May 18, 1954 W. RUEGGEBERG 2,678,994

HIGH-FREQUENCY POWER CONTROL DEVICE

Filed March 30, 1951 2 Sheets-Sheet 1

Fig. 1

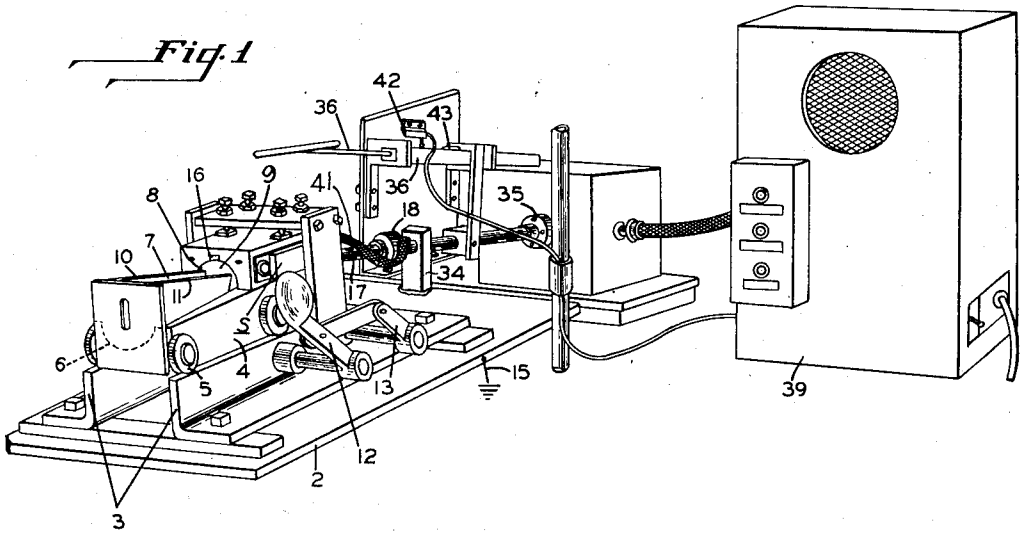
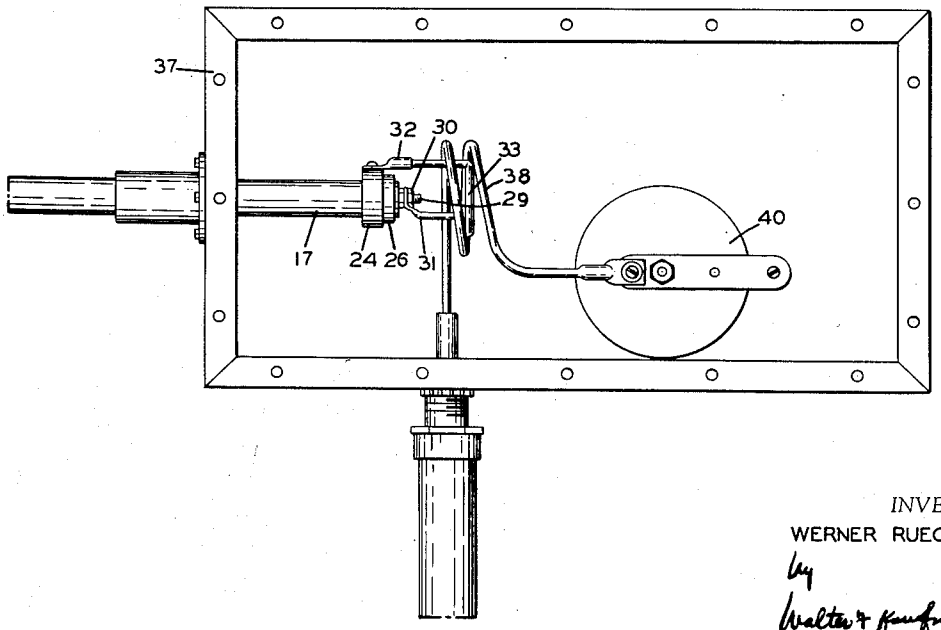


