Feb. 2, 1954 J. G. BERNARD 2,668,226

HIGH-FREQUENCY ELECTRONIC DRYING APPARATUS

Filed June 22, 1950

2 Sheets-Sheet 1

Fig. 1.

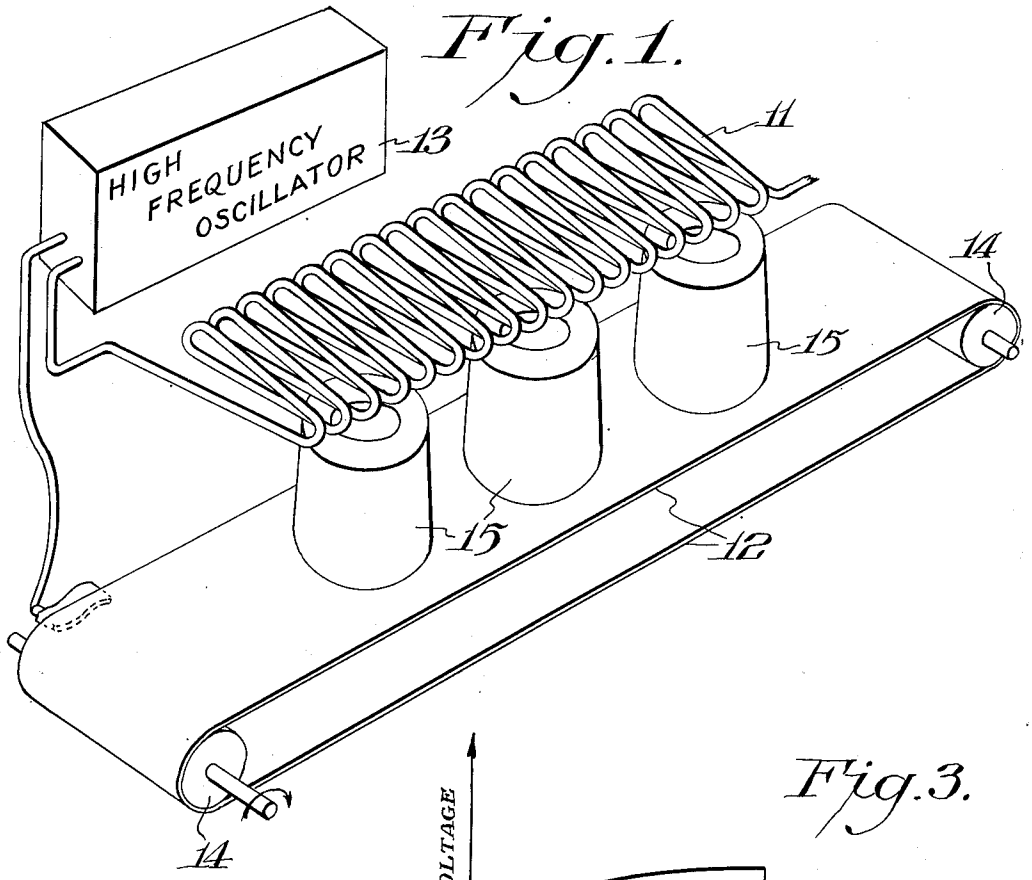
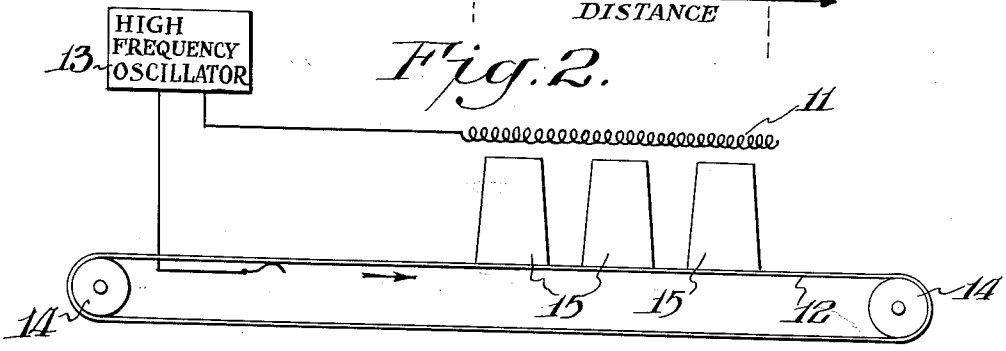


Fig. 3.

Fig. 2.



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Fig. 5.

