

March 15, 1949.

G. W. KLINGAMAN
APPARATUS FOR HEATING DIELECTRIC
MATERIALS ELECTRONICALLY

2,464,403

Filed Aug. 30, 1945

3 Sheets-Sheet 1

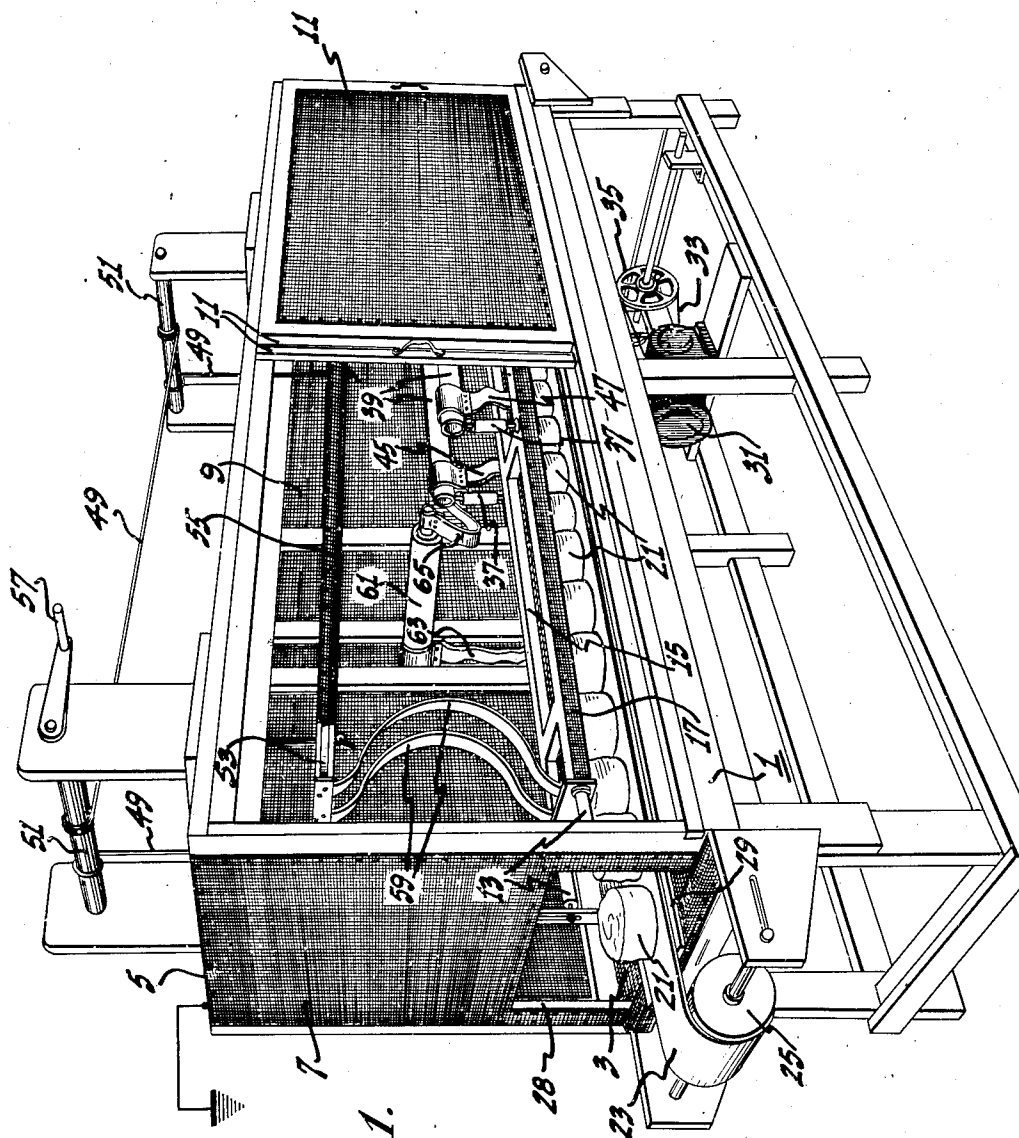


Fig. 1.

