing effects may continue until, at the end of the heating cycle, the grid bias and the plate dissipation are outside the limits specified by the tube manufacturer and outside the desirable and safe operating ranges for the tube. Under such conditions, the oscillator operates most inefficiently at the end of the cycle and at the very time it is called upon to deliver its maximum load. Under conditions of maximum demand, it is most essential from the efficiency and tube-life standpoints to operate the tube within safe limits, and preferably within the ranges specified by the tube manufacturer.

Such excessive anode dissipation at the end of the heating cycle may be avoided by proper selection of the value of resistor 28 and of the setting of inductance 20, but in such case the adjustments will ordinarily result in excess grid dissipation at the beginning of the cycle. In actual operation of systems not utilizing the present invention, these extremes are avoided by manual adjustments made from time to time during the course of the heating cycle by an attendant or operator. This supervision is not required

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in arrangements utilizing the invention and the required adjustments to avoid either excessive grid dissipation or excessive anode dissipation are made automatically as the need arises.

In accordance with the present invention, the direct-current component of the grid current may be utilized to energize the solenoid 24 whose plunger or armature 23 may be made effective to adjust the inductance of coil 20 by an amount adequate to maintain the grid excitation within the range specified by the tube manufacturer and within a relatively narrow optimum range of grid excitation for most efficient operation of the tube 15.

The coil 20 is preferably constructed of a good elastic electrical conductor, so that the turns of the coil 20 themselves form a spring against which the plunger 23 acts. The coil 20 may be of beryllium-copper or any other suitable material, and it may be edge-wound from strip material, or it may be wound of a round conductor. In any case, the adjustment of the solenoid 24 and the coil 20 will be such that the optimum value of inductance is established by the positioning of the turns thereof for the optimum grid bias of the tube 15 as effected by a predetermined magnitude of the D. C. component of the grid current. It will be further understood that as the electrical parameters of the dielectric load change, there will be maintained a balance between the pull of the solenoid 24 and the spring bias exerted by the turns of the coil 20, such that optimum grid excitation is maintained within suitably narrow limits.

By way of specific example and assuming the material to be treated is one whose dielectric constant and power factor increase during the heating cycle; when the oscillator is first turned on, there will be a maximum flow of grid current in the solenoid which will stretch the coil 20 to reduce its inductance so reducing the grid current to the desired optimum value at which time the opposing force of the solenoid is balanced by the spring effect of the coil 20. As the heating cycle progresses, the grid current tends to decrease, for reasons above discussed, with the result that the coil 20 tends to shorten, so increasing its inductance that the opposing forces exerted by the solenoid and the spring effect of the coil 20 are again balanced. The resulting increase in inductance of coil 20 increases the grid drive to restore the desired operating conditions. Therefore, during the heating cycle, the solenoid in effect continuously supervises the operating conditions of the oscillator and effects adjustment of the inductance of coil 20 as and when necessary to maintain the prechosen grid excitation.

From an understanding of the invention as above described, it will now be apparent to those skilled in the art that other modifications of the invention may be made within the scope of the appended claims, and there have been illustrated in Figs. 2 and 3 two such modified forms of the invention. Referring first to Fig. 2, the coil 20 has been illustrated as of fixed shape and size, and the solenoid 24 has been illustrated as being effective to pull within the coil 20 a core 32 against the bias of a spring 33. The core 32 may preferably be in the form of a cylinder of copper or other good non-magnetic conductor, in which case movement of the core inwardly of the coil would decrease the inductance thereof. The effect of movement of the copper core 32 into the grid-coil is generally the same as elongating the

coil as described in connection with Fig. 1. If the core 32 be of magnetic material, such as powdered iron, the effect of moving such a core into the coil is to increase the inductance thereof: use of a high-loss core is to be avoided. An arrangement of either type may be desired depending upon the particular oscillator and the initial position of the core with respect to the coil.

In accordance with Fig. 3, the inductance of the coil 20 is changed to maintain the grid excitation within a desired range by arranging the solenoid 24 to rotate a plurality of conducting plates 34, preferably of copper or other low-loss conductor, between the turns thereof. These conductors or plates upon moving into or out of interleaved position with respect to the turns of the coil 20 vary the inductance thereof automatically to compensate for changes in grid excitation due, for example, to variation in the electrical characteristics of a particular load during its heating cycle or due to the different kinds and sizes of load in different heating cycles.

What is claimed is:

1. In a dielectric heating system comprising an oscillator tube, a tuned anode circuit therefor including plates between which a dielectric load is disposed for heating, and a grid circuit with fixed coupling to said anode circuit, the combination of reactance solely in said grid circuit and adjustable to vary the grid excitation of said tube, and a device energized in accordance with the direct-current component of said grid excitation to adjust said reactance to maintain the grid excitation substantially constant at a preset value despite changes of the electrical characteristics of said dielectric load.

2. In a dielectric heating system comprising an oscillator tube, a tuned anode circuit therefor including plates between which a dielectric load is disposed for heating, and a grid circuit with fixed coupling to said anode circuit, the combination of reactance solely in said grid circuit and whose magnitude determines the grid excitation of said tube, an electromagnetic device energized in accordance with the direct-current component of said grid excitation, and means comprising the armature of said device and opposing spring means for adjusting the effective magnitude of said reactance to maintain the grid excitation substantially constant at a preset value despite changes of the electrical characteristics of said dielectric load.

3. In a dielectric heating system comprising an oscillator tube, a tuned anode circuit therefor including plates between which a dielectric load is disposed for heating, and a grid circuit with fixed coupling to said anode circuit, the combination of reactance solely in said grid circuit adjustable to vary the grid excitation of said tube and comprising a resilient deformable coil, an electromagnetic device energized in accordance with the direct-current component of said grid excitation, and means comprising the armature of said device and mechanical connection therefrom to said coil for adjusting the reactance of the coil in response to changes in magnitude of said direct-current component to maintain the grid excitation substantially constant at a preset value despite changes of the electrical characteristics of said dielectric load.