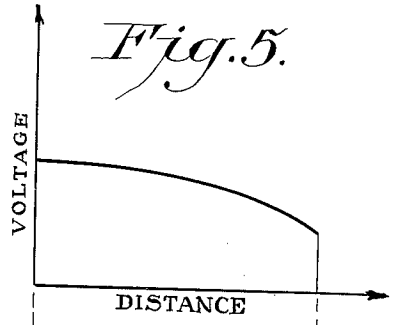


Fig. 4.

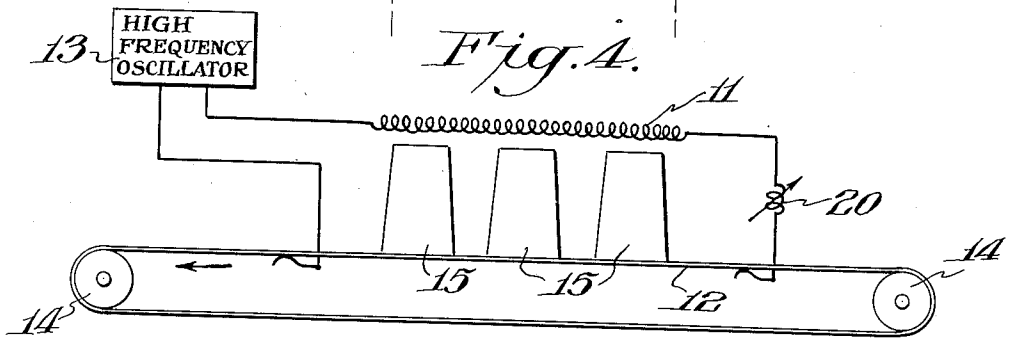


Fig. 7.

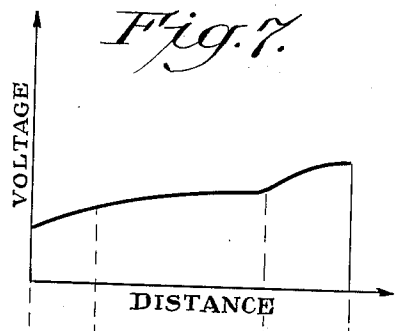
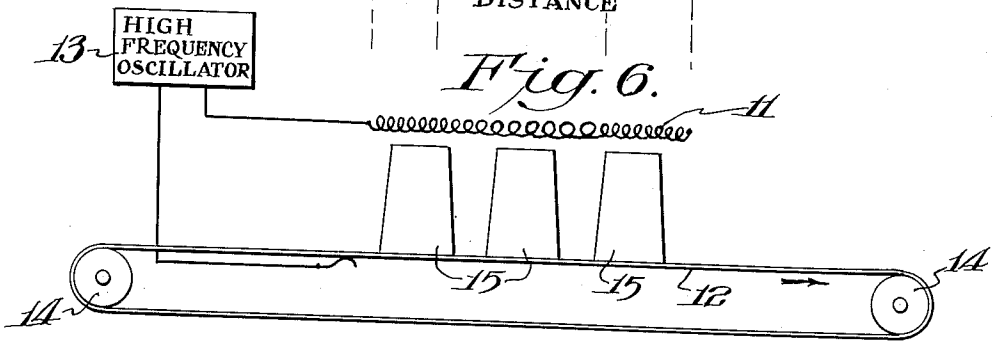


Fig. 6.



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HIGH-FREQUENCY ELECTRONIC DRYING APPARATUS

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1 Claim. (Cl. 219—47)

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This invention relates to high frequency electronic apparatus for continuously heating dielectric materials, and is more particularly concerned with improved means for applying a high frequency electrical field for drying wet material as the material is conveyed through an electronic dryer.

It is frequently necessary to dry materials in a bulky form into which externally applied heat penetrates quite slowly. The rate of drying may be greatly accelerated by heating the material internally, which can be accomplished by placing the material in a high frequency alternating electrical field. Under such conditions a dielectric material will absorb power from the field and become heated throughout. The heat developed in the material will be directly proportional to a property of the material known as the "loss factor," to the frequency of alternation, and to the square of the intensity of the electrical field.

High frequency electrical power is highly effective, for example, in drying rayon yarn cakes or packages produced by the pot or bobbin spinning methods. However, the loss factor of many materials, of which rayon is one, decreases rapidly as the material dries. It is therefore necessary to increase the field intensity by increasing the voltage as such material dries in order to maintain a desirable rate of drying. This is a problem which becomes especially troublesome when it is desired to heat materials containing different percentages of moisture simultaneously, as when wet rayon cakes are advanced continuously on a conveyor through a drier and are to be dry by the time the cakes have passed through the drier.