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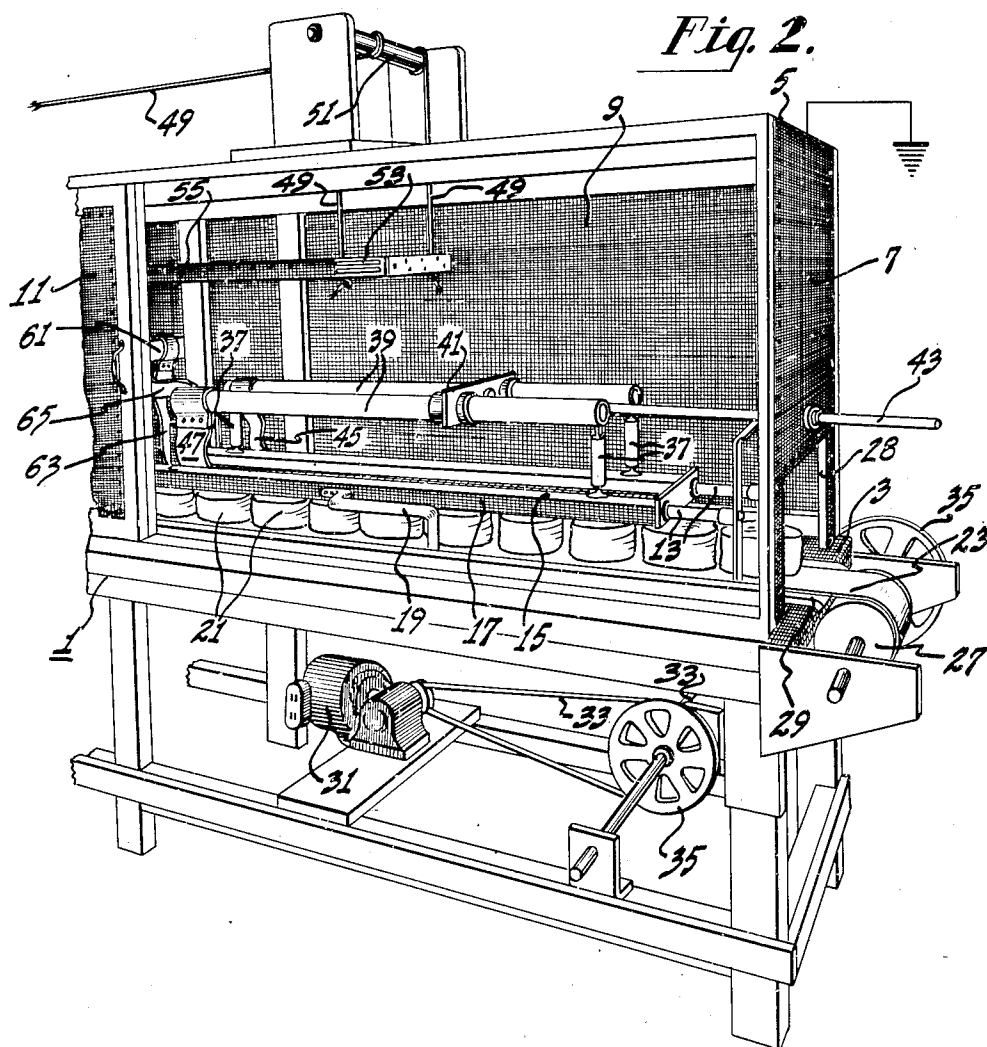
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3 Sheets-Sheet 2