Fig. 2



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Filed March 30, 1951 2 Sheets-Sheet 2

Fig. 3

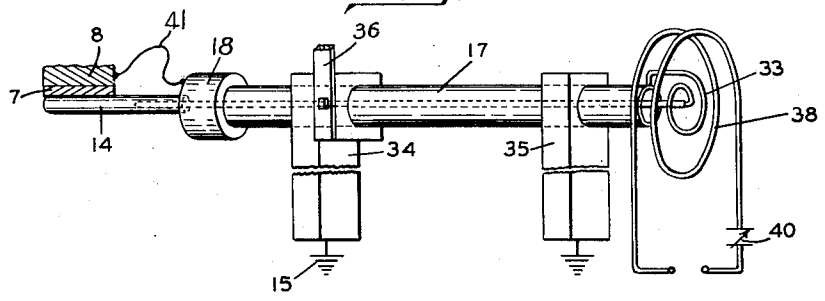


Fig. 4

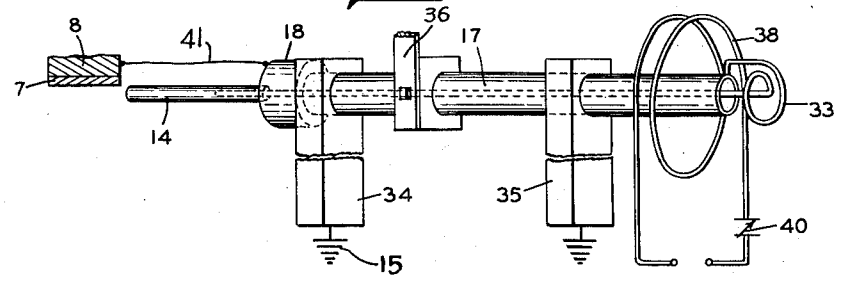


Fig. 5

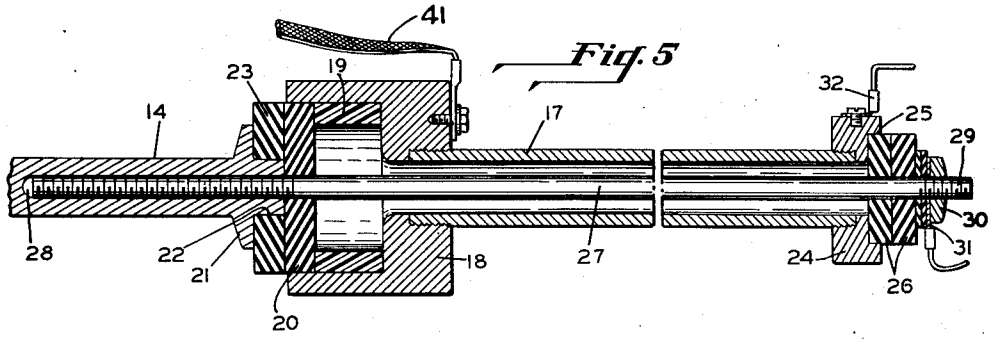
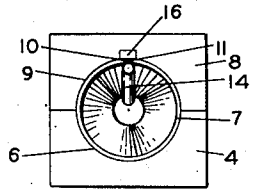


Fig. 6



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UNITED STATES PATENT OFFICE

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HIGH-FREQUENCY POWER CONTROL DEVICE

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Application March 30, 1951, Serial No. 218,321

6 Claims. (Cl. 219—10.75)

1

This invention relates to a high-frequency power control device and is concerned more particularly with an apparatus for automatically controlling the application of a high-frequency field to a workpiece in accordance with motion imparted to one of the electrodes to position such electrode in proper predetermined relationship with respect to the workpiece.