4. In a dielectric heating system comprising an oscillator tube, a tuned anode circuit therefor including plates between which a dielectric load is disposed for heating, and a grid circuit with

fixed coupling to said anode circuit, the combination of reactance solely in said grid circuit adjustable to vary the grid excitation of said tube and comprising a resilient coil anchored at one end, and an electromagnetic device energized in accordance with the direct-current component of said grid excitation and having an armature connected to the free end of said coil to vary its length in sense to maintain the grid excitation substantially constant at a preset value despite changes of the electrical characteristics of said dielectric load.

5. In a dielectric heating system comprising an oscillator tube, a tuned anode circuit therefor including plates between which a dielectric load is disposed for heating, and a grid circuit with fixed coupling to said anode circuit, the combination of reactance solely in said grid circuit adjustable to vary the grid excitation of said tube and comprising a coil of fixed shape and size provided with a movable inductance-varying element, spring means tending to move said element in one direction, and an electromagnetic device energized in accordance with the direct-current component of said grid excitation and having an armature tending to move said element in reverse direction whereby the position of said element is varied in sense to maintain the grid excitation substantially constant at a preset value despite changes of the electrical characteristics of said dielectric load.

6. In a dielectric heating system comprising an oscillator tube, a tuned anode circuit therefor including plates between which a dielectric load is disposed for heating, and a grid circuit with fixed coupling to said anode circuit, the combination of reactance solely in said grid circuit adjustable to vary the grid excitation of said tube and comprising a coil of fixed shape and size provided with an axially movable core, spring means tending to move said core in one direction, and an electromagnetic device energized in accordance with the direct-current component of said grid excitation and having an armature tending to move said element in reverse direction whereby the position of said element is varied in sense to maintain the grid excitation substantially constant at a preset value despite changes of the electrical characteristics of said dielectric load.

7. In a dielectric heating system comprising an oscillator tube, a tuned anode circuit therefor including plates between which a dielectric load is disposed for heating, and a grid circuit with fixed coupling to said anode circuit, the combination of reactance solely in said grid circuit adjustable to vary the grid excitation of said tube and comprising a coil of fixed shape and size provided with vane structure movable between turns of the coil, spring means tending to move said vane structure in one direction, and an electromagnetic device energized in accordance with the direct-current component of said grid excitation and having an armature tending to move said element in reverse direction whereby the position of said element is varied in sense to maintain the grid excitation substantially constant at a preset value despite changes of the electrical characteristics of said dielectric load.

8. In a dielectric heating system comprising an oscillator tube, a tuned anode circuit therefor including plates between which a dielectric load is disposed for heating, and a grid circuit with fixed coupling to said anode circuit, the combination of a coil solely in said grid circuit and whose

self-inductance is adjustable to vary the grid current of said tube, and a device having a winding energized by the direct-current component of said grid current and having a member movable in response to said energization to adjust the self-inductance of said coil in sense to maintain the grid excitation substantially constant at a preset value despite changes of the electrical characteristics of said load.

9. An oscillator system comprising an oscillator tube, a grid circuit therefor, a tuned anode circuit having fixed coupling to said grid circuit to provide a feedback voltage, a reactance solely in said grid circuit adjustable to vary the grid excitation of said tube, and a device energized in accordance with the direct-current component of said grid excitation to vary said reactance in sense to maintain the grid excitation substantially constant at a preset value despite changes in the anode circuit load upon said feedback voltage.

10. In a dielectric heating system comprising an oscillator tube, a tuned anode circuit therefor having fixed coupling to the grid circuit thereof to provide a feedback voltage and including a capacitor having plates between which the dielectric load is disposed for heating; the combination of a reactance solely in the grid circuit of said tube and adjustable to vary the magnitude of said feedback voltage, and a protective device for the tube and the load energized by the direct-current component of the grid excitation of said tube and having a responsive element mechanically coupled to said reactance to vary its magnitude in accordance with variations of said direct-current component and in sense maintaining said feedback voltage substantially constant despite changes in the electrical characteristics of said dielectric load.

11. In a dielectric heating system comprising an oscillator tube and a tuned anode circuit therefor including plates between which a dielectric load is disposed for heating; a feedback capacitance and a coil connected in series with each other from the anode to the cathode of said tube with an intermediate connection to the grid of said tube; and a device energized in accordance with the direct-current component of the grid excitation to vary the self-inductance of said coil to maintain the grid excitation substantially constant for a fixed value of said feedback capaci-

tance and despite changes of the electrical characteristics of the dielectric load.

12. In a high-frequency heating device of the type comprising an oscillation generator supplying a load whose electrical characteristics vary during heating including an oscillator tube having its anode and grid circuits coupled for generation of oscillations, the combination of an inductance in said grid circuit in the form of a winding whose axial length is variable, and means responsive to a current characteristic of said tube for automatically varying the axial length of said winding continuously to maintain the grid excitation substantially constant for a fixed coupling of said circuits and despite aforesaid changes of the load characteristics.

13. In a high-frequency heating device of the type comprising an oscillation generator supplying a load whose electrical characteristics vary during heating including an oscillator tube having its anode and grid circuits coupled for generation of oscillations, the combination of an inductance in the grid circuit in the form of a winding whose axial length is variable, means responsive to the grid current of said tube for automatically varying the axial length of said winding continuously to maintain the grid excitation substantially constant for a fixed coupling of said circuits and despite aforesaid changes of the load characteristics.

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