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3 Sheets-Sheet 3

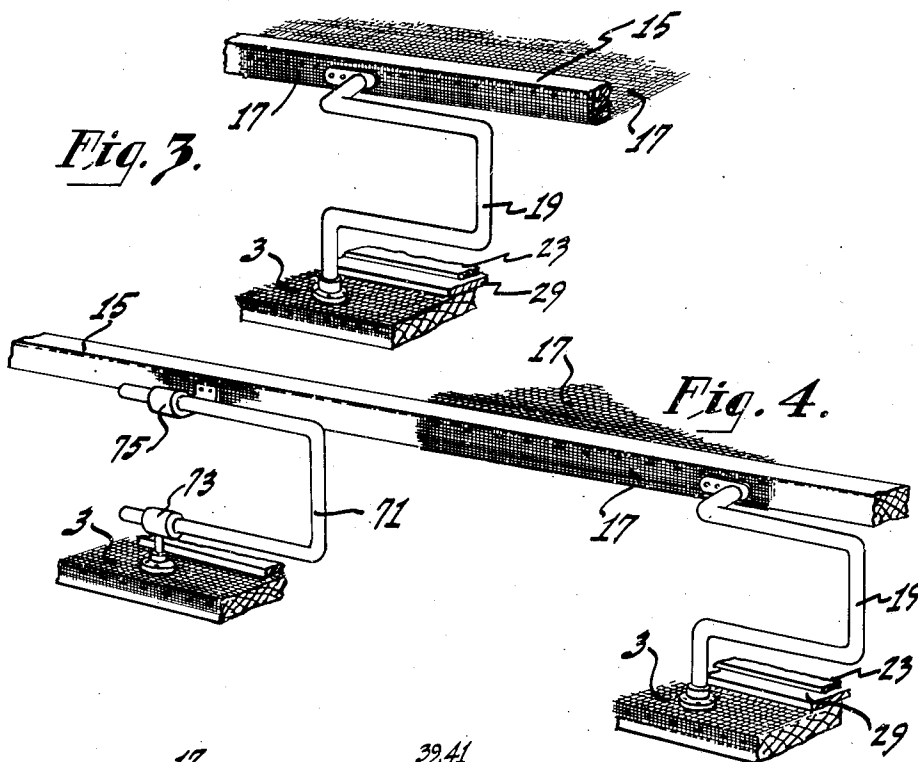


Fig. 5.

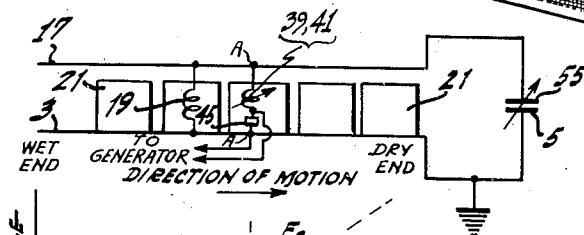


Fig. 6.

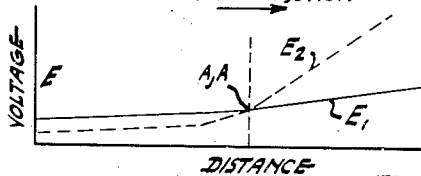


Fig. 7.

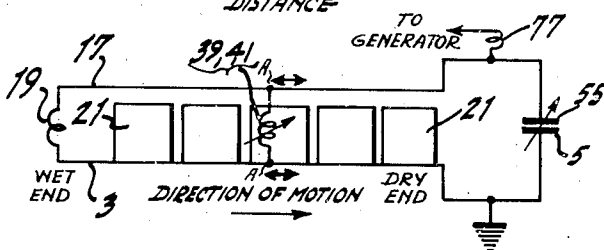
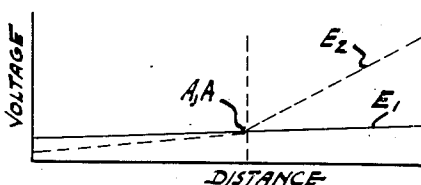


Fig. 8.



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APPARATUS FOR HEATING DIELECTRIC MATERIALS ELECTRONICALLY

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3 Claims. (Cl. 219—47)

1

This invention relates to apparatus for heating dielectric materials electronically, and more particularly to the heating of moisture laden, dielectric articles to expel moisture therefrom.

