

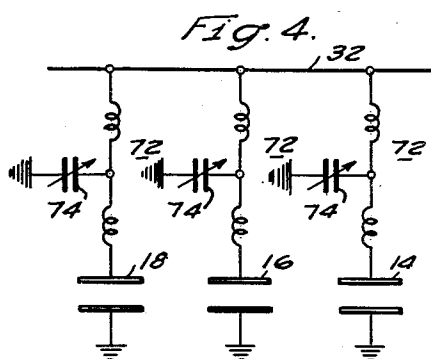
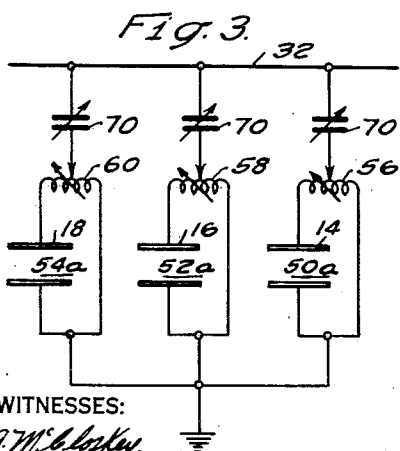
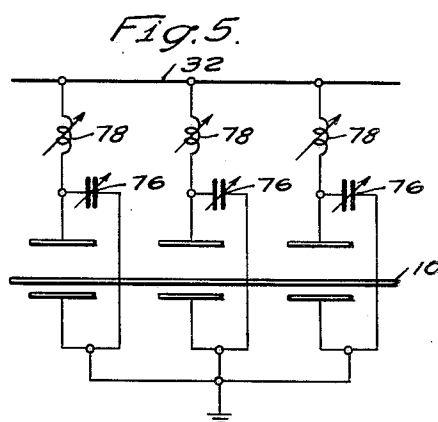
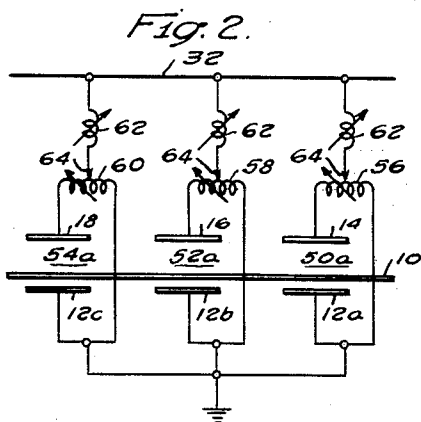
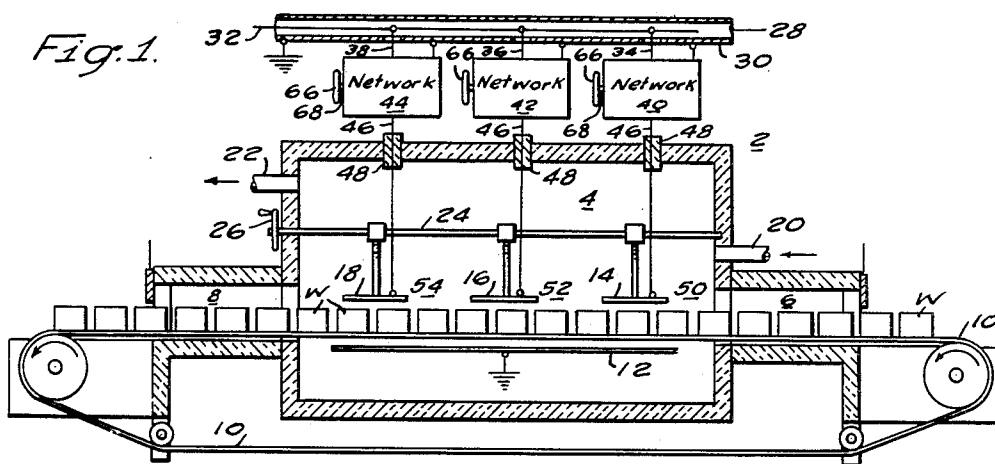
March 20, 1951

T. P. KINN

2,546,004

PROGRESSIVE DIELECTRIC HEATING

Filed July 11, 1947



WITNESSES:

E. A. M. Blakey
W. L. Jones

INVENTOR

Theodore P. Kinn.

