

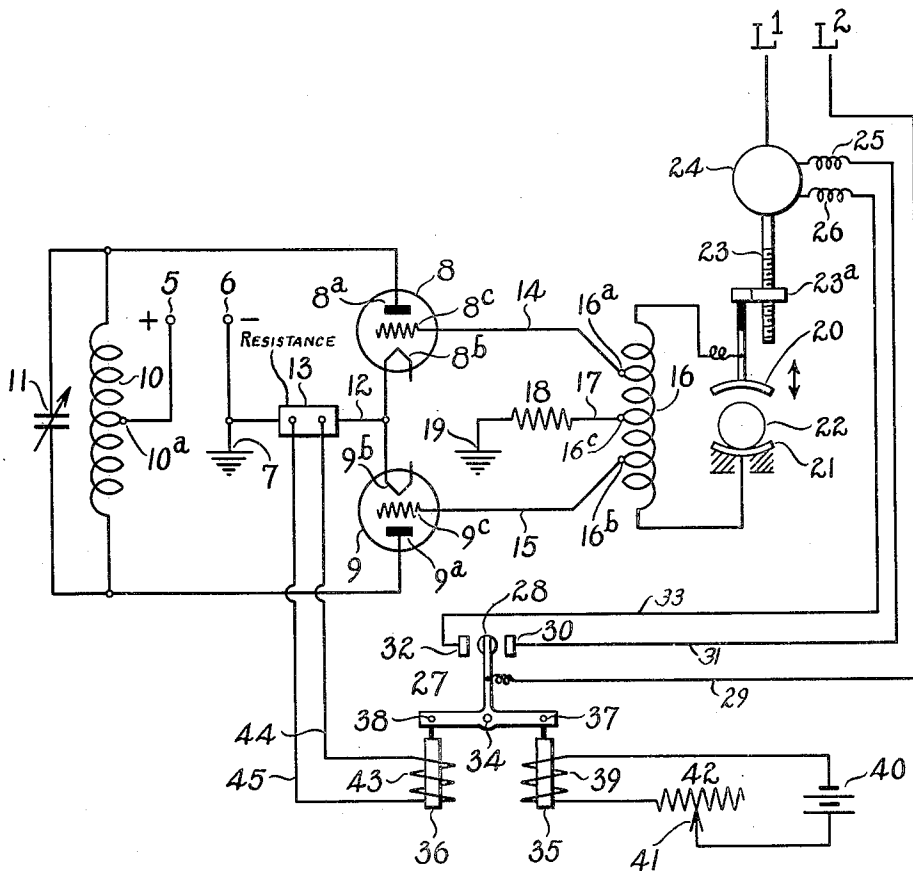
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HIGH-FREQUENCY HEATING OF DIELECTRIC MATERIALS

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## UNITED STATES PATENT OFFICE

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HIGH-FREQUENCY HEATING OF  
DIELECTRIC MATERIALS

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4 Claims. (Cl. 219-47)

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This invention relates to improvements in high frequency heating of dielectric materials.

An object of the invention is to provide a novel method of and apparatus for insuring a substantially constant preset rate of high frequency heating of dielectric materials.

Another object is to insure such a preset rate of high frequency heating regardless of variations in size of the articles sequentially forming the charge or load to be heated, and regardless of variations in the characteristics of a given load of material during heating thereof.

Another and more specific object is to provide for use of the plate or anode current flowing in the high frequency oscillator tubes to provide a signal voltage for comparison with a preset value whereby the rate of supply of the high frequency heating current may be controlled.

Another object is to provide for automatic control of such rate of supply of high frequency heating current.

Other objects and advantages of the invention will hereinafter appear.

The accompanying drawing illustrates diagrammatically one embodiment of the invention, which will now be described; it being understood that the invention is susceptible of embodiment in other forms within the scope of the appended claims.

I have found by experimentation that in an oscillator type of circuit, of a character like or similar to that herein disclosed, the value of the plate or anode current flowing in the high frequency oscillator tubes is variable as a function of variation in the power being dissipated, in the thermosetting plastic article or articles, in the form of heat. By allowing this anode current to flow through a suitable resistor a voltage drop is obtained which may be utilized as a reliable signal voltage. It is only necessary to compare the value of such signal voltage with a preselected power value, and to effect adjustment of one or the other or both of the heating electrodes until the first mentioned value is equalized with respect to the preselected value, thus insuring a substantially constant rate of heating of the plastic material under all conditions. In practice I prefer to effect automatic adjustment of one heating electrode relatively to the other and to the interposed work material, and the system herein disclosed provides for such automatic adjustment.

