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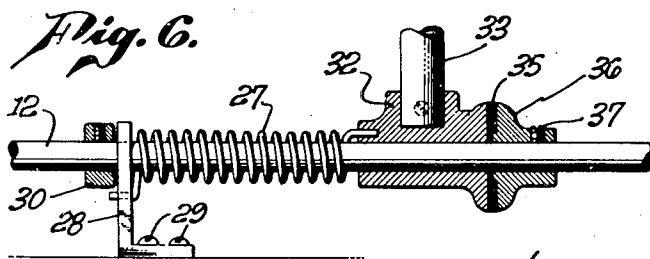
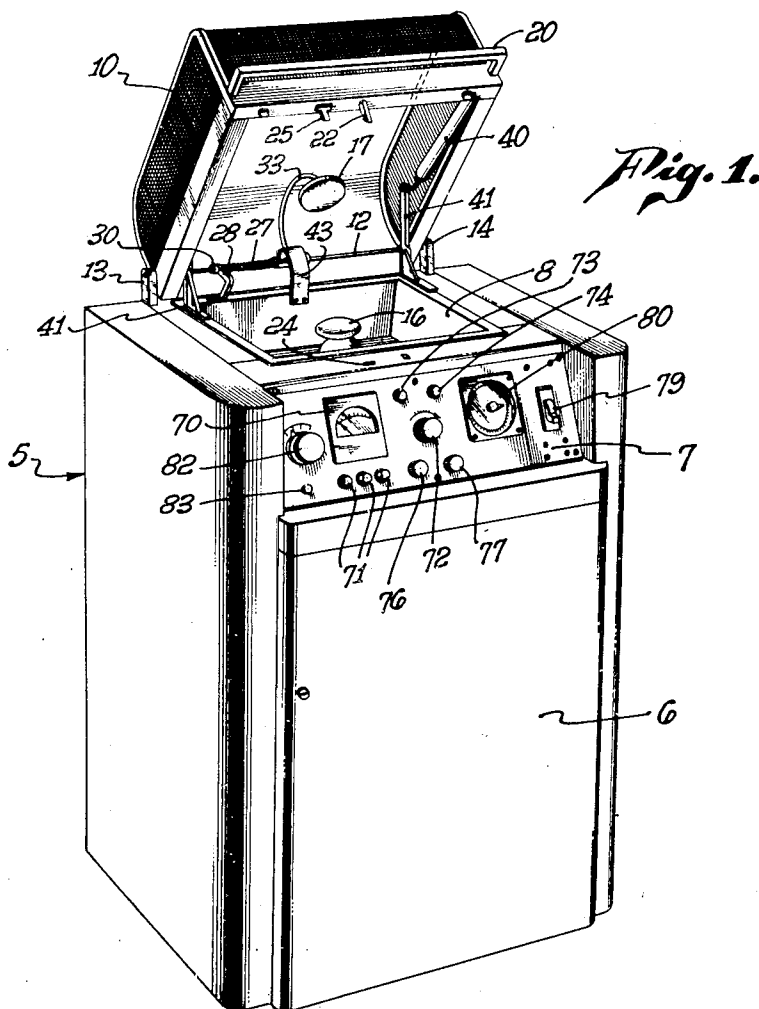
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2,442,451

HIGH-FREQUENCY DIELECTRIC HEATING APPARATUS

Filed Oct. 26, 1944

3 Sheets-Sheet 1



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Fig. 2.

