Sept. 12, 1950 W. N. PARKER 2,521,993

RADIO-FREQUENCY HEATING ELECTRODE FOR FILAMENTARY MATERIAL

Filed April 30, 1948

Fig. 1

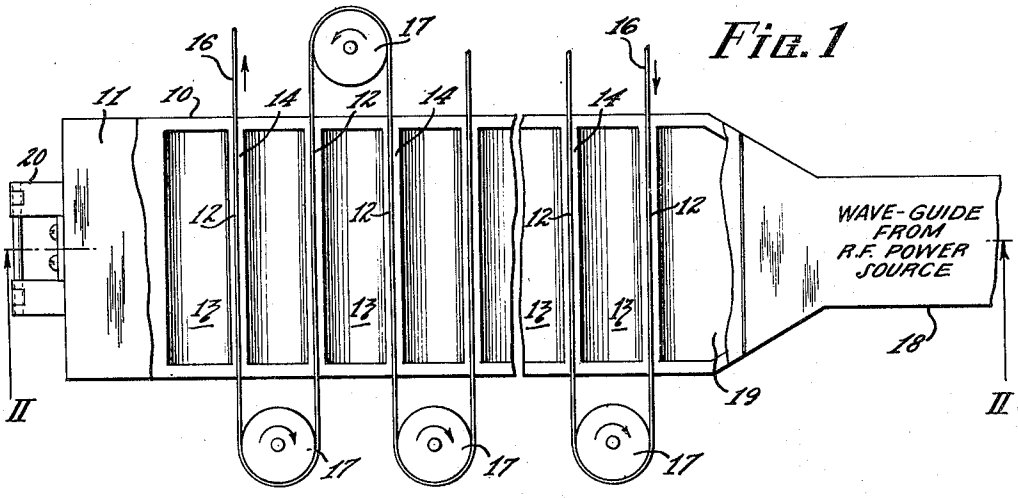


Fig. 2

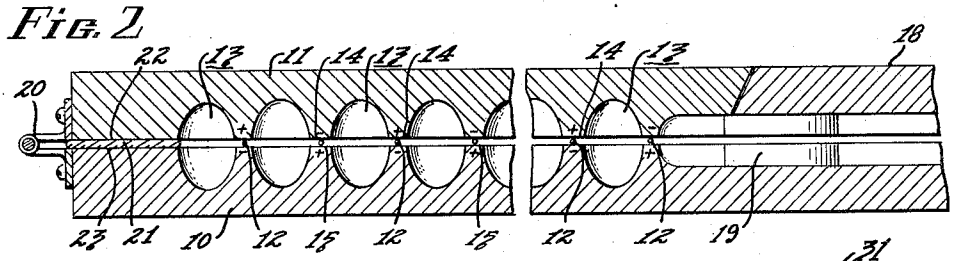


Fig. 3

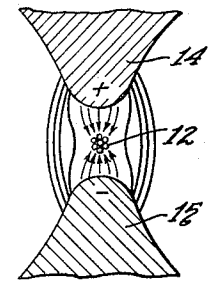
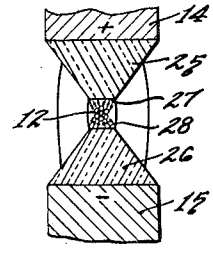


Fig. 4



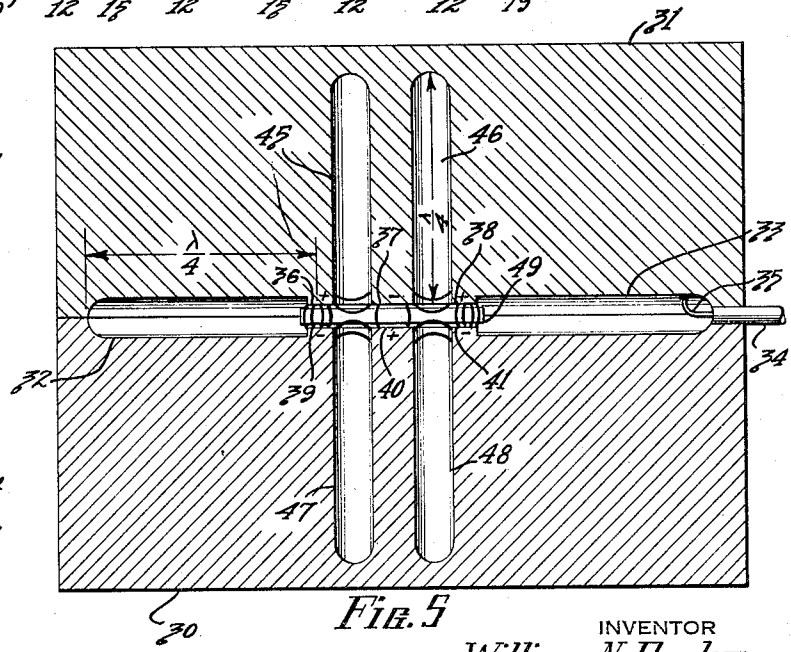


Fig. 5

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RADIO-FREQUENCY HEATING ELECTRODE FOR FILAMENTARY MATERIAL

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13 Claims. (Cl. 219—47)