BY

B. L. Zangwill
ATTORNEY

UNITED STATES PATENT OFFICE

2,546,004

PROGRESSIVE DIELECTRIC HEATING

Theodore P. Kinn, Baltimore, Md., assignor to
Westinghouse Electric Corporation, East Pitts-
burgh, Pa., a corporation of Pennsylvania

Application July 11, 1947, Serial No. 760,348

3 Claims. (Cl. 219-47)

1

My invention relates to dielectric heating systems having spaced heating-electrodes for heating material or work as it is conveyed between the heating-electrodes, the material or work being of a type which changes its dielectric characteristics or heating requirements as it is undergoing dielectric heating. Rayon, plastics, rubber and plywood are illustrations of materials to which my invention is applicable, but my invention is also useful with any similar material which, during dielectric heating, undergoes a change in a physical or chemical property which affects the voltage or voltage gradient to which the material should or may be subjected.

An object of my invention is to provide a dielectric heating system capable of introducing heating energy into material of a type described while the material is being conveyed on a conveyor, the energy being introduced at a uniform or controlled rate along different points of travel of the material.

Another object of my invention is to provide a dielectric heating system of a type described capable of heating traveling material at a maximum possible rate along all points of the system. In accordance with my invention, this objective is obtained by keeping the voltage-gradient in the material always at a high value, but insufficient to cause puncture or other flashover through or around the material.

It is a further object of my invention to provide a dielectric heating system of a type described comprising a plurality of pairs of heating-electrodes through which the material to be heated is successively passed; all pairs of heating-electrodes being energized from a single high-frequency power line.

Still another object of my invention is to dielectrically heat moving material in a manner described and while the material is enveloped by a controlled or other atmosphere.

Another object of my invention is to provide a dielectric heating apparatus for heating moving material, the system comprising a housing inside of which sets or pairs of heating-electrodes are arranged successively along the path of travel in which the material moves through the housing, the sets of heating-electrodes being connected to a common source of high-frequency power through means which permit the voltage across each set of heating-electrodes to be individually adjusted or controlled from outside the housing. A specific object of my invention is to provide a dielectric heating system of a type described which can be safely adjusted from outside the

2

housing in which the heating-electrodes are disposed.

Other features, objects and innovations of my invention, in addition to the foregoing, will be discernible from the following description of preferred and representative embodiments of my invention. The description is limited to such details as will enable an understanding of the invention and is to be taken in conjunction with the accompanying drawing. In the drawing, in which like numerals represent corresponding parts:

Figure 1 is a simplified representation of an embodiment of my invention;

Fig. 2 is a simplified diagram of the electrical circuits found in an apparatus such as disclosed in Fig. 1; and

Figs. 3, 4 and 5 are simplified electrical diagrams of modified forms of electrical elements and connections that can be used in apparatus in accordance with Fig. 1 of my invention.

Referring to Fig. 1, a housing 2 is shown as comprising a main treating chamber 4, an entrance 6 and an exit 8. An endless conveyor 10 has a work-carrying portion which passes through the treating chamber 4. The material, or work W, to be heated, is loaded onto the conveyor in front of the entrance 6 of the housing. The conveyor moves the material W through the housing for dielectric heating, after which the material is removed from the conveyor at a point beyond the exit end 8 of the housing. While traveling through the housing 2, the material passes between an arrangement of heating-electrodes comprising a lower metallic heating-electrode 12, and a plurality of upper insulated heating-electrodes 14, 16 and 18 arranged successively in the direction in which the material travels through the housing. The heating-electrodes 14, 16 and 18 are flat metal plates and are coplanar, but are spaced so that each is electrically insulated from those adjacent to it.

The work W on the conveyor 10 can be heated while enveloped by a controlled atmosphere inside the housing. To this end, the housing is provided with suitable inlets 20 and outlets 22 through which atmosphere may be admitted and exhausted from the housing. However, if no controlled atmosphere is desired, the outlet 22 can be used to exhaust any vapors or fumes that might be generated during the heating of the work.

In order to accommodate different heights of work, the heating-electrodes 14, 16 and 18 can be simultaneously raised and lowered through any suitable and common mechanism shown as comprising a screw 24 of insulating material which

is operated by a manually operable member in the form of a hand wheel 26 on the outside of the housing 2. Such adjustment can be used, if desired, to change the voltage across the pairs of heating-electrodes.