I have shown, by way of example, an oscillator circuit of a character quite similar to that disclosed and claimed in my copending application,

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Serial No. 627,871, filed November 10, 1945, for Oscillator circuit for high frequency heating. It is to be understood, however, that my invention is adaptable for use with various other types of oscillator circuits.

Referring to the drawing, the numerals 5 and 6 respectively designate the positive and negative terminals of a suitable source of supply (not shown) of high-voltage (preferably unidirectional) current. It is to be understood, of course, that a source of low frequency, high-voltage alternating current may be employed if desired, without requiring any substantial variation in or modification of the other elements of the system. The negative terminal 6 is shown as having a ground connection at 7.

The oscillator circuit includes a pair of tubes 8 and 9, preferably of the high-vacuum triode type. The anodes 8<sup>a</sup> and 9<sup>a</sup> are respectively connected with opposite terminal of an autotransformer 10 having a center tap 10<sup>a</sup> which is connected with the aforementioned positive terminal 5. In practice I prefer to interpose a high frequency choke coil (not shown) between tap 10<sup>a</sup> and terminal 5. An adjustable condenser 11 is connected in parallel with winding 10.

The cathode 8<sup>b</sup> and 9<sup>b</sup> of tubes 8 and 9 have a common connection 12, through a suitable resistance, shown diagrammatically at 13, with the aforementioned negative terminal 6. The function of resistance 13 will be described hereinafter.

The grids 8<sup>c</sup> and 9<sup>c</sup> of tubes 8 and 9 are respectively connected by conductors 14 and 15 with taps 16<sup>a</sup> and 16<sup>b</sup> of an inductance 16; said taps being preferably spaced like distances from the center tap 16<sup>c</sup> of said inductance. Said center tap 16<sup>c</sup> is connected by conductor 17, through a resistance 18, to ground at 19. A suitable condenser (not shown) may be connected in parallel with resistance 18, as disclosed in my aforementioned application, Serial No. 627,876.

The opposite ends of winding 16 are respectively connected with the upper and lower electrodes 20 and 21, whereby the latter are supplied with high frequency current for inductively heating an article 22, or articles, positioned therebetween. When the article 22 is composed of dielectric material (such as thermoplastic and thermosetting insulation) preformed to the cylindrical shape illustrated diagrammatically in the drawing, the lower stationary electrode 21, and also preferably the movable upper electrode 20, will be of curved or trough shape in transverse cross section, as indicated. Metal elec-

trodes of such form are disclosed and claimed in Patent No. 2,472,370, granted to me on June 7, 1949, and form no part of the present invention. Thus it will be apparent to those skilled in the art that electrodes of any suitable or desired shape may be employed herein, according to the shape of the dielectric articles to be heated and/or the character of the insulating material of which the same are composed.

As aforeindicated the lower electrode 21 is stationary, whereas the upper electrode 20 is movable. Thus I have shown electrode 20 as supported by a nut 23<sup>a</sup>, in insulated relationship to the latter. Nut 23<sup>a</sup> is internally threaded for cooperation with a threaded shaft 23, whereby the nut 23<sup>a</sup> and electrode 20 are jointly movable upwardly or downwardly, according to the direction of rotation of shaft 23. Shaft 23 is adapted to be driven in reverse directions selectively by a suitable motor 24, which is shown as of the split-field reversible type; the arrangement preferably being such that the field winding 25 when energized is adapted to effect rotation of motor 24 and shaft 23 in a direction to cause downward movement of nut 23<sup>a</sup> and electrode 20 attached thereto; and, alternatively, upon energization of field winding 25 shaft 23 is rotated in the reverse direction to cause upward movement of nut 23<sup>a</sup> and electrode 20. Any suitable means, such as limit switches or the like (not shown) may be associated with nut 23<sup>a</sup> to effectually limit the maximum degree of upward or downward movement of electrode 20. Such limit switches may, of course, be adjustably positioned, to compensate for variations in actual operating conditions, including differences in the vertical dimensions of the thermosetting plastic articles to be positioned between the heating electrodes 20 and 21.

Operation of motor 24 is subject to control by a known form of balanced relay or electromagnetically operable switch 27, having a contactor 28 which may be assumed to be normally biased to its intermediate or "off" position illustrated. Contactor 28 is connected by conductor 29 with line L<sup>2</sup> forming part of a suitable source of current supply. A stationary contact 30 is connected by conductor 31 through the aforementioned winding 25 to line L<sup>1</sup>; and a stationary contact 32 is also connected to line L<sup>1</sup> by conductor 33 and winding 26.

