April 29, 1952 H. C. GILLESPIE 2,594,420

HIGH-FREQUENCY DIELECTRIC HEATING SYSTEM

Filed June 29, 1948

Fig. 1.

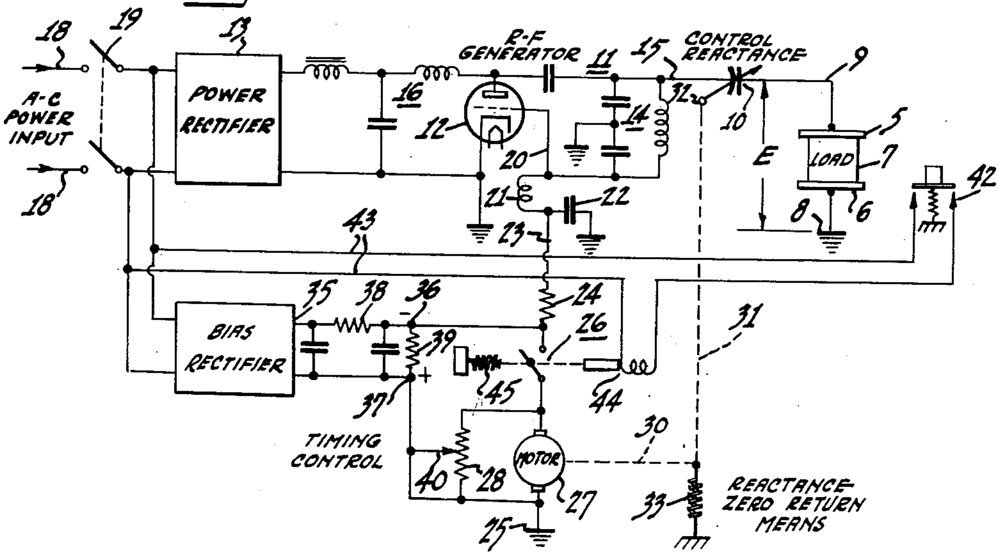
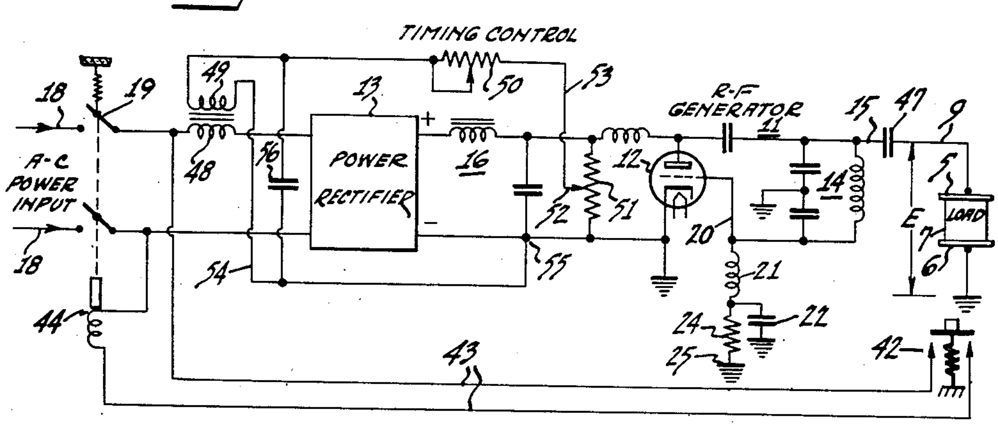


Fig. 2.



INVENTOR
HENDERSON C. GILLESPIE
BY Morris [signature]
ATTORNEY

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HIGH-FREQUENCY DIELECTRIC HEATING SYSTEM

Henderson C. Gillespie, Moorestown, N. J., assignor to Radio Corporation of America, a corporation of Delaware

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1 Claim. (Cl. 219—47)

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The present invention relates to a high frequency dielectric heating system for the bonding of thermoplastic dielectric materials by means of high frequency currents applied thereto through suitable electrodes.