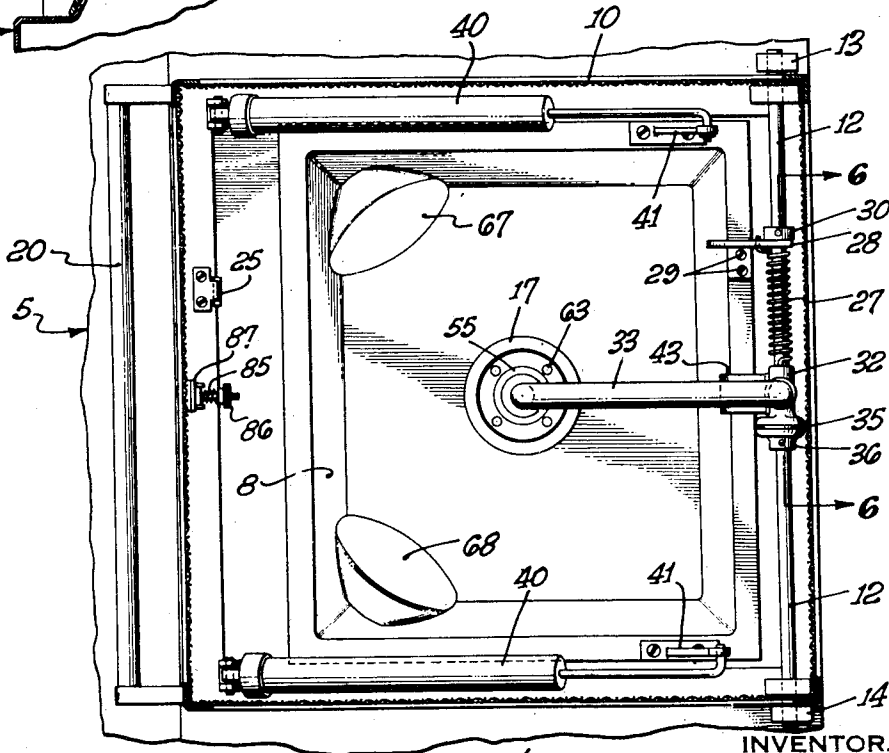
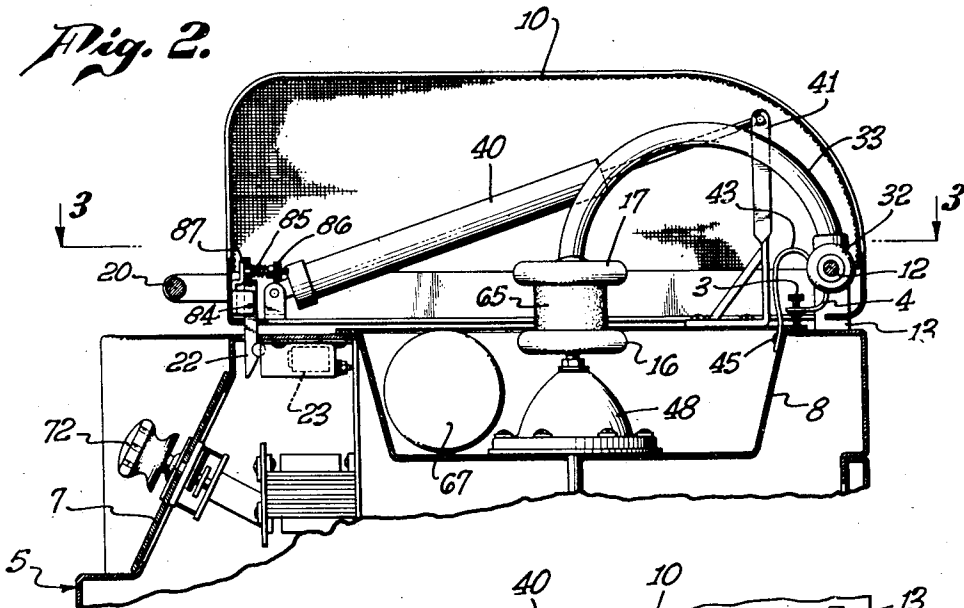


Fig. 3.