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The present invention relates to an applicator for R.-F. heating, and has for its primary object to provide an improved method and means for applying R.-F. power for heating long lengths of dielectric fibers or bundles of fibers, such as continuous cords or threads, rayon yarn, and the like.

It is also an object of the present invention, to provide an improved applicator for R.-F. heating of dielectric materials in continuous long lengths, which provides a relatively long heating path in a short physical space, through the medium of tuned resonant cavities and associated pairs of elongated electrodes, the series of cavities functioning as a single oscillating system several wavelengths long, through which the said materials are passed in a re-entrant multiple-pass path.

In accordance with the invention, a series of pairs of opposed elongated electrodes is arranged in spaced parallel relation along a common plane and are connected by interposed resonant cavities providing high intensity R.-F. fields between the opposed faces of each pair of electrodes, and a continuous cord or thread of dielectric material to be treated, is passed continuously along a path which winds back and forth between the successive pairs of electrodes. In this manner, the thread or cord of dielectric material is drawn continuously through the high intensity fields between opposing pairs of electrodes in sequence, so that the heating takes place along a comparatively long path, while the equipment involved may occupy a relatively small physical space.

The problem of heating small cross sectional bodies of dielectric material, such as rayon thread or cord and the like, is difficult of solution in that a frequency of the order of several hundred megacycles must be used, which ordinarily limits the physical size of the applicator electrodes. If the thread is moved continuously past the applicator electrodes, a relatively low velocity must be used in order to secure sufficient heating at available applicator voltages. Furthermore, in the past, the shape of the applicator electrodes has been such that a considerable portion of the electric flux did not pass through the material to be heated, with resultant lowered effective heating.

It is, therefore, a still further object of the invention, to provide an improved R.-F. applicator for effectively heating continuous cords or threads of dielectric material, which provides a plurality of pairs or sets of electrodes in relatively close spaced relation to each other and coupled by electrically resonant cavities responsive to the R.-F. frequency of the power supply providing

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the heating energy, together with means for drawing the thread or cord continuously between the opposing pairs of electrodes in sequence, thereby effectively to provide an elongated heating path within a small space occupied by the applicator.

It is an object of the invention furthermore, to provide an applicator for R.-F. heating embodying elongated electrodes in pairs, the opposing faces or tips of which are of improved construction and shape for more effectively applying R.-F. heating to thread-like bodies of dielectric material to be heated when placed between said electrodes.

It is also a still further object of the invention, to provide an improved applicator system for applying R.-F. power for heating continuous long lengths of dielectric material, such as rayon threads and cords, which provides an elongated heating path comprising substantially parallel transverse sections spaced along the length of the applicator and connected by resonant cavities constituting a single oscillating system a plurality of electrical wavelengths long, responsive to the frequency of the power supply, and which may readily be threaded or loaded for operation in minimum time and with minimum effort.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawing, in which:

Figure 1 is a plan view of an R.-F. heating applicator embodying the invention,

Figure 2 is a cross sectional view of the applicator of Figure 1, taken on section line II—II,

Figures 3 and 4 are fragmentary views in cross section, of a portion of the apparatus of Figures 1 and 2 showing modifications of the electrode structure thereof, and

Figure 5 is a cross sectional view in elevation of an R.-F. heating applicator embodying the invention, being a modification of the form shown in Figures 1 and 2.

Referring to Figures 1 and 2, the applicator body comprises a pair of elongated spaced plates such as an elongated base plate 10 of conducting material and a cover plate 11 of similar conducting material located one above the other in slightly spaced relation as indicated more clearly in Figure 2, to permit the passage therebetween of a series of parallel spaced dielectric cord elements 12 of any desired size constituting the

work to be heat treated. The opposed faces of the base and the cover plate are provided with opposed grooves in pairs jointly forming a series of spaced resonant cavities 13, and similarly spaced pairs of upper and lower electrodes 14 and 15, respectively, between which the cord elements pass as shown both in Figures 1 and 2. In general, the arrangement is such that the pairs of elongated spaced plates 10 and 11 are provided with complementary substantially parallel grooves along adjacent faces providing a series of spaced resonant cavities and a series of spaced pairs of high voltage electrodes alternately disposed therebetween. It will be noted that the transverse width of the applicator body is such that a considerable length of each cord section 12 is included between the electrodes.