In the manufacture of articles having a small wall thickness, there is present the problem of avoiding arcing between the electrodes under high stress. In the edge gluing of cork compositions, such as in the manufacture of cones used in the textile industry where pieces of cork about one-eighth of an inch thick are bent into cone shape and the abutting edges of the pieces are adhesively joined, the use of high-frequency dielectric heating to activate the adhesive has presented the problem of preventing arcing between the closely spaced electrodes. As is well known, when the electrodes are properly positioned adjacent to the glue line to be activated and the field is applied as by closing a switch energizing the plate circuit of the oscillator, there is an instantaneous build-up or surge of voltage applied between the electrodes, often above the normal or constant voltage applied to the workpiece. This surge may be well above the normal input and may be beyond the puncture point of the workpiece, resulting in arcing between the electrodes and damage to or destruction of the workpiece for its intended purpose. To overcome this, it has been necessary to reduce the voltage applied to the workpiece to a value where the surge is below the range where arcing will occur; but this of course reduces the heating rate, and maximum efficiency of operation is not obtained.

According to the present invention, the application of the field to the workpiece is so controlled that any voltage surge in the output of the oscillaator or other high-frequency current generator which may be occasioned is not transmitted to the workpiece or to the electrodes. Thus the heating of the workpiece may be effected at or close to maximum power input without any serious arcing problem. This may be accomplished by providing a movable electrode and inductively coupling the load to the oscillator by a coupilng coil connected to the electrodes and movable with the movable electrode from a position where the coupling is negligible to a position where close and efficient coupling is obtained. If desired, the high-frequency current generator may be controlled in accordance with movement of the movable electrode such as through a contactor in the plate circuit of the generator. It is not necessary, however, to interrupt the operation of the generator; and the same may be operated continuously, and control of the application of the field to the load may be controlled through movement of the coupling coil.

2

An object of the invention is to provide an automatic control for high-frequency heating systems which will eliminate the need for switches, relays, or other similar control devices customarily employed.

Another object of the invention is to provide a high-frequency power control device which is provided with an inductive coupling arrangement for effecting control of the application of the high-frequency field to the workpiece only when the workpiece and electrodes are in proper relationship for effective use of the high-frequency field upon the workpiece.

An additional object of the invention is to provide a control for the high-frequency input to the workpiece which will be substantially free of initial transient voltages, permitting the use of a greater field intensity without danger of arcing or other deleterious action.

Other objects of the invention will be apparent from consideration of the following description of an embodiment of the invention illustrated in the attached drawings, in which:

Figure 1 is a perspective view of a cone-gluing machine having a high-frequency heating unit incorporating the control device of the present invention;

Figure 2 is a top plan view of the control unit mounted within a shielding container, the top having been removed to show the details of the control mechanism;

Figures 3 and 4 are diagrammatic views illustrating operative and inoperative positions of the control mechanism;

Figure 5 is a detailed sectional view to an enlarged scale showing the connection of one of the electrodes to the control device; and

Figure 6 is a diagrammatic sectional view illustrating the positioning of the workpiece with respect to the movable electrode.

Figure 1 illustrates a device for the gluing of a piece of cork composition into a hollow cone used in the textile industry. This is a typical embodiment of a fabricating operation requiring close control of high-frequency input to the workpiece and is typical of many embodiments in which the present invention may be employed. The details of the structure which supports the

workpiece during the formation of the cone and during the setting of the adhesive which bonds the piece into cone formation are not important insofar as the present invention is concerned. Conventional equipment has been shown in Figure 1 for performing such operations. The arrangement includes a table or platform 2 upon which is mounted a pair of tracks 3. Mounted for reciprocatory motion on the tracks 3 is a carriage 4 having wheels 5 which ride on the tracks 3. The carriage 4 is provided with a cavity 6 shown in dotted lines in Figure 1, and the workpiece 7 is disposed within that cavity by a machine operator. Mounted above the carriage 4 is a mold member 8 which has a cavity 9 complementary to the cavity 6 which, when juxtaposed with respect to the cavity 6, forms the workpiece 7 into a truncated cone, with the edges 10 and 11 thereof lying in abutting engagement. In order to bring the two parts 4 and 8 into such position, mechanism is provided for reciprocating the carriage 4 with respect to the mold member 8. In the embodiment shown, this includes an operating handle 12 and linkage arrangement 13.