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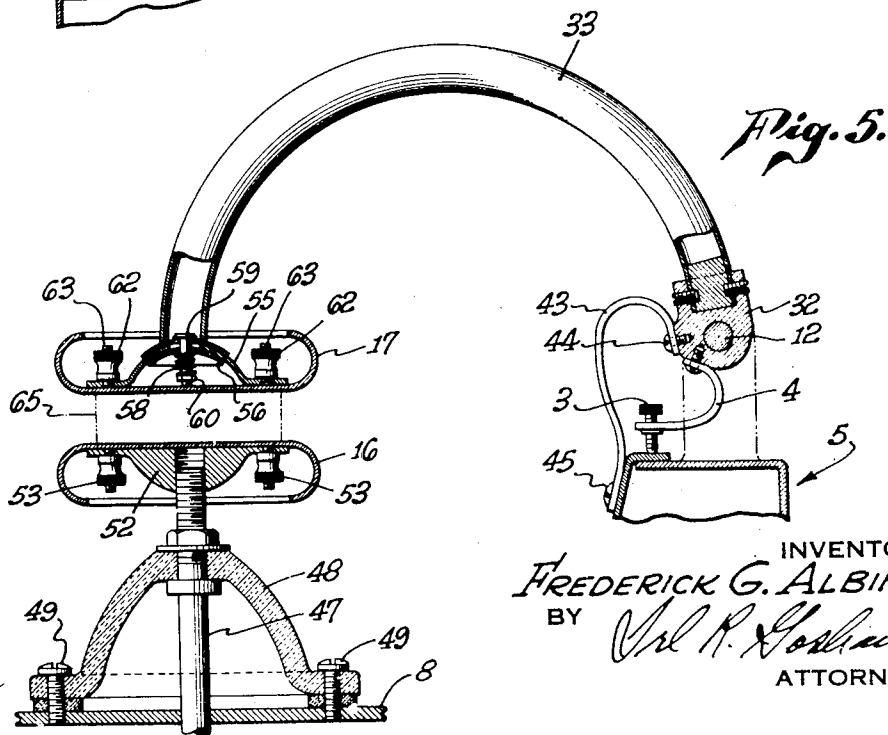
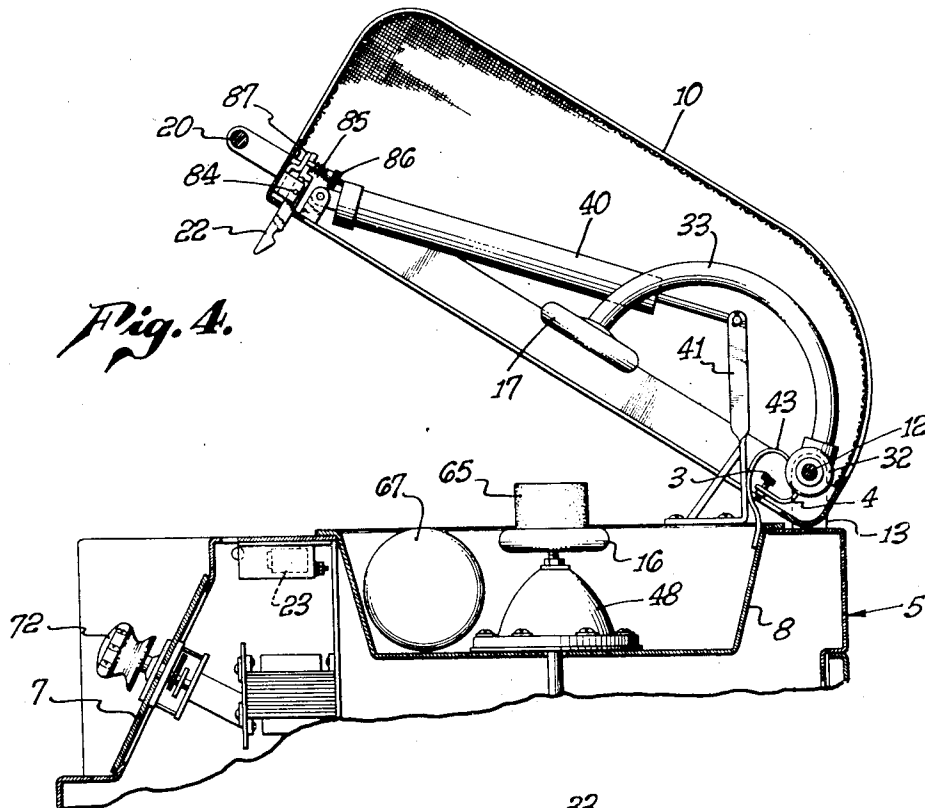
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3 Sheets-Sheet 3