Contactor 28 as shown is of inverted T-shape, and is pivotally supported at 34; the arms of the T respectively having solenoid cores 35 and 36 pivotally attached thereto at 37 and 38 and depending therefrom. Core 35 has associated therewith a winding 39 which is continuously energized to a predetermined degree from a suitable source of constant power supply, such as the battery 40. The effective strength of the current supplied to winding 39 may be adjusted manually, as by means of a contactor 41 forming part of the series rheostat 42. In practice the rheostat contactor 41 will have associated therewith a series of legends (as, for instance, a dial, not shown), whereby said contactor may be adjusted to definitely preselect the rate of input of high frequency heating current to the dielectric article or articles interposed between electrodes 20 and 21.

This result is attained by opposing the electromagnetic pull upon core 35 with the pull upon core 36 afforded by energization of a winding 43. As shown, winding 43 is connected by conductors 44 and 45 in shunt to the aforementioned resistance 13; the value of the voltage drop across

resistance 13 being substantially proportional to the value of the power being dissipated, in the form of heat, in the article or articles 22 between electrodes 20 and 21.

Thus if the rate of dissipation of heat within the dielectric article between electrodes 20 and 21 corresponds exactly with the value thereof preselected by the adjustment of rheostat contactor 41, the electromagnetic pulls upon the cores 35 and 36 will be equalized, and the contactor 28 will assume its intermediate or "off" position, thus entirely disconnecting motor 24 from the line.

If the rate of supply of high frequency current by electrodes 20 and 21 to the dielectric material is greater than that required to effect the rate of heating thereof preselected by the setting of rheostat contactor 41, the resultant increase in value of the voltage drop across resistance 13 will cause the electromagnetic pull upon core 36 to predominate over that upon core 35, so that contactor 28 will be moved counterclockwise into engagement with contact 32. This completes a circuit from line L<sup>2</sup> through winding 26 to line L<sup>1</sup>, whereby motor 24 is rotated in a direction to cause upward movement of nut 23<sup>a</sup> and electrode 20. Inasmuch as the amount of heat generated in the dielectric material is inversely proportional to the size of the air gap or space between the upper electrode 20 and the material, it will be apparent that the decrease in the rate of heating of such material will be proportional to the degree of upward movement of electrode 20. Such upward movement of electrode 20 will be continued automatically until the degree of energization of winding 43 is decreased to a value corresponding to the degree of energization of winding 39, whereupon the contactor 28 will be permitted to return to its "off" position to disconnect motor 24 from the line.

Similarly, if the rate of heating of the dielectric material is lower than the value preselected by the adjustment of rheostat contactor 41, the pull produced by winding 39 will predominate over that of winding 43. Consequently contactor 28 will be moved clockwise into engagement with stationary contact 30, thus completing a circuit for the winding 25 of motor 24. Motor 24 will therefore operate in the reverse direction to effect lowering of nut 23<sup>a</sup> and electrode 20, whereby the rate of heating of the dielectric article 22 will be increased (with a corresponding increase in the value of the voltage drop across resistance 13) until the electromagnetic pull afforded by coil 43 is again equal to that of coil 39. Contactor 28 will therefore be moved to its normal "off" position, thus interrupting the energizing circuit of winding 25 to stop motor 24.

Also, as will be apparent to those skilled in the art, the system herein disclosed is operable automatically in the manner aforedescribed in response to any changes in the physical or dielectric characteristics of the article itself as an incident to heating thereof. For example, any swelling of the material during heating will vary the air gap between the same and the upper electrode 20, with a consequent variation in the rate of generation of heat in the former. Such variation, is, in turn, reflected in a change in the value of the voltage drop across resistance 13, with resultant raising or lowering of electrode 20 relatively to the article 22, as aforedescribed, until the rate of heating preselected by the setting of rheostat contactor 41 is again attained. Any variation in the vertical dimension of the articles 22 sequentially interposed between the

electrodes 20 and 21 will likewise result in automatic adjustment of upper electrode 20 in the manner aforedescribed.

Although I have shown the reversing control means for motor 24 as comprising the balanced relay 27 and its associated parts, it is to be understood that any other suitable means may be employed for controlling motor 24 in response to variations in the signal voltage provided by use of resistor 13. Thus, I may employ a control unit which is composed of four receiver type tubes, in the manner disclosed in the patent of William H. Elliot, No. 2,428,702, granted October 7, 1947, for Electronic motor control. With such a unit, if the control voltage (across resistance 13 herein) deviates from some preset value, which is readily adjustable (as by means of a rheostat contactor) it will cause either one of a pair of relays to operate, depending upon the direction in which the control voltage changes. Such relays will have contacts to respectively control the windings of a split-field reversible motor, like that shown at 24 herein, to effect raising or lowering of the upper electrode 20. As aforeindicated, if the upper electrode 20 is brought closer to the dielectric article to be heated the voltage gradient across the article 22 is increased, thus increasing the rate of heating, and in turn causing the rate of flow of high frequency current between the electrodes to increase. Upon raising of the upper electrode 20 the opposite effect will be obtained, as aforedescribed.