The edges 10 and 11 of the workpiece 7 are coated with an adhesive, and this adhesive may be dried if it is of the solvent type or may be cooled if it is applied in melted condition prior to cone formation. A conventional phenol-formaldehyde resin adhesive will be considered typical for purposes of describing an embodiment of the invention. The adhesive dissolved in a solvent is applied to the edges which are to be joined, and the solvent is permitted to evaporate and the adhesive to dry. The sheets carrying dried adhesive on the edges to be joined are supplied to the machine operator who inserts an individual sheet in the cavity 6, moves the handle 12 in a clockwise direction, thus bringing the carriage 4 into position under the mold cavity 9, and automatically forms the workpiece 7 into a truncated cone shape, with the edges 10 and 11 in abutting engagement as shown in Figure 6. The mold member 8 is preferably heated to about 230° F. to avoid heat loss for the workpiece 7 to the walls of the mold member 8. This may be accomplished by providing an electric strip heater S mounted on the side of the mold member 8 as shown in Figure 1. The adhesive disposed at the zone of juncture is then activated by the application of heat, and the carriage is retracted to the position shown in Figure 1, by operation of the handle 12 in a counterclockwise direction.

An arrangement is shown in the drawings for the dielectric heating of the adhesive to activate the same and includes a movable electrode 14 which is adapted to be disposed within the workpiece 7 closely adjacent to and preferably in contact therewith at the glue line or closely adjacent to it. The stationary mold member 8 is preferably made of a good electrical conductor such as brass or bronze; it constitutes a second electrode. To facilitate cleaning of any excesive adhesive which may be extruded at the joint, a removable insert 16 is provided in the stationary mold member, disposed at the glue line. The movable electrode 14 is of a length sufficient to extend throughout the whole of the glue line to be activated; and, of course, the mold member 8, constituting the other electrode, is of a depth to receive the whole of the workpiece.

As shown in Figure 5, the movable electrode 14 is mounted upon a coaxial feeder including a sleeve 17 which has fastened thereto a cup-shaped coupling member 18 into which is inserted an insulating ring 19 and an insulating disc 20. Electrode 14 is provided with a flange 21 and a projecting stem 22 which is encircled by an insulating washer 23. The opposite end of the sleeve 17 receives a connector 24 which is provided with a recess 25 which receives one of a pair of insulating washers 26. A threaded rod 27 is received within a threaded opening 28 in the electrode 14, and the opposite threaded end 29 of the rod 27 receives a clamping nut 30 which clamps the various parts of the electrode structure into rigid relationship. An electrical connection 31 is made with the electrode 14 through the rod 27 and the clamping nut 30. A second electrical connection 32 is made to the connector 24. The connections 31 and 32 extend to a coil 33 which may be constituted of hollow copper tubing and may have a single turn or slightly more than a single turn as shown in Figures 3 and 4.

The sleeve 17 is mounted in bearings 34 and 35 for reciprocatory motion to bring the electrode 14 into proper relationship with respect to the workpiece and to remove the same from the zone of the workpiece upon completion of the heating. In the embodiment illustrated, an operating handle 36 is provided which may be grasped by the workman and pulled to bring the electrode to the position shown in Figure 3 to effect heating or pushed to retract the electrode to the position shown in Figure 4 upon completion of the heating cycle.