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HIGH-FREQUENCY DIELECTRIC HEATING APPARATUS

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5 Claims. (Cl. 219—47)

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This invention relates to high frequency dielectric heating apparatus, and particularly to the mechanical arrangement of the various elements constituting the generator whereby maximum safety and convenience are provided for the operator, and maximum efficiency is obtained from the generator circuit.

In recent years, the use of high or radio frequency electrical power for heating various types of material has become prevalent. Such power is particularly applicable to the heating of plastic material preformed into the shape of pellets for convenience in handling. This type of plastic material is of the thermal-setting type which polymerizes or changes chemical composition as a function of temperature and time. It is desirable to increase the temperature of these preforms to a relatively high value usually in the neighborhood of 250 degrees Fahrenheit, after which the heated preform must be placed in the mold without delay so that it may be molded into the finished shape of the product before the chemical action has "set" the material. Thus, it is imperative to provide the greatest conveniences possible for the operator to enable him to transfer the preform from the high frequency heating apparatus to the mold in the shortest possible time. By preforming the material, the required weight of the material for certain finished products may be predetermined or measured out so that time for this operation is not consumed by the operator. It has been found, therefore, that an appreciable saving of time and improvement in the final product results from both preforming the material and preheating it, especially the interior of the mass, which accomplishment is readily provided by the use of high frequency electrical power.

The process for heating materials such as just described by means of high frequency power consists in placing the material between two conducting surfaces known as electrodes, between which is a strong high frequency electrical field. High frequency energy is dissipated within the material in proportion to the square of the field strength, and inversely proportional to the electrical resistance of the material at a fixed value of temperature and frequency. In order to realize uniform heating throughout the material, it is necessary to have uniform field strength throughout the material. In practice, it has been found that in some instances the two opposite surfaces of the preform adjacent to the electrodes are not exactly parallel. Therefore, in order that a non-uniform air space between the preform and the

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electrode be eliminated, it is desirable to allow the electrode to adjust its angle so as to conform to the plane of the preform. If an air space is provided between one electrode and the preform to accommodate non-parallelism between the two surfaces, considerable electrical potential is lost across the air gap. However, this method is sometimes used and the present invention provides for obtaining such an air space, if desired.

When heating by high frequency electrical energy, all of the heat is produced within the mass of the material, but heat is lost by radiation, by air conduction, and by metallic conduction through the electrodes. The loss of heat from the surface consequently results in the temperature of the surface being lower than that of the interior. In order to avoid this loss, the present invention provides for the use of one or more infrared heating lamps with the rays directed upon the electrodes and upon the surface of the preform to apply heat thereto and to compensate for the heat that would otherwise be lost, thus maintaining the temperature of the exterior of the material equal to or in the neighborhood of the temperature of the interior of the material.

Since high voltages are generated by high frequency generators of this type, this invention provides a protective cage or cover for the material and electrodes which cage is automatically opened at the end of the heating period or cycle, the raising or opening of the cage also disconnecting the high voltage from the electrodes. The generator is supplied with a series of various sizes of electrodes of a special type, the purpose of which will be explained hereinafter.