Power for heating the material passing between the heating-electrodes is obtained from a single power supply, such as a tank circuit, or from a transmission line of any suitable kind. For simplicity, a transmission line is shown. The line comprises a coaxial cable 28 having a grounded outer conductor 30 and an insulated inner conductor 32. The ground conductor 30 is conductively connected to the lower heating-electrode 12. This can, of course, be accomplished by suitably grounding the heating-electrode 12. Conductors 34, 36 and 38 separately connect the inner conductor 32 to networks 40, 42 and 44, respectively, each of which is individually associated with an insulated heating-electrode. This is represented in Fig. 1 by an insulated conductor 46 extending from each network to the associated heating-electrode 14, 16 or 18, as the case may be, after passing through an insulating bushing 48 in the top wall of the housing 2.

Energization of the power supply line provides an electric field between the heating-electrodes 12 and 14, between the heating-electrodes 12 and 16, and between the heating-electrodes 12 and 18. Since the heating-electrodes 14, 16 and 18 are insulated from each other and spaced edge-wise, the electric fields will be distinct. Hence, electrically considered, the heating-electrodes 12 and 14 form a set or first pair of heating-electrodes, the heating-electrodes 12 and 16 a second pair, and the heating-electrodes 14 and 18 a third pair. In a sense, the same is true physically since each of the insulated heating-electrodes 14, 16 and 18, in providing its associated electric field, cooperates with a portion of the heating-electrode 12 which is distinct from the portions of the heating-electrode 12 with which the other insulated heating-electrodes cooperate. Hence, the pair of heating-electrodes 12 and 14 form a capacitor 50, the pair of heating-electrodes 12 and 16 form a capacitor 52, and the pair of heating-electrodes 12 and 18 form a capacitor 54. The capacitance of these capacitors will also depend on the material being heated.

In order to keep the heating time of the material W to a minimum, it is desirable to provide a voltage across the several pairs of heating-electrodes 12 and 14, 12 and 16, 12 and 18, which will introduce a voltage-gradient through the work that is as high as the work can safely withstand without damage to the work or flashovers around the work. Such dielectric materials as rayon, resin or plywood, for example, cannot withstand a significant voltage-gradient or a large overall voltage during the initial part of the heating because of their relatively high moisture content. However, as the material becomes drier or sets or cures, it usually can have a higher voltage-gradient across it, and can withstand a higher overall voltage. The increased voltage or voltage-gradient results in more power being put into the material so that the material can be more rapidly heated or it can be brought to a higher temperature in a shorter time. It is also sometimes desirable, for other reasons, to control the rate at which energy is introduced into the material in a portion of the complete heating cycle it undergoes while traveling through the housing. In accordance with my invention, the networks 40, 42 and 44 are of a character which

can be conveniently adjusted from outside the housing 2, for adjusting the voltage across the pairs of heating-electrodes, and for impedance matching. The adjusting means has been shown as manually operable for simplicity but it will be clear that the adjustments can be automatically made.

Each of the networks 40, 42 and 44 may comprise combinations of reactances consisting of inductance coils, or capacitors, or both, in any form known to the art. One or more of the reactances is preferably adjustable for the desired power transfer and voltage adjustment, as closely as conditions permit. A scheme for this purpose is shown in Fig. 2 where the network is shown as comprising an L-C resonant circuit in which the capacitance is made up of a pair of heating-electrodes and its heating load therebetween. In Fig. 2, the equivalent of the heating-electrode 12 of Fig. 1 has been shown as consisting of three separate smaller heating-electrodes 12a, 12b and 12c. The section 12a cooperates with the heating-electrode 14; and the sections 12b and 12c cooperate with the heating-electrodes 16 and 18 respectively. The material to be heated is carried successively between the pairs of heating-electrodes 12a and 14, 12b and 16, or 12c and 18, by the conveyor 10. The several pairs of heating-electrodes and the dielectric material therebetween form capacitors 50a, 52a and 54a, respectively. Connected across each capacitor 50a, 52a and 54a, is a variable inductive coil 56, 58 and 60, respectively, which is preferably, but not necessarily, of a reactance, at the supply frequency, which approximates or is somewhat higher than that of its associated capacitor, but can be adjusted to much lower values. The insulated conductor 32 of the power transmission line is separately adjustably connected to each inductive coil through a variable inductor 62 and a manipulatable tap 64 adjustably contacting different points of the associated inductive coil. In Fig. 1, an insulated manipulator for moving a tap is shown as a hand wheel 66 on an adjusting shaft 68 which protrudes from a suitable box that contains the associated network elements.