Mounted within a shielding receptacle 37 is a stationary coupling coil 38 connected to a source of high-frequency power 39 indicated diagrammatically in Figure 1. A one-half kilowatt vacuum tube oscillator operating at a frequency of forty megacycles will be acceptable. A variable condenser 40 may be provided in the shielding container to tune the coupling circuit externally of the high-frequency generator. The coil 38 may be formed of copper tubing similar to the coil 33, and its axis is preferably coincident with the axis of coil 33. The coil 38 is so positioned that, when the electrode 14 is in proper relationship with the workpiece 7, the coil 33 will be disposed in efficient inductive relationship with respect to the coil 38 so that the power from the high-frequency source, such as the oscillator 39, will be supplied to the electrode 14. The coil 38 constitutes slightly more than a single turn. The number of turns in the coils 33 and 38 will be such as to obtain the desired impedance match in the inductively coupled circuits, determined by the frequency at which the system is to operate. When the electrode 14 is moved to the inoperative position shown in Figure 4, the coils 33 and 38 will be out of inductive relationship to such an extent that no substantial high-frequency voltage will be present on the movable electrode 14; and thus the entire heating operation will be effected only when the electrode 14 is disposed fully within the workpiece.

The electrode 14 is at high potential; and the other electrode, the stationary mold member 8, connected by a flexible strap 41 to the outside conductor or sleeve 17 of the coaxial feeder as shown in Figure 5 is near ground potential. Power is received by the coil 33 and is transmitted through the coaxial feeder to the electrode system comprising movable electrode 14 and stationary electrode 8. The workpiece with its adhesive line disposed between the electrodes 8 and 14 is heated when the electrode 14 is moved into proper posi-

tion, bringing the coils 33 and 38 into efficient inductive relationship.

As shown in Figure 1, a microswitch 42 may be provided on the machine to be actuated by a control cam 43 on the actuator arm 36 for moving the electrode 14. This switch may control the plate contactor of the oscillator to energize the coil 38 as the coil 33 approaches coil 38 and to de-energize coil 33 as coil 33 recedes therefrom. Regardless of whether the high-frequency current generator be operated continuously or its output controlled in the manner described above or some other manner, there will be a gradual build-up of voltage at the electrodes as the coil 33 approaches its zone of maximum coupling with coil 38 and electrode 14 assumes its proper position with respect to mold electrode 8 and the workpiece 7. Any substantial voltage surge which may occur with the switching system will be at a time when the coils 33 and 38 are out of efficient coupling relationship; and, consequently, the power input to the electrodes will not approach the arcing stage, although the high-frequency generator may be supplying abnormally high voltages to coil 38.

I claim:

1. In a device for dielectrically heating a workpiece, the combination of: a source of high-frequency alternating electric voltage; a stationary electrode; a movable electrode; means for inductively coupling said electrodes to said source of voltage comprising a stationary coil, a movable coil, means electrically coupling said stationary coil to said source of voltage, and means electrically coupling said movable coil to said stationary electrode and to said movable electrode for the transfer to said electrodes of current induced in said movable coil from said stationary coil coupled to said source; and means for controlling the coupling of said electrodes to said source in accordance with movement of said movable electrode to an operative position comprising means mechanically connecting said movable coil to said movable electrode for movement in unison therewith and means for coincidentally moving said movable coil and said movable electrode to shift said movable coil with respect to said stationary coil from an inoperative position to an operative position in efficient inductive coupling relationship with said stationary coil to inductively couple said electrodes to said source and simultaneously to shift said movable electrode with respect to said stationary electrode from an inoperative position to an operative position where the field established between said electrodes through efficient inductive coupling of said coils will embrace said workpiece.