While the cord sections or work 12 may move or be carried between the electrodes transversely in parallel or in any other suitable manner, it is at present preferred to consider them as joined in one continuous piece of material to be treated, such as cord 16—16 of Figure 1, for which the elements 12 form a part. As shown in Figure 1, the cord 16 is looped back and forth transversely through the applicator between the electrodes in a continuous path of considerable length, being passed over idler wheels 17 at each side of the applicator to reverse the direction of movement of the cord. Thus any length of material may be treated continuously.

The electrodes 14 and 15 in pairs and the resonant cavities are to be arranged in a consecutive series and are supplied with energy from a wave guide 18 coupled to one end of the series through a matching wave guide 19. The wave guide may be coupled to any suitable source of high frequency R.-F. power (not shown). The cavities may each be an electrical half wavelength long in a longitudinal direction through the applicator, and are arranged to provide R.-F. high voltage points at the tips of the electrodes with the relative instantaneous polarities shown.

A strong concentrated electrical field results between each pair of electrodes which heats the dielectric material to be treated as it is drawn continuously in a path which winds back and forth through the pairs of electrodes. The heating path, therefore, extends transversely through the applicator, and is re-entrant from side to side, being substantially continuous and of comparatively long total effective length. At the high frequencies employed, the R.-F. power may be coupled to the series of resonant cavities by any other suitable means, although the wave guide arangement shown is at present preferred.

In order to permit loading or threading of the material through the applicator and between the electrodes, and also for cleaning and inspection, the applicator is arranged to be opened. In this case, the upper portion or cover plate is hinged to the base plate as indicated at 20 at the opposite end from the wave guide, and a suitable bypass capacitor is provided across the hinged end by providing a plate of dielectric material 21 between opposite faces 22 and 23 of the two portions of the casing as shown in Figure 2. The bypass capacitor section may constitute a quarter wavelength line section to terminate the series of resonant cavities.

From the foregoing description it will be seen that a series of elongated spaced electrode pairs are provided in relatively close parallel spaced relation and are coupled by suitable cavities electrically resonant to the R.-F. frequency of the power supply, and that the thread or cord comprising the body of dielectric material to be heated is drawn continuously between the opposing pairs of electrodes in sequence, from the wave guide or power input end to the quarter wave bypass capacitor section, so that the R.-F. heating takes place along a comparatively long path comprising the total of the various lengths 12 of the cord or dielectric body.

In general, therefore, the applicator arrangement is such that a pair of separable conductive plate or body elements provide a series of electrically coupled resonant cavities and a plurality of pairs of spaced electrodes carried by said body elements located in substantially a common plane passing between said elements and through said cavities, and lying each between successive pairs of said cavities to concentrate R.-F. voltage at said electrodes.

The length of the applicator is determined by the number of passes required to include a desired length of the work piece under treatment, and the available power which, in turn, determines the number of cavities and electrodes, while the width of the applicator body preferablly is limited such that the cord sections may be drawn between the electrodes without substantial contact therewith.

The preferred shape of the electrodes, and the relative spacing with respect to a cord section are shown in Figure 3, in which like reference numerals are applied to like parts as in Figures 1 and 2. The enlarged cross section of the electrodes 14 and 15 indicates that for the greatest utilization of the electrical flux, the width and spacing of the pole pieces should not be too large relative to the diameter of the cord or work piece.

In certain cases, to further concentrate the electric field in the moving fibers or work pieces, the pole tips may be provided by specially shaped low-loss dielectric material as indicated at 25 and 26 in Figure 4. In this case, the electrodes 14 and 15 are provided with elongated tips of low-loss dielectric material having relatively narrow opposing faces 27 and 28 on opposite sides of the work piece 12. It will be noted that the R.-F. field is highly concentrated in the construction shown in Figure 3 and even more highly concentrated by the arrangement shown in Figure 4. Most dielectric materials have a dielectric constant greater than that of the surrounding air so that the lines of electric flux tend to pass through the dielectric tips and thus concentrate in the work to be treated.

These dielectric pole tips serve also as insulating means for preventing local heating of the work due to arcing, as might result in case the cord should touch either of the pole pieces. The transverse width of the applicator is less limited through use of such pole tips, thereby permitting longer lengths of the work material to be treated at each pass through the applicator. This feature is also important where considerable moisture is being removed from the cord or work piece and humid chemically active atmosphere may be present.