The adjustable upper electrode of the invention is so connected to the opening cage lifting mechanism that it is simultaneously lifted off of the material when the cage is lifted, and is replaced on the new preform to be heated when the cage is lowered. However, the electrode may be independently positioned on the material at any time without closing the cover. The generator is also provided with safety switches, automatic overload relays, and an automatic adjustment for the purpose of subjecting the material to a constant power for material of varying sizes, and to a single preform during the heating period if it dries or otherwise changes its characteristics during the heating period, such as its effective capacity and resistance. The electrical circuits for accomplishing these results are disclosed and claimed in my copending application, Ser. No. 540,767, filed June 17, 1944, and a copending application to J. E. Young and E. Miller, Ser. No.

544,510, filed July 12, 1944, the latter circuit being particularly adaptable to the controls described hereinafter.

The principal object of the invention, therefore, is to facilitate the heating of plastic preforms by high frequency electrical energy.

Another object of the invention is to provide improved facilities for loading and unloading a high frequency generator for heating plastic preforms.

A further object of the invention is to provide an improved mechanism for protecting an operator while loading and unloading a high frequency generator.

A further object of the invention is to provide a method of and system for independently heating the exterior surface of material being internally heated by high frequency electrical energy.

A further object of the invention is to provide a method of and system for independently and automatically controlling the positioning of high voltage electrodes of a high frequency generator on and off of material being heated.

A further object of the invention is to provide an improved system for applying electrical energy to material varying in shape by the use of surface adjusting electrodes.

A still further object of the invention is to provide heating electrodes of a high frequency electrical generator which are adjustable to any surface variations of material to be heated, which may be maintained in either an inoperative or operative position or automatically removed from the material when a safety cover is opened, and which may be independently placed on the material or placed thereon during the closing of the safety cage.

Although the novel features which are believed to be characteristic of this invention will be pointed out with particularity in the appended claims, the manner of its organization and the mode of its operation will be better understood by referring to the following description read in conjunction with the accompanying drawings forming a part hereof, in which:

Fig. 1 is a perspective view of an electrical generator in its cabinet with the safety cage and upper electrode in raised positions.

Fig. 2 is a cross sectional view of the upper portion of the generator showing the safety cage in closed position and the electrodes in operative position on the material to be heated.

Fig. 3 is a plan view taken along the line 3—3 of Fig. 2.

Fig. 4 is a cross sectional view similar to Fig. 2 showing the safety cage and upper electrode in raised positions.

Fig. 5 is a detailed cross sectional view of the electrodes in operative position, and

Fig. 6 is a detailed view of the raising and lowering mechanism of the upper adjustable electrode.

Referring to the drawings, in which the same numerals refer to like elements, and particularly to Fig. 1, the electrical circuit elements disclosed and claimed in the above mentioned copending applications are housed in a paneled rectangular casing or cabinet 5 having a front door 6, a sloping panel section 7, and a sink top 8. A wire mesh safety cage or cover 10 mounted on a shaft 12, rotatable in bearing supports 13 and 14, is mounted on the rear section of the cabinet 5, the cage covering or enclosing a fixed electrode 16 and movable electrode 17 and the material to be heated therebetween when closed. The cage

10 has a handle 20 by which it may be closed and opened, although in general use, it is automatically released and raised at the end of a predetermined heating cycle. It is held in a closed position by a latch 22 when the end of a release lever actuated by coil 23 is in the notch of the latch 22 as shown in Fig. 2. A projection 25 is positioned adjacent the latch 22, this projection entering a slot 24 in the cabinet when the cover 10 is closed to close a power application switch to apply high frequency power to electrodes 16 and 17 and the material therebetween. When the cover is lifted, the switch is opened to disconnect the high voltage from the electrodes 16 and 17.

The mechanism associated with coil 23 functions so that it is in locking position except when coil 23 is energized. Thus, if latch 22 were rigid, cage 10 could be neither opened or closed except when coil 23 is energized. This condition would be inconvenient when electrical power is not available and it is desired to open or close cage 10. To permit the cage to be opened without energizing coil 23, latch 22 is arranged to pivot in a forward and backward direction near its mid-point on a pin 84. A spring 85, with an adjusting nut 86, is arranged to urge the top end of latch 22 in a forward direction against a stop 87. Thus, the lower end of latch 22 assumes a normally locked position, but if the cage is manually urged open by pressure on the handle 20, the upper end of the latch will move forward against the spring 85, releasing the latch from the locking pin of coil 23. Thus, cage 10 may be either opened or closed, even though coil 23 is not energized, by applying the proper force on cage handle 20.