2. In a device for dielectrically heating a workpiece, the combination of: a source of high-frequency alternating electric voltage; a stationary electrode; a movable electrode; means for inductively coupling said electrodes to said source of voltage comprising a stationary coil, a movable coil, means electrically coupling said stationary coil to said source of voltage, and a coaxial feeder electrically coupling said movable coil to said stationary electrode and to said movable electrode for the transfer to said electrodes of current induced in said movable coil from said stationary coil coupled to said source; and means for controlling the coupling of said electrodes to said source in accordance with movement of said movable electrode to an operative position comprising means mechanically connecting said movable coil to said movable electrode for movement in unison therewith and means engageable with said coaxial feeder for coincidentally moving said movable coil and said movable electrode to shift said movable coil with respect to said stationary coil from an inoperative position to an operative position in efficient inductive coupling relationship with said stationary coil to inductively couple said electrodes to said source and simultaneously to shift said movable electrode with respect to said stationary electrode from an inoperative position to an operative position where the field established between said electrodes through efficient inductive coupling of said coils will embrace said workpiece.

3. In a device for dielectrically heating a workpiece, the combination of: a source of high-frequency alternating electric voltage; a stationary electrode; a movable electrode; means for inductively coupling said electrodes to said source of voltage comprising a stationary coil, a movable coil, means electrically coupling said stationary coil to said source of voltage, and a coaxial feeder comprising an outer tubular conductor electrically coupled to said stationary electrode and an inner conductor electrically coupled to said movable electrode for the transfer to said electrodes of current induced in said movable coil from said stationary coil coupled to said source; and means for controlling the coupling of said electrodes to said source in accordance with movement of said movable electrode to an operative position comprising means mechanically connecting said movable coil to said movable electrode for movement in unison therewith and means for coincidentally moving said movable coil and said movable electrode to shift said movable coil with respect to said stationary coil from an inoperative position to an operative position in efficient inductive coupling relationship with said stationary coil to inductively couple said electrodes to said source and simultaneously to shift said movable electrode with respect to said stationary electrode from an inoperative position to an operative position where the field established between said electrodes through efficient inductive coupling of said coils will embrace said workpiece.

4. In a device for dielectrically heating a workpiece, the combination of: a pair of electrodes relatively movable from an operative position where the field established between said electrodes will embrace said workpiece to an inoperative position; means for inductively coupling said electrodes to a source of high-frequency alternating electric voltage comprising a stationary coil, a movable coil, means electrically coupling said stationary coil to said source of voltage, and means electrically coupling said movable coil to said stationary electrode and to said movable electrode for the transfer to said electrodes of current induced in said movable coil from said stationary coil coupled to said source; means for relatively moving said electrodes from said inoperative position to said operative position; and means responsive to said relative movement of said electrodes for varying said inductive coupling of said electrodes to said source to gradually increase the coupling as said electrodes reach said operative position.

5. In a device for dielectrically heating a workpiece, the combination of: a pair of electrodes relatively movable from an operative position where the field established between said electrodes will embrace said workpiece to an inop-

erative position; means for inductively coupling said electrodes to a source of high-frequency alternating electric voltage comprising a stationary coil, a movable coil, means electrically coupling said stationary coil to said source of voltage, and means electrically coupling said movable coil to said stationary electrode and to said movable electrode for the transfer to said electrodes of current induced in said movable coil from said stationary coil coupled to said source; means for relatively moving said electrodes from said inoperative position to said operative position; and means carried by said moving means for controlling the application of said source to said inductive coupling means and also for varying said inductive coupling of said electrode to said source to gradually increase the coupling and the intensity of the field established between said electrodes as said electrodes reach said operative position.

6. In a device for dielectrically heating a workpiece disposed between a pair of electrodes to which there is supplied a high-frequency alternating electric voltage from a source thereof, the combination of a stationary coil connected to said source, a movable coil connected to said

electrodes, a switch for controlling the output of said voltage from said source to said stationary coil, means for moving said movable coil from an inoperative position to an operative position in efficient inductive coupling relationship with said stationary coil, and means carried by said moving means for controlling said switch to energize said stationary coil as said movable coil approaches said operative position with respect thereto.

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