July 30, 1946. E. T. HSU 2,405,037

HIGH FREQUENCY HEATING APPARATUS

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Fig. 1.

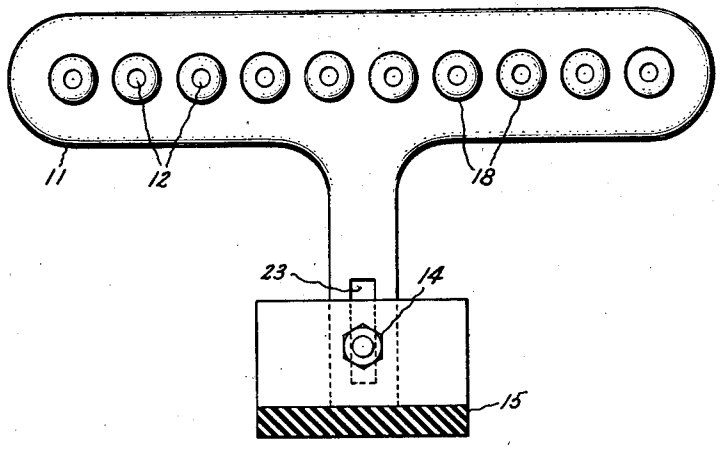
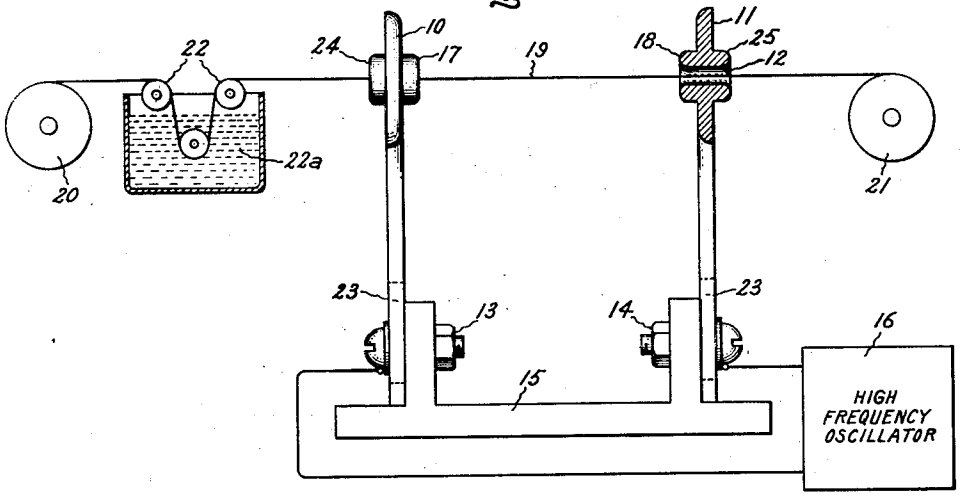



Fig. 2.




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Fig. 3.

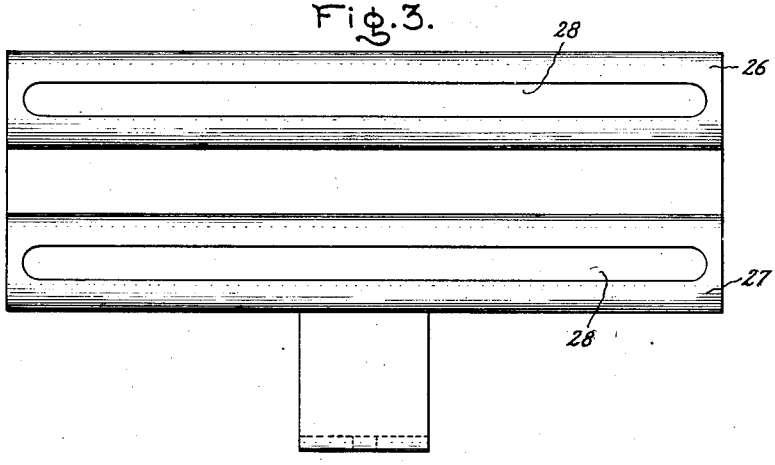



Fig. 4.

