

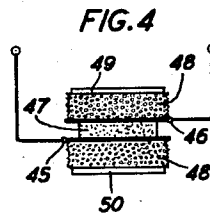
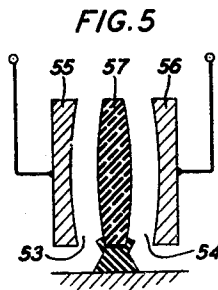
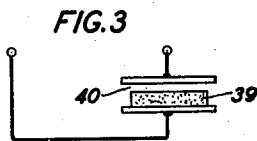
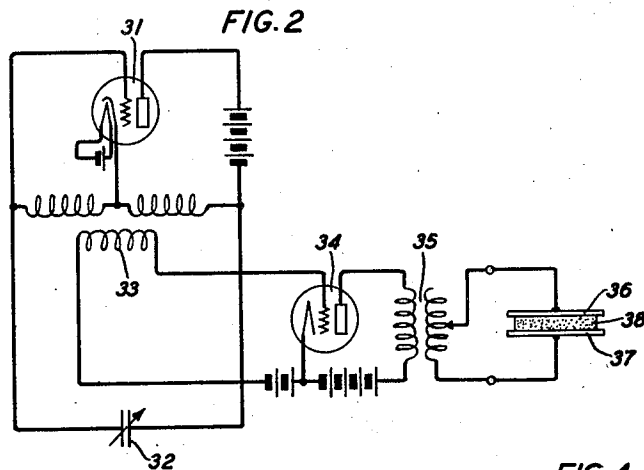
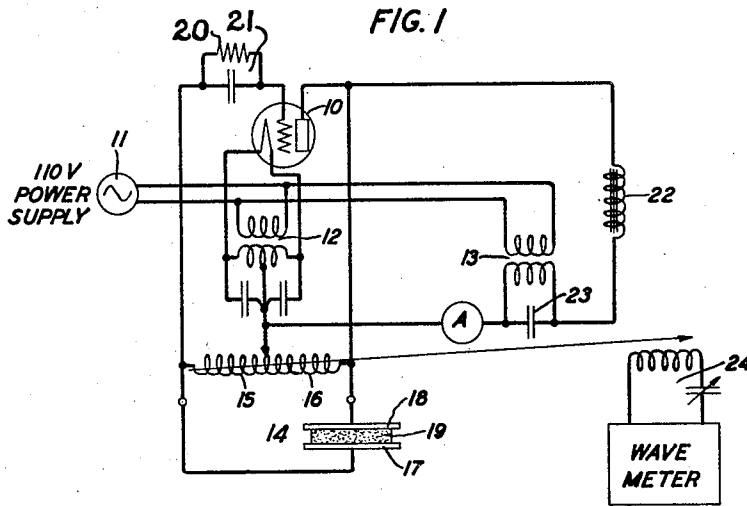
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METHOD AND APPARATUS FOR HEATING DIELECTRIC MATERIALS

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METHOD AND APPARATUS FOR HEATING
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This invention relates to methods of and apparatus for heating non-conducting molding materials and the object of the invention is to heat such materials quickly and uniformly throughout their mass.

In general, non-conducting molding materials are poor conductors of heat and it is, therefore, difficult to raise the inner portions of such materials quickly to molding temperature with ordinary heating methods without subjecting the outer layers of the material to excessive temperatures. With molding materials which are critical as to thermal history it is important not only to avoid excessive temperatures in any part of the material but also to reduce to a minimum the time interval during which the material is in a plastic condition.

According to this invention, such materials are heated uniformly and simultaneously throughout their mass by means of the dielectric loss produced in the material itself when it is subjected to a relatively high voltage, high frequency field, the heating circuit preferably being tuned to the frequency of the high frequency field. In one embodiment of the invention the material and the electrodes constitute a tuning condenser for a power oscillator supplying the heating current. In such a system any changes in the capacity of the heating circuit due to variations of the dielectric constant of the molding material as the heating progresses, produce corresponding changes in the frequency of the oscillator, thereby keeping the dielectric loss in the material at a maximum throughout the heating operation. The frequency of the oscillator at any instant is, therefore, a measure of the temperature of the material at that time and when the pieces of material to be heated are preformed to standard dimensions, the operator can determine when the molding temperature has been reached by observing a wavemeter which is loosely coupled to the oscillating circuit in the usual manner.