In the course of manufacturing various articles of dielectric materials, it is frequently necessary to subject the articles to a washing operation during which they are, of course, rendered wet. Thus, in the course of producing rayon thread, artificial sponges, and the like, of cellulosic materials, one or more washing operations may be encountered. It then becomes necessary to expel the moisture from such articles, since they are eventually supplied to the market or are utilized in the dry or substantially dry state.

In the manufacture of rayon thread or yarn, for example, it has been proposed heretofore to dry the so called wet rayon "cakes" or "packages" by subjecting them to the influence of a high frequency electric field. Rayon and many other dielectric materials which are capable of absorbing moisture have the characteristic that the power factors thereof vary as a function of the moisture content. Thus, as the rayon cakes or packages are dried, the power factor thereof changes and, for a given voltage which is applied to the work, a point is reached sooner or later where it becomes very difficult to put enough power into the work to continue the drying process at an adequate rate.

The primary object of my present invention is to provide apparatus for heating dielectric articles the power factors of which change appreciably during the heating process, which apparatus will not be subject to the above mentioned difficulty.

More particularly, it is an object of my present invention to provide apparatus for heating wet dielectric articles which will effectively carry out the drying operation in an efficient manner.

Another object of my present invention is to provide apparatus as aforesaid which can be used readily in a continuous heating or drying process as distinguished from a process involving batch treatment.

Still another object of my present invention is to provide apparatus for drying moisture laden, dielectric articles as above set forth in which the heating and drying may be effected rapidly and in great quantities.

According to my present invention, I enclose within an electrically shielding housing a heating unit comprised essentially of an electroconductive network or system including a pair of elongated, opposed, conductors or conductive portions or

2

elements, spaced from each other to receive therebetween the wet articles which are to be dried. An endless conveyor is arranged so that one lay thereof passes between the aforesaid conductors and thus advances the wet articles between said conductors in energy transfer relation with respect thereto. The conductors are connected to a suitable source of high frequency electrical energy for establishing between the aforesaid portions thereof a high frequency electrical field which produces dielectric losses in the articles and heats them to expel the moisture. A variable capacitor is connected across one end of the aforesaid conductors for tuning the heating circuit, and at a point intermediate the ends of the conductors, a variable inductor is connected across the said conductors. With this arrangement, the voltage across the two conductors between the end thereof at which the fresh, wet articles are introduced and the point at which the variable inductor is connected thereto will vary at a relatively low rate sufficient to expel most of the moisture from the wet articles. By the time the articles have been advanced to the point where the variable inductor is connected across the main conductor portions, they will have had a considerable part of the moisture expelled therefrom and the power factor thereof will have changed considerably, so that the effectiveness of the field must be increased from that point on. With the arrangement above described, the voltage from that point on to the outlet end of the main conductors will increase at a much higher rate, and therefore more power will be applied to the work for a unit distance along which the work is advanced. By the time the work has reached the outlet end of the main conductors, the work will have attained a minimum moisture content and will have become as dry as may be desired. In other words, the voltage between the opposed conductors is so distributed that the wet articles encounter a stronger and stronger field as they become progressively drier, this field becoming progressively more effective at rates which will insure substantially equal power input to all of the articles as they are advanced through the heating unit. The length of the main or heating conductor elements is governed primarily by the power concentration in the work and can be made short compared to the wave length at the frequency of the applied power.

The invention, together with additional objects and advantages thereof, will be better understood by reference to the accompanying drawings in which

3

Figure 1 is a perspective view, as seen from one end, of one form of apparatus according to my present invention.

Figure 2 is a fragmentary perspective view thereof as seen from the opposite end thereof,

Figure 3 is a fragmentary, perspective view showing a detail of the main, heating conductor.

Figure 4 is a similar view showing a detail of a modified form of apparatus according to my invention,

Figure 5 is a diagrammatic view of one circuit arrangement embodying my present invention,

Figure 6 is a curve showing approximately the voltage distribution in a system such as shown in Figure 5,

Figure 7 is a diagrammatic view of a somewhat different circuit arrangement embodying my present invention, and

Figure 8 is a curve showing approximately the voltage distribution in a system such as that shown in Figure 7.