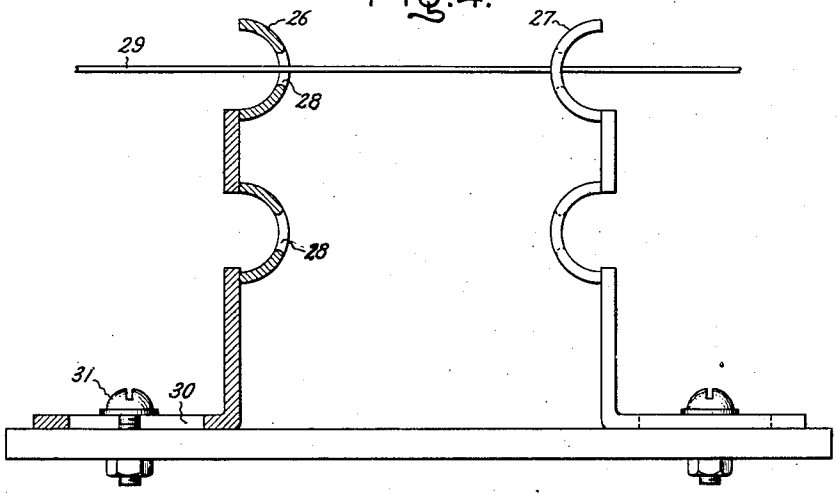
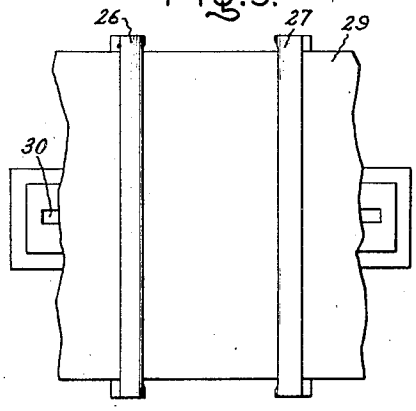



Fig. 5.




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# UNITED STATES PATENT OFFICE

2,405,037

## HIGH-FREQUENCY HEATING APPARATUS

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Application March 17, 1944, Serial No. 526,925

5 Claims. (Cl. 219—47)

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My invention relates to high frequency electric heating apparatus, more particularly to high frequency induction heating apparatus for continuously heating elongated or strip dielectric material, and has for its object a simple, reliable and efficient heating apparatus of this type.

More particularly, my invention relates to heating apparatus for heating elongated dielectric materials having relatively small cross sections, such as in the form of cord, yarn, thread or thin strips. The materials may be organic or inorganic, such as cotton, wool, cellulose plastic, rubber, glass, etc.

In carrying out my invention in one form, I pass the materials continuously through an electrostatic field set up between two electrically conducting electrodes which are connected to the terminals of a source of high frequency electric current supply. More particularly, I provide openings such as slots or apertures in the electrodes through which the material is passed so as to extend between the electrodes. I also provide projections around the openings on the sides of the electrodes adjacent each other for concentrating the electrostatic field along the length of the material whereby the material is very efficiently heated throughout by electrostatic induction, i. e., dielectric loss or molecular friction.

For a more complete understanding of my invention, reference should be had to the accompanying drawings, Fig. 1 of which is the front elevation view partly in section of an electrode embodying my invention; Fig. 2 is a partly diagrammatic side elevation view of heating apparatus for threadlike materials embodying my invention; Fig. 3 is a view similar to Fig. 1 but showing the electrodes provided with slots for the passage therethrough of strip material; Fig. 4 is a partial view similar to Fig. 2 showing a setting apparatus embodying the electrodes shown in Fig. 3; while Fig. 5 is a plan view of Fig. 4 to a reduced scale.

Referring to Figs. 1 and 2 of the drawings, in one form of my invention I provide two plate shaped electrodes 10 and 11 each of which is provided with a transversely extending aperture 12, which electrodes are suitably secured as by bolts 13 and 14 to a support 15 made of a suitable electrically insulating material such as rubber or porcelain. The plates made of suitable electrically conducting material, such as copper or aluminum, are suitably spaced apart and are electrically connected to the terminals of a suitable high frequency oscillator 16, preferably of the electric discharge device type.

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An important feature of my invention is the provision of annular or tubular electrostatic field concentrating projections 17 and 18 on the electrodes around the apertures 12. As shown, these projections are in effect tubular extensions of the electrodes around the apertures. All edges of the tubular extensions should be rounded and the projections may be substantially hemispherical in shape. These projections serve the purpose of directing and concentrating the electrostatic field along the length of the threadlike article 19 extending between the two electrodes so that this length of the article is in the field and surrounded by the field and is thereby heated quickly by the electric energy dissipated as heat within the body of the article itself by dielectric loss. As shown, the thread 19 is passed from the roll 20 to the roll 21 by means of suitable driving means (not shown) for the rolls. From the roll 20, the thread is directed by a series of rolls 22 downward through a suitable impregnating liquid 22a, such as a rubber or cellulose plastic material which liquid either coats or impregnates the material, such as cotton, of the thread. In passing between the two plates, the thread is heated to a temperature high enough to vulcanize or set the material with which it is treated. A suitable tension is maintained on the thread so as to hold it, as shown, in spaced relation with the walls of the holes through the electrodes. The thread is maintained in a central position with respect to the holes, as shown.

Any suitable spacing between the electrodes and frequency of the current supplied to the electrodes may be used although the spacing between the electrodes and the size of electrodes are dependent upon the frequency used. In a typical heater the two electrodes were spaced apart approximately two inches and current was supplied to them having a frequency of approximately 40,000,000 cycles a second and a voltage of approximately 2500.