The effectiveness of the coupling for the different pairs of electrodes, to control the rate of temperature rise or to allow for changes in the electrical properties of the material being treated as it loses moisture, may readily be varied by varying the shape or spacing of the pole pieces.

Also control of heat distribution may be obtained during operation by means of small changes in the frequency of the R.-F. power source.

Because of the relatively close electrical coupling provided by the alternate arrangement of cavities and coupled electrode pairs, the entire series of cavities may function substantially as a single oscillatory system several electrical wavelengths in total length. At the normal operating frequency, which may preferably be of the order of several hundred megacycles, the voltage peaks occur at the pole pieces in the manner shown in Figures 1, 3 and 4.

At a slightly higher frequency, the system of cavities will be somewhat longer electrically, with the result that the voltage peaks will shift slightly toward the cavities near the rear or hinged end of the applicator body. This shift of voltage peaks or maximum voltages will progressively be greater with each step away from the rear or bypass end. In this way the voltage across the pairs of poles nearest the wave guide or input end of the series of cavities may be made nearly zero, while maintaining normal voltage on the poles nearest the bypass.

By this arrangement, furthermore, the work or cord is progressively heated to higher degrees as it progresses in its passage through the applicator. A similar effect may be obtained by using a slightly lower frequency, thereby to follow variations in the material being processed.

While the applicator shown in Figures 1 and 2 is adapted for use at microwave frequencies where actual resonant cavities are practical, it is contemplated within the scope of the invention, to provide means whereby lower frequencies may be utilized in a similar manner for heating a body of cord-like or solid material as desired. In utilizing lower frequencies, the cavities may be sections of a transmission line as shown more clearly in the modification illustrated in Figure 5, to which attention is now directed.

In Figure 5, the lower or base section 30 and the removable upper section 31 of the applicator body or casing, both of conducting material as in the preceding embodiment, are provided with resonant line sections 32 and 33 substantially one quarter wavelength long are arranged symmetrically about the dividing line between the base and cover sections, and one of the sections 33 is supplied with R.-F. energy through a concentric conductor or line 34 having a coupling loop 35 within the cavity.

Between the two spaced sections of the transmission line cavities 32 and 33, are a series of spaced upper electrodes 36, 37 and 38 and a corresponding series of lower electrodes 39, 40 and 41 cooperating with the respective upper electrodes in opposed relation in pairs. Interposed between the pairs of electrodes are further transverse quarter wave resonant line sections 45, 46, 47 and 48 for concentrating the electrical field at the electrodes. In this case the work may be a body of dielectric material 49 which lies or passes between the electrodes or the arrangement may be in accordance with Figures 1 and 2 to provide a continuous re-entrant path between the pairs of electrodes. In any case, it will be seen that the electrical field is concentrated between the pairs of electrodes and through the dielectric material constituting the work body. By suitably proportioning the spacing between the adjacent pairs of poles and between the tips of each pair a substantially uniform electrical field can be obtained throughout a large piece of work with lower frequencies at the supply source.

From the foregoing description it will be seen that the problem of heating small cross sections of dielectric material such as rayon thread, may be simplified considerably by the use of a series of spaced resonant cavities coupling interposed pairs of electrodes in an R.-F. heating applicator which provides a space between the electrodes along a plane passing through the centers of the series of cavities, and causing the work to be drawn continuously between the pairs of opposing electrodes in sequence, so that the heating takes place along a series of sections or lengths, the aggregate of which is relatively great, thereby contributing to the rapid and effective processing of dielectric and similar materials constituting the work. It will further be seen that the pole pieces or electrode tips may be constructed of dielectric material tending to concentrate the R.-F. flux in the material, thereby enhancing the heating effect and conserving the available power derived from the power source.

I claim as my invention:

1. An R.-F. application for heating dielectric material and the like, comprising means providing a series of alternate resonant cavities and spaced pairs of electrodes, said pairs of electrodes electrically coupling said alternate resonant cavities, means for passing dielectric material between said pairs of electrodes in substantially parallel sections, and means for applying R.-F. energy to at least one of said series of resonant cavities thereby to energize said electrodes.

2. In an R.-F. heating applicator, means providing a series of pairs of spaced elongated electrodes extending transversely through said applicator in substantially parallel relation to each other, means providing a series of resonant cavities interposed between and electrically coupled by pairs of said electrodes, and means for passing a continuous length of dielectric material back and forth through said applicator between said electrodes progressively to effectively heat said material.