In bonding two or more layers of dielectric material, particularly in the form of thin sheets, it has been found that the voltage applied may break down and puncture the material or in some cases may arc over between the electrodes and burn the material, thereby damaging its quality. On the other hand, however, the heating of the material is dependent upon the voltage applied as well as the frequency, and higher voltages, as well as higher frequency, are desirable from the standpoint of speed of bonding.

It is, therefore, a primary object of this invention, to provide an improved high frequency dielectric heating system which is effective to apply to the output electrodes a voltage which builds up gradually to a predetermined desired maximum, which, it has been found, may be higher than that which would normally be possible to apply directly, without danger of flashover.

It is also an object of the invention, to provide an improved control system for high frequency oscillator or generator circuits, whereby a rapidly rising and initially low voltage may be applied to a work load of dielectric material between a pair of electrodes without danger of arc-over or puncture of the material, while at the same time attaining a desired maximum high voltage for effecting bonding or heating of the material with maximum efficiency.

In electronic heat sealing of thermoplastic dielectric materials as normally carried out, the electrodes are brought into contact with a body of the material or a stack of laminations thereof, and the full high frequency voltage to be used is suddenly applied thereto. The tuning of the load circuit is such that the envelope of the high frequency voltage may be abruptly rectangular or have a steep wave front falling off after the first part of the heating cycle, and may cause arcing and burning or puncturing of the material.

It has been found, however, that if, in accordance with the invention, the electrode voltage is made to rise after an initial low value has been applied, considerably higher voltages may ultimately be reached and better seals may be obtained than ordinarily is possible. It appears that the material is softened to a certain degree at the low voltage and the electrodes may, therefore, be brought into more intimate contact with the material so that air is more completely driven out of the space between the electrodes and the material as the voltage rises to the maximum value.

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The invention will, however, be further understood from the following description, when considered in connection with the accompanying drawing illustrating certain embodiments of the invention, and the scope of the invention will be pointed out in the appended claims.

In the drawing:

Figure 1 is a schematic circuit diagram of a high frequency dielectric heating system embodying the invention, and

Figure 2 is a further schematic circuit diagram of a high frequency dielectric heating system also embodying the invention, as a modification of the system of Figure 1.

Referring to Figure 1, the spaced electrodes **5** and **6** of a high frequency dielectric heating system are shown, with a body or block **7** of dielectric material to be heated, located therebetween. The electrode **6** is connected to ground, as indicated at **8**, and the high voltage electrode **5** is connected through a supply circuit **9** and a variable series reactance device **10** in the circuit, with a high voltage R. F. generator **11**, comprising an electronic oscillator tube **12**, which is supplied with energy from a power rectifier **13**.

The electronic oscillator tube **12** is provided with a tuned oscillation generating tank circuit **14** which is connected through a power output circuit having an output lead **15**, with the variable reactance device **10** for supplying energy to the load therethrough. The oscillator circuit is energized from the power rectifier **13** through a suitable filter circuit **16**, the low potential side of which is connected to cathode and ground as indicated. The power rectifier is energized from suitable alternating current power supply lines **18** through a control switch **19** which is closed to energize the generator.

The grid circuit **20** of the oscillator is connected through an R. F. choke coil **21** having a bypass capacitor **22**, with a control lead **23** in which is located a series bias resistor **24** for the grid. The grid circuit is provided with a D. C. return path from the resistor **24** to ground **25** and cathode, through a switch **26**, and a small D. C. motor **27** having a potentiometer resistor **28** connected in shunt therewith, as shown.

The motor is connected, as indicated by the dotted connection lines **30** and **31**, with the variable control element **32** of the variable reactance device **10**, which, in the present example, is illustrated as a variable capacitor, this being a present preferred form of variable reactance for the purpose. The capacitor is normally fully open or at substantially zero capacity, and is caused to return to or assume that condition of adjustment by any suitable means, such as a biasing force provided by a spring 33, the motor, when operating, tending to drive the capacitor to the closed or maximum capacity position of adjustment, against the biasing force of the spring.