Referring more particularly to the drawings, wherein similar reference characters designate corresponding parts throughout, there is shown a housing 1 which may be of wood or any other suitable material having a floor or bottom 3, a top 5, end walls 7 and back wall 9 all formed of wire screening which is preferably connected to ground. The front wall of the housing is constituted by a pair of sliding panels 11 also covered with wire screening which has electrical connection with the grounded floor or bottom 3 and the top 5. Thus, the housing 1 acts as an electric shield for the contents thereof.

Mounted within the housing 1 above the grounded screening 3 by means of insulating members 13 is a wooden or other suitable, dielectric frame 15 which carries a wire screen 17 in spaced relation to and parallel with the grounded screen 3. An inductor 19 comprising a winding of at least a partial turn or of any suitable number of turns is connected between the conductive screens 3 and 17, either in proximity to one end of the screen 17 (as shown in Fig. 4) or at some point intermediate the length thereof (as shown in Figs. 2 and 3). Thus, the screens 3 and 17 and the fixed inductor 19 form a single turn, main heating conductor network or applicator. When high frequency current is passed through this applicator, the elongated portions 3 and 17 of the applicator will have a potential difference between them which will establish a high frequency electric field between the conductor portions 3 and 17 for heating the wet, dielectric articles when such articles are passed therebetween. The articles, which are illustrated as rayon "cakes" 21, may be advanced through this high frequency electric field by means of an endless belt 23 of fabric or the like which is trained around a pair of rollers 25 and 27 and passes through openings 28 in the housing end walls 7. The upper lay of the belt 23 is arranged parallel to the conductor portions 3 and 17 and passes over a conductive plate 29 which rests on the grounded screen floor 3 and serves as a solid support for the articles 21 as they are advanced between the screens 3 and 17. Power may be applied to the roller 27 for driving the belt 23 from a motor 31 by means of a suitable belt and pulley drive 33, 35.

Supported on the frame 15 by means of insulators 37 are a pair of parallel conductors 39 of copper tubing or the like shunted by a conductive bridge 41 which is slidably carried thereby and which may be adjusted along the length of

4

the conductors 39 by means of a rod 43 of insulating material which passes through one of the end walls 7. One of the conductors 39 is connected to the grounded screen 3 by a conductive strap 45 of suitable impedance, while the other of the conductors 39 is connected to the screen 17 by a conductive strap 47. The straps 45 and 47 are connected to the screens 3 and 17, respectively, at some point A, A intermediate the ends of the screen 17 and referred to more particularly hereinafter. It will thus be seen that the conductors 39 and the bridge 41 thereacross will constitute a variable inductor which is connected across the main heating conductors 3, 17, and that the reactance of the variable inductor 39, 41 can be varied by sliding the bridge 41 along the conductors 39 to any desired position.

Suspended from the top of the housing 1 by flexible cords or the like 49 which are trained around rollers 51 is a framework 53 of insulating material carrying a wire screen 55. The screen 55 is spaced from the grounded top 5 of the housing and forms therewith a variable capacitor the capacitance of which can be varied by merely raising or lowering the framework 53 upon turning a crank 57 which is secured to one of the rollers 51. The capacitor screen 55 is connected to the high potential screen 17 by one or more conductive straps 59, two of which are shown in Figure 1 arranged in parallel. Thus, the variable capacitor 5, 55 is connected across the outlet end of the conductor screens 3, 17 and may be varied to tune the heating circuit to resonance at the operating frequency of a suitable high frequency power source, such as a vacuum tube oscillation generator (not shown) operating at radio frequency. The output of the generator may be connected to the heating circuit by means of a concentric transmission line 61 the outer conductor of which is connected directly to the grounded screen 3 by means of a conductive strap 63, and the inner conductor of which is connected by means of a conductive strap 65 and the strap 45 of suitable impedance to the grounded screen 3.