I contemplate that each electrode may be provided with a plurality of holes 12, as shown in Fig. 2, whereby a plurality of strands of material may be passed between two electrodes having similar apertures. As shown in Fig. 1, the electrode is elongated horizontally in the plane of the drawing and provided with a single row of holes which may be of different sizes. Obviously, any suitable arrangement of the holes may be used. The number of holes, each with its own field concentrating projection as previously described, will of course be dependent upon the size of the electrode, and the size of the electrode

in turn is dependent upon the frequency of the electric current supplied to the electrodes. When a plurality of holes are used, it is important that the electrodes be maintained in parallel relation with each other so that electrostatic fields of uniform strength are maintained between the projections 17 and 18 of each opposed pair.

For purposes of adjustment in a vertical direction, I have shown the electrodes provided each with a vertical slot 23 through which its clamping bolt extends, whereby by loosening the bolt the electrode can be adjusted vertically with respect to the thread so as to bring the thread in the center of the hole.

I have also shown projections 24 and 25, similar to the projections 17 and 18, on the opposite sides of the electrodes, i. e., on the outer non-adjacent sides, although these projections are not absolutely necessary because most of the lines of force concentrate between the electrodes.

In the modified form of my invention shown in Figs. 3, 4 and 5, the electrodes are provided with opposite semi-cylindrical portions 26 and 27, each of which is provided with a slot 28 through which the strip material 29 is passed continuously. Thus, as shown, the convex sides of the semi-cylindrical portions 26 and 27 are adjacent each other, whereby they form projections to direct and concentrate the electrostatic flux into the strip 29. In this modified form of my invention, the lower ends of the electrodes are provided with lateral extensions, horizontal as seen in the drawing, having a slot 30 through which extends the clamping bolt 31. By loosening the bolt, the electrode can be adjusted with respect to the other electrode, thereby to vary the spacing between them and also bring them into parallel relation with each other.

The strip material 29 of this form of my invention may, as described in connection with Figs. 1 and 2, be made from a fibrous material which is impregnated with a rubber or cellulose plastic material and then passed between the plates and heated to set the rubber or plastic, or it may be a rubber or plastic strip.

As with the form shown in Figs. 1 and 2, the slotted electrodes of Figs. 3, 4 and 5 can be provided with any suitable number of slots for the simultaneous heating of a plurality of strips. As shown, each electrode is provided with two slots whereby two strips can be heated.

It will be understood that the annular projecting portions 17 and 18 are the effective portions of the electrodes. When a single strand or thread is to be heated any suitable electrically insulating support may be provided for these annular portions, the plate portions being omitted. Moreover the openings or apertures in the electrodes may be in the form of slots so that the material may be initially moved sidewise into the openings without threading through the openings.

While I have shown a particular embodiment of my invention, it will be understood, of course, that I do not wish to be limited thereto, since many modifications may be made and I, therefore, contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. Electric heating apparatus comprising a pair of spaced apart plate electrodes, an electrostatic field concentrating projection on each of said electrodes provided with a central aperture, said projections being oppositely disposed with respect to each other on adjacent sides of said electrodes, and electric connections for supplying high frequency current to said electrodes thereby to produce a high frequency electrostatic field between said projections and in an article to be heated extending through said apertures between said projections.



2. Electric heating apparatus for the continuous heating of elongated dielectric material comprising means for moving the material to be heated along a predetermined path, a pair of electrodes spaced apart along said path of movement, each of said electrodes being provided with an opening through which said material extends, a projection on each of said electrodes on the side adjacent the other electrode and surrounding the opening in said electrode, and electric connections for supplying a high frequency current to said electrodes thereby to produce a high frequency electrostatic field between said projections and in said material whereby said material is heated.

3. Electric heating apparatus for the continuous heating of a thread of dielectric material comprising two electrodes made of electrically conducting material, a substantially annular projection on each of said electrodes provided with a central longitudinal aperture extending through the electrode, said annular projections being secured to adjacent sides of said electrodes, a support on which said electrodes are secured in electrically insulated spaced relation with each other, and electric connections for supplying a high frequency current to said electrodes having a frequency of at least substantially 40 million cycles a second thereby to produce a high frequency field between said projections and in a thread of dielectric material passed through said apertures.

4. Electric heating apparatus for the continuous heating of threads of dielectric material comprising two plate electrodes made of electrically conducting material, each of said electrodes being provided with a plurality of apertures, electric field concentrating projections on each of said electrodes surrounding each of said apertures on the side adjacent the other electrode, an electrically insulating support on which said electrodes are secured in a predetermined spaced relation with each other, and electric connections for supplying a high frequency current to said electrodes thereby to produce a high frequency field between said projections and in a plurality of threads of dielectric material passed through pairs of opposite apertures in said plates.

5. Electric heating apparatus for the continuous heating of elongated strip dielectric material comprising two electrodes made of electrically conducting material, a substantially semicylindrical portion on each of said electrodes provided with a central longitudinal slot, the convex sides of said semicylindrical portions being adjacent each other, a support made of electrically insulating material on which said electrodes are secured in a predetermined spaced relation with each other, and electric connections for supplying a high frequency current to said electrodes having a frequency of at least substantially 40 million cycles a second thereby to produce a high frequency field between said semicylindrical portions and in a strip of dielectric material passed through said slots.

EUGENE T. HSU.