When the power mains are closed to the power rectifier and the oscillator is energized, oscillations are suppressed and the generator is maintained in an inoperative or non-oscillating condition by means of a control potential applied to the control grid circuit 20 of the oscillator tube 12 through the lead 23, and the biasing resistor 24. This hold-off potential is provided, in the present example, by a bias rectifier 35 connected with the power supply leads 18 through the switch 19, whereby it is energized simultaneously with the power rectifier.

The bias rectifier is provided with an output circuit having a negative terminal 36 and a positive terminal 37, the latter being connected to ground and the former being connected to the grid through the input end of the grid resistor 24 at the switch 26. A relatively high resistance series limiting resistor 38 is provided in the bias supply circuit, and a high resistance load for the rectifier is provided by a load resistor 39 connected between the terminals 36 and 37.

The biasing or hold-off potential provided by the bias rectifier, for the control grid circuit of the oscillator tube 12, is such that oscillations are normally suppressed when the switch 26 is open. When the switch is closed, the oscillator grid circuit is completed through a low impedance path comprising the motor 27 and the shunt resistor 28, any portion of which resistor may be applied across the motor by movement of a control arm or contact 40 thereon. As the oscillator builds up grid current, oscillations are built up in the tuned tank circuit 14 and are applied through the output circuit 15 to the variable reactance device 10 which is conditioned for maximum impedance, so that minimum power output or voltage is applied to the load circuit 9 and to the electrodes 5 and 6. The bias voltage at the terminals 36 and 37 is reduced substantially to that across the motor by the potential drop in the resistor 38 which operates as a high resistance current limiter. The bias potential is thus immediately restored upon opening of the switch 26.

Simultaneously with the building up of oscillations, the grid current flowing in the oscillator grid circuit causes the control motor to operate and to gradually reduce the reactance of the device 10, thereby causing substantially a linear build up of operating voltage E on the electrodes 5 and 6, until the reactance is reduced to a minimum and full voltage is applied from the generator 11 to the load 7. This operation may be adjusted to extend over a time interval from a fraction of a second to several seconds depending upon the material being heated, its mass and thickness, and the degree to which it is desired to heat the material.

In any case, it has been found that a considerable improvement in the heating or welding of thermoplastic material results from the timed building up of potential on the work load from an initial low voltage. The system shown has the further advantage that reduction of the impedance or reactance in the work circuit begins simultaneously with the start of oscillations in the generator, thereby fully utilizing the power available in the heating cycle.

The control switch 26 may be operated automatically or manually. By way of example, for convenient manual operation, a control switch or push button 42 may be located adjacent to the operating point, where the load is to be placed between the electrodes 5 and 6, and the control switch may be connected through a suitable supply circuit 43 with a solenoid device 44 for remotely operating the switch 26 as shown. In the present example the switch is opened by means of a retractile spring 45 and maintained in the open position thereby, and is closed by energizing the solenoid device 44 through closure of the switch 42. The supply leads 43 as shown, may be connected with the supply leads 18 through the switch 19 and the control circuit is thereby energized simultaneously with the power rectifier 13 and the bias rectifier 35.

The contact 40, in connection with the potentiometer resistor 28 which is connected in shunt with the motor 27, operates as the timing control means for the system, whereby the rate of voltage increase on the load may be adjusted as desired for any particular material, to prevent arc over. It will be seen that as the potentiometer contact 40 is moved to short circuit a greater portion of the resistor 28, the resistance across the motor will be decreased, thereby shunting a greater portion of the grid current through the resistor element 28 of the potentiometer device and causing the motor to operate at a slower speed. The slower the motor operates, the lower is the rate at which the control reactance is reduced in value, and the rate of the voltage increase on the load is correspondingly reduced. Therefore, by this means the build up of potential on the load may be adjusted for any desired time interval from minimum to maximum.

Referring now to Figure 2, in which like circuit elements and parts are designated by like reference characters as in Figure 1, the R. F. generator 11 is coupled to the load through a fixed coupling device such as a capacitor 47 located between the output lead 15 of the tank circuit 14 and the load circuit 9 connected with the electrode 5.

