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J. E. JOY
CONSTANT POTENTIAL GRADIENT
DIELECTRIC HEATING DEVICE
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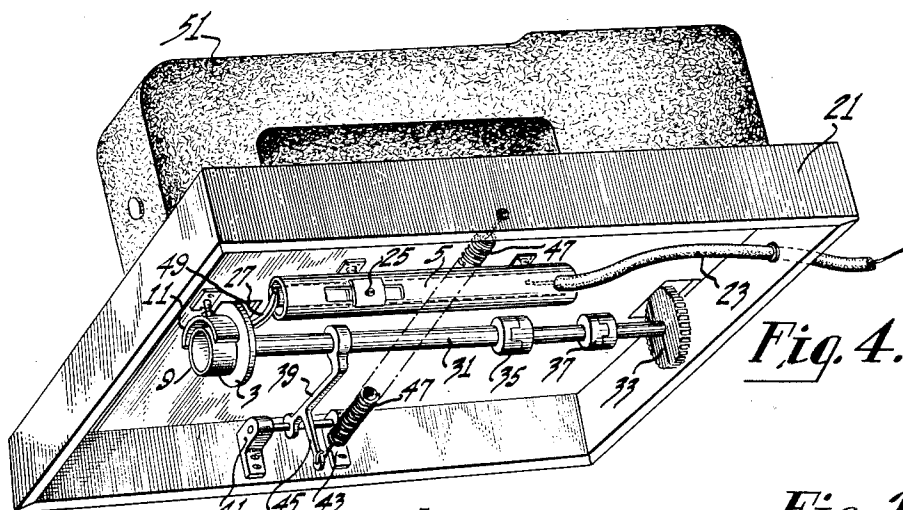


Fig. 4.

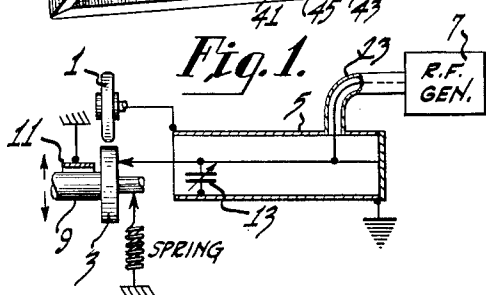


Fig. 1.

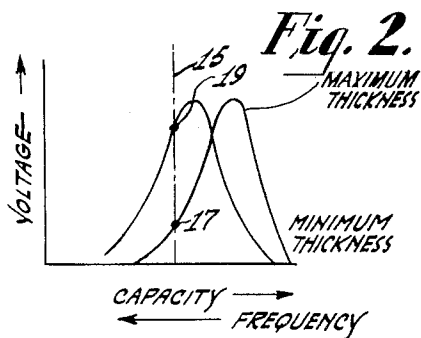


Fig. 2.

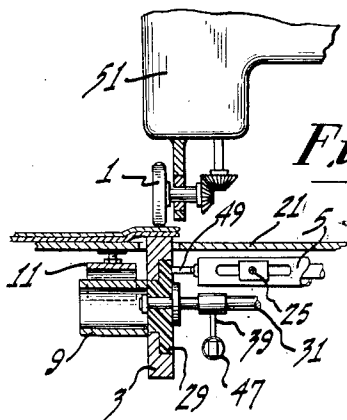


Fig. 3.

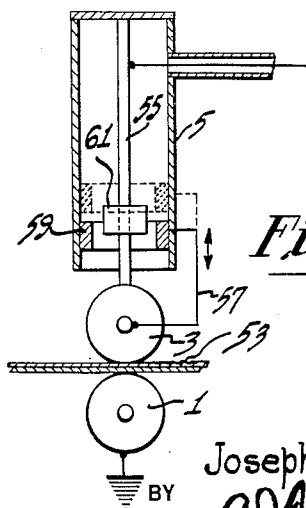


Fig. 5.

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4 Claims. (Cl. 219-47)

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This invention relates to the art of high frequency heat sealing, and in particular to a method of and means for automatically compensating for the detuning effects caused by variations in thickness of thermoplastic materials being heat sealed between energized electrodes and for automatically adjusting the radio frequency potential between the electrodes to apply the proper voltages to effect heat sealing for various thicknesses of material.