High frequency electronic driers have been designed which provide a rapid increase in field voltage after material being dried has reached an intermediate point in its passage through the drier. One such arrangement involves the use of a heating unit comprised essentially of an inductor constituted by a pair of elongated, opposed electrodes spaced from each other to receive therebetween the material to be heated and having an inductor connected thereacross in proximity to the inlet end. To tune the circuit there is provided a variable capacitor which is connected across the other end of the electrodes. At a point intermediate the ends of the inductor electrodes, a second inductor is connected across the electrodes. With this arrangement the voltage will increase at a relatively low rate from the inlet end to the intermediate point, and the voltage will then increase at a relatively high rate

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from the intermediate point to the outlet end of the electrodes.

There are two major disadvantages with the arrangement described. One of these is that the tuning capacitor uses up power and lowers the efficiency of the system. A circuit has been proposed for overcoming this deficiency in which one of the two electrodes is divided near the middle into two sections, one section being inductive and the other capacitive in operation. The two sections of divided electrode are connected at the point of division by a variable inductor, one lead from a source of high frequency alternating electrical power is connected to the inductive section of the divided electrode at the point of connection of the above inductor, and the other power lead is connected to an intermediate point of the undivided electrode. A second variable inductor is connected across the ends of the two electrodes in the inductive section, this being the inlet end where the wet material is introduced. By suitable choice of constants, and by adjusting the variable inductors, the circuit can be tuned into resonance without the necessity of using a power consuming tuning capacitor.

With this arrangement there will be an abrupt increase in voltage in passing from the inductive section to the capacitive section, but the voltage will rise only by a relatively small amount between the ends of these respective sections. Hence the voltage is not a continuous function of the distance along the electrode. In both this case and the arrangement described previously the voltage is a discontinuous function of electrode distance, in that there are abrupt changes in the rate of voltage increase. On the other hand, the loss factor of a material such as rayon varies as a continuous function of the moisture content, so the voltage should vary in a similar manner with distance along the path of travel between the electrodes, if the material is to be kept drying at the optimum rate as it is conveyed along. A disadvantage of the circuit arrangements discussed is that the voltage cannot be varied to provide a preferred rate of heating in all positions in the field.

To vary the voltage continuously along the distance traveled, electrodes in the form of long straight conductors could be used. The voltage variation along such conductors would be approximately sinusoidal, and the distance between maximum and minimum voltage would be approximately one fourth of the wave length corresponding to the frequency of electrical oscil-

lation. To obtain appreciable variation, then, such an electrode would have to be nearly one quarter wave length. At frequencies commonly used for drying moist dielectric materials, such lengths are often uneconomical of space and too great for practical application.

It is an object of the present invention to provide an improved high frequency electronic apparatus of a size sufficiently small for practical application for continuously drying moist dielectric materials, provided with means for varying the field voltage as a continuous function of the distance of travel through the heating zone of the drier. A further object of the invention is to provide such an apparatus in which the field voltage increases with distance of travel through the field in a continuous manner and as rapidly as desired to two or more times the supply voltage. Other objects of the invention will appear hereafter.

The objects of this invention are accomplished by an apparatus for continuously drying moist dielectric materials which comprises conveying means for continuously advancing material to be dried through a heating zone and a pair of elongated metallic electrodes connected to a source of high frequency electrical oscillations and arranged on opposite sides along the path of travel of the material to create a high frequency alternating electrical field between the electrodes suitable for heating the material, one or both of the electrodes being formed in the shape of a flattened helix of multiple turns to provide a relatively rapid variation of field voltage as a continuous function of distance of travel through the field.

The voltage along an electrode thus formed into a flattened helix will vary sinusoidally similar to the variation along the long straight conductor previously described. The distance between voltage maxima and minima, however, can be made as small as desired, and can be made considerably smaller than one quarter wave length by properly spacing the turns of the helix. The "electrical length" of such an electrode is therefore larger than its physical length. Electrical length is here defined as the physical length of a long straight conductor having essentially an equivalent voltage distribution. The electrical length increases as the physical length is increased, and/or as the turn spacing is decreased.