The fresh, moisture laden articles 21 are placed on the moving belt 23 at the right hand end thereof, as seen in Figures 1, 2, or at the left hand end as seen in Figures 5 and 7, and are advanced thereby between the elongated heating conductors 3 and 17 at a suitable speed depending upon such factors as the nature of the material of the articles 21, the moisture content therein, the applied voltage, the frequency of the electric field, etc. In one particular installation in which the screening 17 was about twelve inches wide and eight feet long and was disposed about a half inch above the tops of the wet rayon "cakes" to provide a small air-gap therebetween, and where the power was supplied to the heating circuit at a frequency of about 24 megacycles per second, the belt was advanced at a rate of about three inches per minute. In the absence of the variable inductor 39, 41, a system as above described would have a voltage distribution along the length of the heating conductors 3, 17 approximately as shown by the solid line E₁ in the curve of Figure 6, and would heat the wet rayon cakes relatively rapidly to a point approximately half way along the length of the screening 17 in the direction of travel of the articles 21. This point is marked A, A in Figures 5 and 6 and is the point (hereinafter referred to) at which the variable inductor 39, 41 is connected across the heating conductors 3, 17. By the time the articles 21 have reached this

5

point, a sufficient amount of moisture has been expelled therefrom to make them fairly dry, so that the power factor thereof has been decreased considerably. Hence, it becomes rather difficult to put more power into the drying articles at the applied voltage E_1 . By adding the variable inductor 39, 41 as described above, the voltage distribution along the length of the heating conductors 3, 17 becomes more nearly like that shown by the dash line E_2 of Figure 6, the portion to the left of the point A, A dropping somewhat and the portion to the right of the point A, A increasing very sharply. This results from the fact that the inductor 39, 41 drains off some of the current which would normally flow along the whole length of the main heating conductor network 3, 19, 17. It is apparent, then, that the voltage increases gradually at a low rate from the wet or entrance end of the heating conductor network up to the point A, A, and thereafter increases at a much higher rate. Thus, the effectiveness of the electric field is increased beyond the point A, A in the direction of travel of the articles 21 so that proper, continued drying of the leading articles on the belt 23 will be maintained and the power is kept approximately equal in all of the articles 21. It will be apparent, therefore, that uniform, progressive drying of all of the articles 21 will be obtained, the load on the generator will be practically uniform at all times, and the drying process can be carried out in a continuous manner regardless of the number of articles between the heating electrode portions 3, 17 at any time.

In Figure 4, I have shown a slight modification of the apparatus embodying my present invention. In this form of apparatus, the inductor winding 19, again shown as a partial turn, is connected between the screens 3 and 17 in proximity to the inlet end of the screen 17. The inductor 19 may, of course, comprise a winding of one or more turns, as may be found necessary. Instead of arranging the variable inductor 39, 41 as in Figures 1 and 2, the form of the invention shown in Figure 4 employs a substantially U-shaped inductor loop 71 which is slidably received in a pair of conductive sockets or sleeves 73 and 75, the former connected to the grounded screen 3 and the latter connected to the screen 17.

In another modification, shown diagrammatically in Figure 7, the fixed inductor loop 19 is connected across the inlet or "wet" end of the conductor screens 3, 17, and the variable inductor 39, 41 or 71, as the case may be, may also be made slidable along the screens 3 and 17 to locate the points A, A at any suitable distance from either end of the screen 17. This is shown diagrammatically by the slidable arrow heads at the terminals of the variable inductor in Figure 7. The voltage distribution along the length of the conductor screens 3, 17 is again made to change from a low rate of increase to a high rate of increase at any desired point along the length of the heating conductor network by merely moving the variable inductor in one direction or the other therealong. Connection to the power generator may be made by means of a low impedance winding 77, as shown in this figure.

From the foregoing description, it will be apparent that I have provided an improved method of and apparatus for heating dielectric articles the power factors of which change appreciably during the heating process, as in the case of wet articles which are being dried. Although I have shown and described several embodiments of my invention, it will undoubtedly be apparent to those

6

skilled in the art that other modifications thereof and changes in the ones described above are possible. I therefore wish it to be understood that I do not consider myself limited merely to the precise forms herein described and/or shown in the accompanying drawings.