A further and important advantage of the adjustable networks resides in the fact that they can be changed so as to compensate for the change in the capacity of the several pairs of heating-electrodes which occurs when the heating-electrodes are adjusted through operation of the hand wheel 26. Accordingly, the addition of the adjustable networks also makes the apparatus more universal for treating materials of different heights, dielectric constants and loss factors.

In Fig. 2, the voltage across the pairs of heating-electrodes will usually be at or above the line voltage. By inserting variable capacitors 70 in the connections to the networks, as shown in Fig. 3, the voltage across the pairs of heating-electrodes can be lowered to values below that of the line, and impedance matching restored by changing the tap-point on the inductive coils 56, 58 and 60.

Figs. 4 and 5 illustrate further forms of the many networks which can be interposed between the power supply line and the pairs of heating-electrodes for enabling the voltage across the pairs of heating-electrodes to be more readily adjusted in accordance with the voltage required for heating the work at the desired rate. In Fig. 4, a T network 72 is provided for each pair of

heating-electrodes, having a leg which includes an adjustable capacitor 74. An advantage of this embodiment lies in the fact that the moving plates through which the capacitors 74 are adjusted, can be grounded. In Fig. 5, a variable capacitor 76 is connected in parallel with each pair of heating-electrodes, and a variable inductor 78 is in the connection of each parallel circuit-arrangement to the conductor 32.

In general, if a network has the net effect of an inductive reactance, the voltage across the associated pair of heating-electrodes will be raised as compared to the voltage on the line, and if the net effect of the network is that of a capacitance then the voltage on the pair of heating-electrodes will be lowered. By suitable connections, as shown, for example in Figs. 4 and 5, a movable member of the networks can be grounded.

While I have described my invention in various forms, it is obvious that many equivalents can be substituted, and that principles of my invention can be applied in many different embodiments.

I claim as my invention:

1. Dielectric heating equipment comprising a housing, a conveyor having a material-carrying portion inside said housing and a loading portion outside said housing, a plurality of pairs of heating-electrodes inside said housing, each pair comprising heating-electrodes on opposite sides of said material-carrying portion of said conveyor, one of each of said pair of heating-electrodes being insulated from the associated heating-electrode paired therewith and from a heating-electrode of a different pair, common means for adjusting said insulated heating-electrodes to vary the spacing thereof with respect to the associated heating-electrodes, a high-frequency power line outside said housing, a plurality of networks at said housing, there being a separate network for each pair of heating-electrodes, and conductor means connecting said networks to said power line and connecting each of said networks separately to an individual pair of said heating-electrodes, each of said networks comprising an adjustable reactance member, and means outside said housing for adjusting said reactance member, each network and the associated pair of heating-electrodes forming a tunable load circuit.

2. Equipment for the dielectric heating of dielectric material, conveyor means adapted to

move dielectric material, said equipment comprising a plurality of pairs of heating-electrodes, each pair comprising relatively insulated heating-electrodes spaced from each other, the spaces between the heating-electrodes of the respective pairs merging and being arranged to form a substantially straight path through which a particular portion of the material can be substantially rectilinearly moved by said conveyor means from a position between a first pair of said heating-electrodes to a position between a next succeeding pair of said heating-electrodes, each of the last said pairs including relatively insulated heating-electrodes which lie on the same side of said path but are spaced from each other in the general direction in which the material moves, means supporting an insulated heating-electrode of each of said pairs relatively movable with respect to the associated heating-electrode for varying the spacing therebetween a single source of high-frequency energy comprising an insulated power-conductor, and circuit-branch means connecting said single source of energy to said pairs of heating-electrodes, said circuit-branch means including a network comprising a separately adjustable inductance connected between said power-conductor and said adjustably supported heating-electrode of a first of said pairs of heating-electrodes, and a variable capacitance across the last said pair of heating-electrodes.

3. An invention including that of claim 2 but characterized by said variable capacitance having a grounded adjusting element.

THEODORE P. KINN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,309,303	Crandell	Jan. 26, 1943
2,321,131	Crandell	June 8, 1943
2,403,800	Hoyler	July 9, 1946
2,415,025	Greil et al.	Jan. 28, 1947
2,421,334	Kline et al.	May 27, 1947
2,428,615	Brown	Oct. 7, 1947
2,432,412	Hacklander	Dec. 9, 1947
2,436,732	Rowe	Feb. 24, 1948
2,458,012	Madsen	Jan. 4, 1949
2,464,403	Klingaman	Mar. 15, 1949
2,464,404	Gillespie	Mar. 15, 1949