Alternatively, the heating current may be derived from a fixed frequency source and the frequency used may be so chosen with respect to the initial capacity of the heating circuit that the capacity changes effect the required degree of automatic regulation in the time rate of heat generation in the material.

These and other features of the invention will be more clearly understood from the following detail description and the accompanying drawing in which:

Fig. 1 shows a system in which the frequency

of the field is controlled by the capacity of the heating circuit;

Fig. 2 shows a system in which the frequency of the field is independent of the capacity of the load circuit; and

Figs. 3 to 5 show various electrode arrangements.

It can be shown that the power loss in molding materials which are relatively good dielectrics and in which the direct current conductance is negligible is approximately

$$P=2\pi f E^2 C \phi$$

where

P is the power loss in watts,
f is the frequency of the power source in cycles per second,

E is voltage applied to the electrodes between which the material is placed,

C is the capacity in farads of the condenser formed by the material and the electrodes, and
 ϕ is the power factor of the material being used.

Since the dielectric loss is directly proportional to the frequency of the supply, this frequency should be very high (of the order of 1 to 50 megacycles) to avoid the necessity of using an unduly high voltage to reduce the heating time to the value required.

In molding phonograph record pressings, for examples, the powdered molding material is sometimes first made into a "preform" or disc about 8 inches in diameter and about $\frac{1}{4}$ inch thick. Such a disc of one suitable material requires about 300 watt-hours to bring it to molding temperature but due to the poor heat conductivity of the material and the necessity of avoiding excessive temperatures in the outer portions of the disc, the heating cycle must be of the order of 20 to 30 minutes when ordinary oven methods are used. With the electrostatic method of this invention the heating cycle may be readily reduced to 2 or 3 minutes or less to keep step with the molding cycle so that the material is in the heated condition for only a very short time and the deterioration of the material is, therefore, a minimum.

In the system of Fig. 1 the tube 10 is a power oscillator of sufficient capacity for the particular application and operates directly from the alternating current supply 11, through a filament transformer 12 and a plate transformer 13. The tuning condenser 14 shunting the grid and plate circuit inductances 15 and 16 comprises electrodes 17 and 18 with the material 19 to be

heated disposed between them. The grid circuit is provided with a grid leak 20 and condenser 21 and the plate circuit with a radio frequency choke 22 and a condenser 23 shunting the secondary of the transformer 13 to keep the radio frequency energy out of the transformer. While the circuit shown is very simple, efficient and convenient to use it will be understood that any other well-known type of oscillating circuit may be employed though obviously from an efficiency standpoint the tuning condenser should be in the plate circuit.

For most molding materials, the dielectric constant will increase in magnitude as the temperature of the material rises but since the capacity of the tuning condenser 14 determines the oscillator frequency, the load circuit is always resonant to the oscillator frequency. The reduction of the oscillator frequency during the heating operation will, of course, vary with the nature of the material used and the temperature range. Since, as pointed out above, the power loss is a function of the frequency, this reduction in frequency gradually reduces the power dissipated as the material heats and permits a somewhat higher initial rate of dissipation than would otherwise be practical.

When, as in the case of molding records, the heating operation is carried out repeatedly with identical preforms, a conventional wavemeter 24 may be disposed with its pick-up circuit in the field of the oscillator and the reading of the meter when the molding temperature is reached determined empirically. When this has been done, the operator may then use the meter as a thermometer for determining when molding temperature has been reached in all subsequent operations.