I claim as my invention:

1. In electrical heating apparatus for heating moisture laden, dielectric articles the power factor of which changes as a function of the moisture content, the combination of a pair of elongated, electro-conductive members spaced from each other for the reception of said articles therebetween in energy transfer relation with respect thereto, means for connecting said members to a source of alternating electrical potential whereby to establish between said members an alternating electric field for producing in the articles between said members dielectric losses to thereby heat said articles and expel the moisture therefrom, said connecting means including a variable inductor device comprising a pair of elongated parallel tubular conductors in spaced relation to each other extending along said pair of conductive members and being connected each with one of said conductive members between the ends thereof, a conductive bridge element shunting said parallel tubular conductors and being movable therealong to vary the inductance provided by said conductors, and an input connection for said alternating electrical potential at one end of said tubular conductors, means for progressively advancing said articles along the length of said members, and means for establishing between said members along the lengths thereof progressively varying voltages which vary at at least two different rates, said last named means including an inductance element connected between said pair of elongated electroconductive members between points intermediate between the ends thereof and a variable capacity device including a ground screen and a movable conductor connected each with one of said pair of elongated electroconductive members and being relatively movable whereby the capacity between said conductive members is varied.

2. In electrical heating apparatus for heating moisture laden, dielectric articles the power factor of which changes as a function of the moisture content, the combination of a pair of elongated, electro-conductive members spaced from each other for the reception of said articles therebetween in energy transfer relation with respect thereto and having inlet and outlet ends, means for progressively advancing said articles along the length of said members from said inlet end to said outlet end, means for connecting said members to a source of alternating electrical potential whereby to establish between said members an alternating electric field for producing in the advancing articles between said members dielectric losses to thereby heat said articles and gradually expel the moisture therefrom as they are advanced whereby to gradually vary the power factor thereof, said connecting means including a variable inductor device comprising a pair of elongated parallel tubular conductors in spaced relation to each other extending along said pair of conductive members and being connected each with one of said conductive members between the ends thereof, a conductive bridge element shunting said parallel tubular conductors and being movable therealong to vary the inductance provided by said conductors, and an input connection for said alternating electrical potential at one end

of said tubular conductors, and reactance means connected across said members at a point intermediate the length thereof for so altering the voltages across said members at successive points along the length thereof as said articles are advanced that said voltages will progressively vary at a relatively low rate between said inlet end and said point and at a higher rate between said point and said outlet end to thereby correspondingly alter the effectiveness of said field along the length of said members and thus compensate for changes in said power factor, said reactance means including an inductance element connected between said pair of elongated electroconductive members between points intermediate between the ends thereof and a variable capacity device including a ground screen and a movable conductor connected each with one of said pair of elongated electroconductive members and being relatively movable whereby the capacity between said conductive members is varied.

3. High frequency electrical heating apparatus comprising in combination a pair of elongated electroconductive screen members spaced one from the other in substantially parallel relation for the reception of articles to be heated therebetween under the influence of an electrostatic field, a pair of elongated parallel tubular conductors extending partially along and in spaced relation to each other and to said first named electroconductive members, a conductive strap connection intermediate between the ends of one of said tubular conductors and a point intermediate between the ends of one of said electroconductive members, a second strap connection between the ends of the other of said tubular conductors and the other of said electroconductive members intermediate between the ends thereof, an adjustable shunting conductive bridge element connecting said tubular conductors and to provide

therewith a variable inductance device, high frequency power input connections between one of said electroconductive members and one end of the tubular conductor which is strap-connected thereto, a fixed inductance element connected between said electroconductive members between points thereon intermediate between the ends thereof, and variable capacity means connected between the outlet ends of said electroconductive members with respect to the movement of articles to be heated therebetween, whereby a predetermined voltage distribution characteristic is imparted to said apparatus for the progressive heating of moisture laden articles the power factor of which changes as a function of the moisture content thereof.

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