It is well known that there are a number of synthetic resins which become soft in the presence of sufficiently high temperature and which may thus be bonded together by the application of heat. These materials are generally classed as thermoplastics, and include such commercial materials as "Pliofilm," "Vinylite," "Koroseal" and the like. These materials are very useful in the fabrication of waterproof coverings, air-tight enclosures and packages for the shipment and storage of foods, chemicals or other materials which deteriorate in the presence of air or moisture. It has been customary to seal materials of this type by passing the thermoplastics between heated rollers which bring the material to the point of plasticity and permit bonding under pressure. The advantages of inducing radio frequency heat energy in thermoplastic materials held between bar or roller electrodes has been pointed out in an article by C. N. Hoyer in "Electronics" for August, 1943, entitled "An Electronic Sewing Machine." He points out that when a radio frequency field is applied across the seam, heat is generated uniformly in the thermoplastic by dielectric loss. Due to the thermal conductivity of the electrodes which make contact with the outer surfaces of the thermoplastic, the softening effect is limited to the inner surfaces of the materials which are to be bonded. This makes possible a greatly improved bond without distortion of the outer surface of the material.

For a given thickness of thermoplastic, the maximum R. F. voltage between the electrodes which is permissible is determined by the characteristics of the material. If the voltage is too high, the material will break down and the radio frequency voltage will puncture the material causing faults in the bond. If the radio frequency voltage between the electrodes is too low there will be insufficient heating to cause a uniform bonding. It is therefore necessary to adjust the equipment carefully to produce the required voltage between the electrodes, taking into consideration the thickness of the material,

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its R. F. breakdown resistance and the speed with which it is desired to complete the bonding.

Commercial applications of radio frequency heating frequently require the bonding of seams in which a plurality of layers of material pass between the electrodes at one time and relatively few layers of the material pass between the electrodes at other times. Due to the variation in the distance, and thus capacity, between the opposed electrodes, the normally resonant radio frequency circuit of which the electrodes are a part becomes detuned, thus radically changing the radio frequency voltage between the electrodes and causing an improper voltage to be impressed on the electrodes from time to time. It is expected that some commercial applications may require anywhere from two to eight layers of material to pass between the electrodes in the process of "sewing" thermoplastic materials. It is the primary purpose of this invention to provide an automatic means for adjusting the radio frequency voltage between the electrodes to maintain the proper value for all thickness of material. It is a further object of this invention to provide an improved electronic sewing machine. A still further object of this invention is to provide means for automatically compensating for variations of capacity between the electrodes of a radio frequency sewing machine caused by variations in the thickness of material being treated or in the number of layers of such material.

This invention will be better understood from the following description when considered in connection with the accompanying drawings, and its scope is indicated by the appended claims.

In the drawings:

Figure 1 is a schematic view of one embodiment of this invention;

Figure 2 is a curve illustrating the operation of this invention;

Figure 3 is a plan view partly in cross section of a portion of an electronic sewing machine;

Figure 4 is a perspective view of a portion of an electronic sewing machine illustrating this invention; and

Figure 5 is an alternative embodiment, shown in schematic form.

Similar elements in the drawings will be indicated by similar reference numerals.

Referring to Fig. 1, thermoplastic materials to be bonded are passed between two roller electrodes 1 and 3. Electrode 1 is grounded, while electrode 3 is connected to the high potential radio frequency source provided at the output

terminals of a quarter wave section of a concentric line 5 energized by a source of radio frequency energy 7 in the conventional manner. To enable material of various thicknesses to pass between the rollers 1 and 3, one of the rollers, preferably the high potential roller 3, is spring biased so as to maintain the desired pressure against the fixed roller by any convenient means. The movable roller 3 is provided with an extension 9 which is associated with and spaced from a grounded plate 11, and constitutes a capacity therewith. Energy is supplied to electrode 3 by a wiping spring contact which is connected to the inner conductor of concentric line 5.

It will be appreciated that as the thickness of material increases, it will be necessary to provide a higher voltage between electrodes 1 and 3 if the heating effect is to be maintained constant. The required potential difference between the electrodes is approximately proportional to the thickness of the material, that is, the potential gradient between the two electrodes should be approximately constant. In actual practice there will be a small deviation from this theoretical value, particularly when very thin layers of material are being processed, since in that case a relatively large amount of the generated heat will pass to the cool electrodes and thus be lost. The total effect is, of course, dependent upon the heat conductivity of the material in question. When thicker layers, or a larger number of layers, are being used, those layers not in direct contact with the electrodes do not tend to lose their heat and therefore the heating is effected more efficiently and a slightly lower potential gradient will accomplish the desired result. To accomplish the automatic adjustment of the potential gradient in accordance with the present invention, I take advantage of the change in capacity between the two electrodes or between the high potential electrode and ground or a combination of both, occasioned by the movement of one of the electrodes produced by variations in thickness of the material to be treated.

The method of accomplishing this adjustment is illustrated by the curves shown in Fig. 2, to which reference is now made. The curves represent the voltage vs. capacity resonance of the concentric line 5, including the capacitive loading produced by electrode 3 together with variable capacitor 13 which may be connected across the high potential terminal of the concentric line.