For most applications the source of high frequency oscillations is connected across the electrode ends at the inlet to the heating zone, the outlet ends of the electrodes are left open, and the electrical length of the electrodes is not more than one-quarter wave length at the operating frequency. Under these conditions the field voltage will increase from that of the source to a maximum at the open outlet ends which may be two or more times that of the source, depending on the electrical length of the electrodes. The rate of increase and the shape of the voltage versus distance-of-travel curve is determined by the number and spacing of the turns of the helix to which the electrode is formed. A turn spacing may be provided which changes gradually from a relatively wide spacing to a relatively close spacing, to cause the field voltage to increase at an increasing rate with distance.

For some applications it may be desired to have the field voltage decrease from the ends connected to the source of high frequency oscillations, instead of increasing as described above. In this case it is merely necessary to connect an inductor across the other ends of the electrodes. This may be a variable inductor to permit tuning. It may be desired to have the field voltage decrease to a minimum and then increase to a maximum. This may be accomplished by making the electrical length of the electrodes greater than one-quarter wave length by increasing the number of turns of the flattened helix. For a fixed length of heating zone the increased number of turns can be spaced more closely in achieving the increase in electrical length.

The invention will now be described in connection with the accompanying drawings, wherein like reference numerals designate corresponding parts.

Fig. 1 is an elevation in perspective of an apparatus for practicing the invention,

Fig. 2 is a diagrammatic view of the apparatus shown in Fig. 1,

Fig. 3 is a graph of the type of field voltage distribution obtained with the arrangement shown in Fig. 2,

Fig. 4 is a diagrammatic view of a different circuit arrangement from that shown in Fig. 2,

Fig. 5 is a graph of the type of field voltage distribution obtained with the arrangement of Fig. 4.

Fig. 6 is a diagrammatic view of an apparatus similar to that of Figs. 1 and 2, but with the electrode modified by varying the spacing of the turns, and

Fig. 7 is a graph of the type of field voltage distribution obtained with the arrangement of Fig. 6, showing the variation in rate of increase of voltage with distance which results.

Referring to Figs. 1 and 2, an electrode 11, of an electrically conductive material, is formed in the shape of a flattened helix of multiple turns and spaced opposite and parallel to another electrode 12. This second electrode could be similar to the first, but it is simpler to have this electrode 12 also serve as a support and conveyor for material to be dried. The electrodes are connected to the terminals of a source of high frequency electrical energy, indicated diagrammatically at 13, a vacuum tube oscillator being suitable. The combined electrode and conveyor 12, an endless belt of electrically conductive material, passes around rollers 14, which support it at the ends of travel. Material to be dried, here shown as rayon cakes 15, are placed on the left or wet end of the belt 12, advanced to the right beneath the electrode 11, where the material is heated by the field of high frequency electrical energy, and is then removed from the right or dry end of the belt 12 when sufficiently dry.

As shown in Fig. 3, the field voltage with this arrangement increases as a continuous function of the distance from the end of the electrode connected to the high frequency oscillator. When the circuit is modified by connecting a variable inductor 20 across the open ends of the electrodes 11 and 12, as shown in Figs. 4 and 5, the field voltage decreases as a continuous function of the distance from the end of electrode 11 which is connected to the oscillator. With this arrangement the material to be dried should be conveyed from right to left, making the end connected to the oscillator the dry end.

With either of the arrangements discussed in connection with Figs. 1 to 5, the shape of the voltage versus distance curve may be modified greatly by changing the number and spacing of the turns of electrode 11. In Figs. 6 and 7 the

effect is shown of spacing the turns closely near the ends and relatively wide apart in the central portion. The voltage curve rises rapidly at first, then gradually, and finally rapidly again. While it might be difficult to fit a mathematical expression to this curve, it is obviously a continuous function, there being no abrupt changes in the voltage. In this manner a field voltage distribution can be arranged to provide any desired optimum heating cycle for materials being conveyed through the heating zone at a uniform rate in continuous drying. As a result, material can be dried more uniformly and quickly, and the apparatus can be made as compact as desired for this purpose.

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited to the specific illustrations given except as defined in the appended claim.

What is claimed is:

In an electronic drier for drying moist dielectric material including conveying means for continuously advancing material to be dried through the drier and a pair of elongated metallic electrodes connected to a single source of high frequency electrical oscillations and arranged on opposite sides along the path of travel of the material through the drier to create a high frequency electrical field between the electrodes for drying the material, the improvement which comprises arranging one of said electrodes in the shape of a

flattened helix having multiple turns spaced more closely in one part of the helix than in another part and forming a rectangularly shaped, generally zig-zag pattern parallel to said path of travel of the material adapted to provide a relatively rapid increase of field voltage at a controlled rate between said electrodes as a continuous function of the distance of travel of the material to compensate for decreasing loss factor of the material as the material dries.

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