#### I claim:

1. In apparatus for high frequency heating of dielectric material in which the rate of heating is maintained substantially constant, the combination of a tuned-plate, tuned-grid oscillator having a pair of triode tubes of the high vacuum type and wherein the grid tank circuit constitutes the heating circuit, a pair of relatively movable heating electrodes operably connected in the heating circuit, a resistor of predetermined value in the plate circuit of said tubes and through which the plate current passes to produce a signal voltage of a value corresponding thereto, means comprising a balanced type relay for comparing said signal voltage value with a predetermined constant value, and means acting automatically in response to said relay to raise or lower one of said electrodes with respect to the other accordingly as the signal voltage varies from the predetermined value, whereby the plate current and consequently the rate of heating are maintained substantially constant.

2. In apparatus for high frequency heating of dielectric material interposed between electrodes forming part of a high frequency oscillator circuit in which the rate of heating is maintained substantially constant, the combination of a tuned-plate, tuned-grid oscillator having a pair of triode tubes of the high vacuum type and wherein the grid tank circuit constitutes the heater circuit, a resistor of predetermined value through which the plate current flowing in the high frequency oscillator tubes is caused to pass to produce a voltage drop of corresponding value, means for connecting one coil of a balanced type relay in parallel with said resistor to produce an electrical effect proportional to the value of said voltage drop, means for subjecting the other coil of said relay to a source of electrical power of preselected constant value to produce an electrical effect opposed to that aforementioned, a reversible electric motor having a mechanical

driving connection with one of the aforementioned electrodes to effect raising or lowering thereof with respect to the other, and means for subjecting said motor to control by said relay whereby the plate current and consequently the rate of heating are maintained substantially constant.

3. In an oscillator circuit of the tuned plate, tuned grid type adapted for high frequency heating of dielectric articles, the combination with a pair of high vacuum tubes of the triode type, means for connecting the anodes of the respective tubes to opposite ends of an inductance having a center tap connection with one terminal of a suitable source of power supply, means for jointly connecting the cathodes of the respective tubes to the other terminal of said source and to ground, a second inductance having a center tap connection to ground, means for connecting the grids of the respective tubes to taps spaced like distances from said center tap last mentioned, a pair of spaced electrodes connected to opposite ends of said last mentioned inductance and adapted to provide for high frequency heating of dielectric material interposed therebetween, a split field reversible motor having a positive mechanical driving connection with one of the aforementioned electrodes to effect raising or lowering thereof with respect to the other, whereby the air gap between one of said electrodes and said dielectric material is varied, a resistor of predetermined value through which the plate current flowing in the aforementioned tubes is caused to pass to produce a voltage drop of corresponding value, means comprising a balanced type relay for comparing the value of said voltage drop with a preselected constant electrical value, and said last mentioned means being operable to effect operation of said motor in reverse directions selectively in accordance with the difference in said values, whereby the value of said voltage drop is maintained substantially constant.

4. In an oscillator circuit of the tuned plate, tuned grid type adapted for high frequency heating, the combination with a pair of vacuum tubes of the triode type, means for connecting the anodes of the respective tubes to opposite ends of an inductance having a center tap connection with one terminal of a suitable source of power supply, means for jointly connecting the cathodes of the respective tubes to the other terminal of said source and to ground, a second inductance having a center tap connection to ground, means for connecting the grids of the respective tubes to taps spaced like distances from said center tap last mentioned, a pair of spaced electrodes connected to opposite ends of said last mentioned inductance and adapted to provide for high frequency heating of dielectric material interposed therebetween, a resistor of predetermined value through which the plate current flowing in the aforementioned tubes is caused to pass to produce a voltage drop of corresponding value, means for connecting one coil of a balanced type relay in parallel with said resistance to produce an electrical effect proportional to the value of said voltage drop, means for subjecting the other coil of said relay to a source of electrical power of preselected constant value to produce an electrical effect opposed to that aforementioned, a reversible electric motor having a mechanical driving connection with one of the aforementioned electrodes to effect raising or lowering thereof with respect to the other, and said motor

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being subject to control by said relay, whereby the value of said voltage drop is maintained substantially constant.

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