Two resonant curves are now shown, the one on the left representing the condition when the output circuit is substantially resonant at the operating frequency, while the other curve on the right shows the displaced condition of resonance in which the operating frequency lies well down on the slope of the resonant curve. Movement between these two conditions will of course cause the output voltage to vary in the manner desired.

As is well known, the voltage across the resonant circuit and thus between the electrodes 1 and 3, is a maximum at the point of resonance. The frequency of the oscillations produced by the radio frequency generator 7 is represented by the vertical line 15 which remains fixed at a value of the order of 200 megacycles. Capacity 13 is then adjusted to tune the system to the low frequency side of resonance, when the thinnest material to be treated is between electrodes 1 and 3, by an amount sufficient to bring the operating point 17 to a position on the right

hand resonance curve which will produce the desired potential difference between the electrodes. When a thicker material comes between the electrodes they will move apart so as to accommodate the increased thickness, and this will inherently reduce the capacity between the two. From Fig. 2 it will be seen that the point of operation then moves nearer to resonance and a higher potential difference appears between the two electrodes. The maximum thickness of material to be treated should likewise fall on the low frequency side of resonance, for example, at point 19 on the left hand curve. If the inherent capacity change between the two electrodes is not sufficient to produce the desired capacity change, additional capacity may be provided by means of plate 11 which is capacitively coupled to the extension 9 of the high potential electrode 3. It will be understood that the total capacity change may be adjusted to any value by suitable selection of the size of the capacity 11 or by adjustment of its spacing from electrode 9. The overall range of the capacity variation, and thus the range between maximum and minimum voltages, may be controlled by suitably adjusting the ratio of capacity 13 with respect to the net capacity change effected by the movement of the electrode. These values must be determined in any particular case by the specific requirements, and will depend on the operating frequency, and the nature of the material being treated.

A practical embodiment of this invention as applied to a radio frequency sewing machine is illustrated in Figs. 3 and 4, to which reference is now made. Fig. 4 is a perspective view of the under side of the bed plate 21 which is also shown in cross sectional elevation in Fig. 3. The quarter wave concentric line 5 is mounted under the bed plate 21 and its outer conductor is grounded thereto. Radio frequency voltage is supplied from a source, not shown, through concentric cable 23. To provide an adjustable capacity as indicated by capacitor 13 in Fig. 1, the inner conductor of the concentric line 5 is provided with an enlarged section at its outer end which may be brought into capacitive relationship with a grounded ring, adjustably movable in a longitudinal slot and held by a set screw 25. An aperture 27 is provided in the bed plate 21 through which a portion of the high potential electrode 3 extends so that it may engage the material to be treated on the upper surface of the bed plate 21. Electrode 3 consists of a metallic ring supported by an insulating washer 29 which is in turn supported by a rotatable shaft 31. The shaft is coupled to a driving motor, not shown, through a gear 33 and a pair of universal coupling elements 35 and 37 which permit slight vertical movement of the electrode at one end of the shaft without affecting its rotation. At a point near the electrode the shaft is supported by a bearing arm 39 which is pivoted at one end in supports 41 and 43 which are fixed to the bed plate 21. A pin 45 extends at right angles from the bearing arm 39 and is connected to a spring 47 which provides a tensional force in such direction that the shaft 31 is resiliently held against the grounded electrode 1 which is mounted above the bed plate. A semi-cylindrical plate 11 is mounted on the bed plate 21 and capacitively coupled to the extension 9 of the high potential electrode 3. Radio frequency energy is applied to the electrode through a brush 49 which is connected to the outer end of the inner

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conductor of concentric line 5 so as to engage the metallic outer portion of the electrode 3.

Cooperating with the high potential electrode 3 is a grounded electrode 1 which is mounted in the upper head portion 51 of the sewing machine. Electrode 1 is driven by the motor, not shown, which also drives gear 33, both electrodes rotating in such a direction and at such a speed that the material to be treated is caused to pass between them. There may also be provided a hand or foot operated mechanism for lifting electrode 1 upwardly so as to permit placement of the material to be treated between the two electrodes.

An alternative arrangement for automatically adjusting the capacity is illustrated in Fig. 5, which shows schematically a grounded electrode 1 and a high potential electrode 3 positioned so as to contact opposed surfaces of the material 53 which is to be treated. Electrode 3 is energized by a connection to the inner conductor 55 of concentric line 5 and is mechanically coupled, as indicated by line 57, to a movable metallic ring 59 which cooperates with an enlarged section 61 of the inner conductor 55 to form a loading capacity across the resonant circuit. The ring 59 may be located at either end of the enlarged section 61. In one case its movement in a given direction will increase the loading capacity of the line and thus decrease its resonant frequency. In the other case, illustrated by the dotted line, movement in the same direction will decrease the loading capacity. Variations in the thickness of the material to be treated, which cause a change in the capacity between the electrodes, may thus control a capacity which is variable in such direction as to compensate for this change, or, as in the case previously discussed, to augment the change so as to maintain constant the potential gradient between the electrodes.