The R. F. generator or oscillator tube 12 receives anode current through the filter circuit 16 from the power rectifier 13, which is energized from the leads 18 through the switch 19. A series reactor 48 is connected between one of the leads 18 and the rectifier 13, and the reactor is provided with a D. C. saturating winding 49 which is connected to the output circuit of the power rectifier to receive controlling current therefrom through a series variable impedance or resistor 50 and a potentiometer device 51.

The potentiometer device 51 is connected in shunt across the output filter circuit 16 of the rectifier, intermediate the ends of the filter circuit. A variable tap connection 52 for the potentiometer is connected through a lead 53 and the variable resistor 50 to one terminal of the saturating winding 49. The opposite terminal of the saturating winding 49 is connected through a lead 54 with the negative side of the rectifier output circuit as indicated at 55. A capacitator 56 is connected in shunt with the saturating winding 49.

The oscillator grid circuit 20 is connected directly to cathode and ground 25 through the choke coil 21 and the grid resistor 24 without the intermediary of the motor control circuit, in the system of the present example.

The control or push button switch 42, representing any manual or other power control element for the system, is connected through the lead 43 with the solenoid device 44, which in the present example, is connected to operate the switch 19, whereby the power is applied to the R. F. generator by energizing the power rectifier and supply circuits thereof, when power is desired to be applied to the load.

The operation of the system is as follows: The build up of voltage on the load is controlled by a variable control reactance, which is saturable reactor 48—49 in the power supply to the rectifier, that is, the power supply to the oscillation generator. When the switch 19 is closed, D. C. saturating current is supplied from the potentiometer 51—52 in the output circuit of the rectifier to the saturating winding 49, building up to decrease gradually the reactance of the reactor 48, and thereby causing the rectifier output voltage to build up on the generator. The rate of build up may be controlled by adjustment of the value of the resistor 50 and by the value of the capacitor 56, and the initial current is controlled by the potentiometers 51—52. The combination of the normal RC build up curve, and the rising voltage from the rectifier at the terminal 52 of the potentiometer 51 provides a nearly linear increase in the rectifier output and accordingly in the output voltage E of the oscillator as applied to the load.

The rising voltage output from the rectifier 13 is then applied to the plate of the oscillator 12 and the high frequency load voltage E, also rising linearly, is applied to the electrodes 5 and 6 and thence to the load 7. The gradual build up of voltage thereby attained, prevents arc-over and burning of the material, while at the same time providing a maximum voltage rise and maximum heating of the material in a given time interval.

It has been found that the voltage for flash-over when suddenly applied to .010 inches cellulose acetate by rectangular bar electrodes at 27 megacycles, for example, may be of a value of 850 volts, whereas the flash-over voltage when starting at 400 volts and increasing at 400 volts per second, may be as high as 1200 volts on the same material and at the same frequency, thereby indicating the value in the use of a system in accordance with the invention.

From a foregoing consideration of the present embodiments of the invention it will be seen that an R. F. heating system in accordance with the invention provides advantages, some of which are as follows: (1) greatly increased speed of heat sealing by the use of higher voltages, and (2) the heat sealing of materials which could not otherwise be bonded by electronic power is made possible. This is for the reason that heating of the material at lower voltages precedes a controlled increase of the operating voltage to its maximum, whereby better contact between the electrodes and the work is obtained and a higher maximum potential is applied to the work for effecting the heat sealing, than has heretofore been possible by any known method or means.

I claim as my invention:

In a high frequency dielectric heating system, the combination with a high frequency oscillation generator having an output circuit, dielectric heating electrodes connected with said output circuit, and means for controlling the application of operating voltage to said electrodes from said generator comprising a power rectifier for energizing said generator, a saturable reactor in circuit with said power rectifier for controlling the application of operating current thereto, a D. C. saturating winding on said reactor, and a variable resistance-capacitance network including a winding connected with the D. C. output side of said power rectifier and responsive to the operating voltage applied to said generator, for gradually increasing the output voltage of said generator on said electrodes.

HENDERSON C. GILLESPIE.

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