In the system of Fig. 2, the oscillating tube 31 may be of the low voltage, low power capacity type and is tuned to the desired frequency by the variable condenser 32. By means of the winding 33 a potential of the oscillator frequency is applied to a conventional amplifier 34 which may have as many stages as necessary to provide the power required. The amplifier output is supplied through a transformer 35 to the electrodes 36, 37 between which the molding material 38 is located to form a condenser which tunes the secondary circuit of the transformer to the oscillator frequency. With this circuit the oscillator frequency will be essentially fixed by the condenser 32 and it is, therefore, independent of the capacity variations incident to temperature changes in the molding material. In most cases it will be desirable to adjust the inductance of the heating circuit to a resonant frequency somewhat below the oscillator frequency so that as the material 38 heats up, the circuit passes through resonance. This gives an increasing dissipation up to resonance and then a decreasing dissipation thereby affording a measure of automatic heat regulation which reduces the danger of impairing the material by overheating.

In some cases, particularly for materials having a wide variation of dielectric constant with temperature, it may be desirable to space one or both of the electrodes a short distance from the material as shown in Figs. 3 and 5, respectively. While the use of an air-gap makes a higher voltage necessary to obtain the same heating effect, the power loss in the gap is very small and the change in the capacity of the condenser as the material heats may be readily reduced to any desired value. For example, with one well-known material, if the preform 39 of Fig. 3 is $\frac{1}{4}$ inch

thick and has a 100 per cent variation of its dielectric constant when heated to molding temperature, a $\frac{1}{8}$ inch gap 40 reduces this variation to about 10 per cent.

If the gap is evenly divided into two gaps 53 and 54 on opposite sides of the preform 57 as shown in Fig. 5, the same result is obtained with the further advantage of a reduction or elimination of any tendency toward the spotty heating which sometimes occurs due to poor contact between the electrodes and the material. When the material 57 has non-planar surfaces more uniform heating will be obtained by contouring the opposed surfaces of the electrodes 55, 56 to give constant impedance for all paths between them. While in general this requires that the electrode surface follow the contours of the surface of the material, best results will be obtained by determining the final shape by experiment.

When the surface of the material to be heated is somewhat irregular and the use of air-gaps is undesirable, improved contact and more uniform heating can be obtained, as shown in Fig. 4, by using thin metal electrodes 45, 46 which are deformed and pressed into firm contact with the material 47 by resilient material 48 such as sponge rubber held in place by the backing plates 49, 50. In general, however, it will be found preferable to use an air-gap to avoid excessive heating in certain parts of the material but when very rapid heating of irregular shapes is required, the two-gap system with empirically contoured electrodes, as shown in Fig. 5, gives best results.

While the invention has been described with reference to particular embodiments for the purpose of illustration, it will be understood that the invention is to be limited only by the scope of the following claims.

What is claimed is:

1. In an electrostatic heating system, heating electrodes, material to be heated between the electrodes and an oscillation generator having a frequency determining circuit comprising inductance and capacity, the capacity consisting substantially entirely of that between said electrodes.
2. A system according to the preceding claim, in combination with means for determining the temperature of the material being heated comprising a wavemeter indicating the frequency of the generator oscillations.

3. In an electrostatic heating system for materials having irregular surfaces, a pair of thin plate electrodes, a source of high frequency energy connected to the electrodes, and means for deforming and pressing the electrodes into firm contact with the opposite sides of the material to be heated.

4. The step in the method of heating materials by means of the dielectric loss produced in the material when it is subjected to a high frequency field which comprises tuning the heating condenser to an initial resonant frequency such that the variation in the dielectric constant of the material with temperature causes the circuit to resonate at the frequency of the field at an intermediate temperature in the heating range.

5. The method of heating materials having low conductivity and a dielectric constant which varies with temperature, which comprises subjecting the material to a high frequency field, varying the frequency of the field in accordance with the variation in the dielectric constant of the material, determining the relationship between the controlled frequency and the tempera-

ture of the material and measuring the frequency to indicate the temperature of the material.

5 6. In an electrostatic heating system, an oscillation generator having input and output circuits connected to react on each other to produce oscillations, material to be heated and electrodes forming with the material a capacity which is directly connected to at least one of the circuits and serves as the principal means of determining
10 the frequency of the generator oscillations.

7. The method of heating materials which comprises preforming the materials to standard dimensions, subjecting the preformed material to a high frequency field to produce a dielectric loss in the material and utilizing the change in the dielectric constant of the material with temperature to change the frequency of the field so as to maintain the loss in the material substantially constant as the heating progresses. 5

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