What I claim is:

1. A radio frequency device for heating a plurality of layers of thermoplastic materials of varying thicknesses comprising a pair of opposed electrodes adapted for engaging said layers of materials therebetween, said electrodes being rotatable to provide for movement of said materials in a predetermined direction, a resonant circuit including the capacity between said electrodes as an element thereof, means for resiliently positioning and biasing one of said electrodes for movement toward the other electrode to maintain a constant pressure on said materials when different thicknesses of said materials pass between said electrodes, means including a concentric transmission line for applying radio frequency power at a predetermined substantially fixed frequency to said resonant circuit and for impressing a high frequency voltage between said electrodes, and means for adjusting the resonant frequency of said circuit substantially to and below said predetermined frequency when materials of maximum thickness to be treated are positioned between said electrodes, said last named means comprising a conductive extension element for the movable electrode, an auxiliary electrode element mounted in variably spaced relation to said extension element and providing therewith additional tuning capacity in said resonant circuit, and said extension element being movable with said movable electrode for decreasing the spaced relation with respect to said auxiliary electrode element in response to a reduction in thickness of said materials there-

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by further to detune said circuit from and below said predetermined frequency.

2. A radio frequency heating device comprising a pair of opposed electrodes adapted to receive therebetween various thicknesses of dielectric material to be heated; resilient supporting and positioning means connected with said electrodes for bringing said electrodes into contact with opposite sides of said material so that the relative spacing of said electrodes is determined by the thickness of said material; a source of radio frequency energy; conductor means including a resonant circuit for applying said energy to said electrodes; and variable capacity means comprising one of said electrodes and an auxiliary electrode element responsive to variations in the relative spacing of said electrodes for varying the resonant frequency of said circuit, and additional variable tuning means for adjusting the resonant frequency of said circuit substantially equal to and below the frequency of said energy when the thickest material to be heated is between said electrodes, and said first named variable capacity being operative in response to relative movement of the electrodes to lower said resonant frequency with respect to the frequency of said energy and to lower the applied voltage on said electrodes when the thinnest material to be heated is between said electrodes to a degree to maintain the potential gradient between said electrodes substantially constant.

3. A radio frequency heating device for uniting multiple layers of thermoplastic dielectric material, comprising in combination, a bed plate having an opening providing communication between the upper and lower sides thereof, a rotatable electrode positioned above said opening, a second rotatable electrode positioned below said opening within said bed plate and in opposed relation to said first named electrode, a resiliently mounted supporting shaft for said second electrode carried by said bed plate and extending along the lower surface thereof to carry said second electrode into engagement with said first electrode through said opening, concentric line means for supplying radio frequency power to said electrodes at a predetermined substantially fixed frequency and including a fixed tubular concentric line extending along the lower surface of said bed plate, a flexible contact element connected between the terminal end of said last named concentric line and said second electrode, means providing a conductive cylindrical extension for and coaxial with said second electrode, an adjustable auxiliary electrode carried by said bed plate in spaced relation to said electrode extension, the relative positions of said auxiliary electrode and extension electrode being such that the spacing therebetween increases in response to an increase in the thickness of material passing between said first and second electrodes, and a variable capacity device carried by said second concentric line providing jointly with said auxiliary and extension electrodes a tuning capacity for resonating said concentric line to a frequency of the order of and less than the power supply frequency when materials of maximum thickness are introduced between said first and second electrodes, and said auxiliary and extension electrodes being effective to increase said last named tuning capacity in response to a minimum thickness of materials between said first and second electrodes and to shift the resonant

frequency of said second concentric transmission line below the frequency of the power supply to a degree such that the potential gradient through the material is maintained substantially constant.

4. Apparatus for bonding together a plurality of dielectric parts of varying thickness, comprising a plurality of spaced, continuously rotating electrodes adapted for receiving and continuously advancing said parts therebetween, a source of high frequency electrical energy, at least one of said electrodes being yielding urged toward the other and separable from the other in response to the thickness of said parts, and means coupling said electrodes to said source, said means including an inductance device and a variable capacitor electrically connected in parallel with said electrodes capable of varying the rate at which energy is supplied to said parts, said variable capacitor comprising a generally cylindrical extension of the said yielding urged electrode adapted to rotate continuously with said electrode and a generally curved plate co-operating with and spaced from said cylindrical extension whereby variations in thickness of said parts in the region of said electrodes cause variations in the relative spacing of said cylindrical extension with respect to said curved plate so as to control said rate.

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