3. An R.-F. heating system comprising a pair of separable conductive elements providing a series of spaced electrically coupled resonant cavities and a plurality of pairs of spaced electrodes carried by said conductive elements located in substantially a common plane passing between said elements and through said cavities and lying between successive pairs of said cavities to concentrate R.-F. voltage at said electrodes, means for passing a continuous length of dielectric material between said electrodes progressively in a re-entrant path from one pair of electrodes to another, and means for coupling high frequency R.-F. energy to said series of cavities to energize said electrodes.

4. A high frequency dielectric heating applicator structure comprising a pair of elongated opposed spaced plates of conductive material having complementary substantially, half wavelength parallel grooves along adjacent faces to provide a series of spaced resonant cavities and a series of spaced pairs of high voltage electrodes alternately disposed therebetween, and means for propagating high frequency R.-F. power into said series of resonant cavities.

5. A high frequency dielectric heating applicator structure comprising a pair of elongated opposed spaced plates of conductive material having complementary substantially half wavelength parallel grooves along adjacent faces to

provide a series of spaced resonant cavities and a series of spaced pairs of high voltage electrodes alternately disposed therebetween, means to propagate high frequency R.-F. power into said series of resonant cavities comprising a wave guide and matching wave guide section coupled to the first one of the series of resonant cavities, and terminating capacitor means for the series of cavities at the opposite end thereof comprising a thin body of dielectric material between said plates.

6. An R.-F. heating applicator comprising a series of pairs of opposed elongated electrodes in spaced parallel relation in a common plane, means for applying R.-F. energy to said electrodes including a series of resonant cavities alternately disposed in parallel with and along the series of electrodes between successive pairs thereof, means including a wave guide and matching section coupled to one end of the series of cavities to supply R.-F. energy thereto, bypass capacitor means terminating said series of cavities at the opposite end thereof, and means providing an R.-F heating path for filamentary work material between the successive pairs of electrodes.

7. An R.-F. heating applicator as defined in claim 6 wherein the cavities form electrical half wave resonant line sections between successive pairs of electrodes, and wherein the R.-F. heating path for the work material is re-entrant from side to side progressively along the series of pairs of electrodes.

8. An R.-F. heating applicator comprising a series of pairs of opposed electrodes in spaced parallel relation in a common plane, means for applying R.-F. energy to said electrodes including a series of resonant quarter wave cavities alternately disposed in parallel and along the series of electrodes between successive pairs thereof, means including a resonant quarter wave cavity coupled to each end of the series of cavities to supply R.-F. energy thereto at one end and terminating said series of cavities at the opposite end thereof, and means providing an R.-F. heating space for work material between the several pairs of electrodes.

9. An R.-F. power applicator for dielectric heating of continuous lengths of dielectric material and the like of relatively small cross section, comprising means providing an elongated conducting body, a plurality of transversely extending substantially parallel pairs of spaced electrodes located along the length of said body, the electrodes in each pair being spaced on opposite sides of a common plane dividing said body, a plurality of resonant high frequency cavities interposed between adjacent pairs of electrodes to provide R.-F. coupling means therefor, bypass capacitor means in said conducting body at one end of the series of cavities, wave guide means for applying R.-F. energy to said series of resonant cavities at the opposite end of said series, and means providing a passage for dielectric material between said electrodes progressively in a continuous re-entrant path from one end of the applicator to the other, whereby the length of material which simultaneously may be heated is substantially the total of the lengths of said pairs of electrodes.

10. In an R.-F. heating applicator structure, an elongated split casing comprising two oppositely disposed spaced conducting members, said members having complementary spaced substantially parallel grooves uniting to define a series of resonant cavities spaced an electrical half wave length apart along the length of the casing and transverse ridges between said grooves in each section constituting spaced elongated electrodes in pairs between and coupled by said cavities, said electrodes being shaped to provide concentrated high voltage fields between successive pairs thereof, and means for conveying dielectric work material in thread-like form between said electrode pairs successively in a continuous re-entrant path through said casing from side to side threading said fields successively from one end of the casing to the other.

11. In an R.-F. heating applicator structure, the combination as defined in claim 10, wherein each electrode is provided with a tip element of high dielectric constant material shaped to provide a relatively narrow operating edge for concentrating the field between the electrodes.

12. In an R.-F. heating applicator structure, the combination defined in claim 10, wherein the series of spaced resonant half wave cavities is terminated at one end by a bypass capacitor comprising a body of dielectric material located between said spaced conducting members, and is coupled to a source of R.-F. power at the opposite end by a wave guide and matching section.

13. In an R.-F. heating applicator structure, the combination defined in claim 10 wherein one of the spaced conducting members is movable with respect to the other to open the applicator structure and to separate the electrodes along the split in the casing, whereby the structure may be loaded and inspected.

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