The cage is actually lifted by a pair of openers 40, which are connected to the top of the cabinet 5 by brackets 41. The openers comprise a coil spring and piston within the cylinder and a piston rod extending through one end of the cylinder, such as are commonly used for the closing of house doors or screens. When the lid is closed, the spring is compressed within the cylinder, and by the action of the spring extending itself, the piston and rod are pulled into the cylinder to raise the cage 10. The piston makes an air seal between it and the cylinder, and thus, compresses the air in the cylinder as the cage opens, the air escaping through a small adjustable orifice at the end of the cylinder. Thus, the velocity of the cage during opening is retarded at the end of its travel and the tendency to rebound is damped by the escape of the air.

Surrounding the shaft 12 to which the cage is attached, is a coil spring 27 (see Fig. 6), one end of which engages a fixed bracket 28 fastened to the top of the cabinet 5 by any suitable means, such as screws 29, and in which the shaft 12 is rotatable. A collar 30 maintains the shaft 12 in fixed position longitudinally. The other end of the spring 27 is fitted into a hole in a rotatable clutch member 32 on which is mounted a goose-neck support 33 for the electrode 17, the end surface of the member 32 bearing against a cork or similar type of washer 35. The other side of the washer 35 bears against a co-operating clutch plate 36 fixedly mounted on the shaft 12 by a set screw 37. When assembling the apparatus, the clutch member 36 is urged toward the bracket 28 to put the spring under compressive tension. The compressive force of spring 27 exerts pressure on the surfaces of the washer 35, while the torsional force tends to raise the elec-

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trode 17. The initial torsion on the spring 27 should be zero when the electrode gooseneck arm 33 is rotated upwardly from its lowermost position approximately 270 degrees. The strength of the spring 27 is so chosen that the counter balancing force is approximately 10 percent less than the force of gravity on the combination of the arm 33 and electrode 17 with the electrode arm itself in its lowermost position. By this arrangement, there is provided a toggle action for the electrode arm 33, whereby the electrode 17 is held in either its upper or lower extreme position. However, because of the friction existing between the clutch member 36, fixedly mounted to the shaft 12, rotatable with cage 10, and the clutch member 32 attached to the spring 27 on the surfaces of the cork washer 35, the electrode 17 also raises and lowers with the cage 10.

With the above described arrangement, the upper electrode 17 will remain fixed when placed on the material resting on electrode 16, as shown in Fig. 2, and also remain fixed when raised to its upper position shown in Fig. 1. However, when the cage is closed and opened, the electrode 17 will also be lowered and raised with it. The electrode 17 is grounded through a copper strap 43 attached to cabinet 5 by means of screws 44 and 45 (see Fig. 5), electrode 16 being the high potential electrode. An arm 4 attached to the member 32 supporting electrode arm 33 has an adjustable finger screw 3 therein for the purpose of limiting the lower position of electrode 17 when the cage is closed, as will be described later.

Referring particularly to Fig. 5, the mounting of the electrodes 16 and 17 and their construction will now be described. The lower electrode 16 is the high potential electrode and is connected to the electrical circuit housed within the cabinet 5 through a rod 47, mounted on an insulator 48, which, in turn, is fastened to the bottom of the sink 8 by means of screws 49. The upper end of the rod 47 has threaded thereon a fixture 52 to which the electrode 16 is attached by means of thumb screws 53 threaded on studs from the electrode 16 which pass through holes in the fixture 52. This type of mounting permits the ready exchange of electrodes of different sizes.

The upper electrode 17 on the gooseneck 33 is of similar design and is similarly mounted except that it is adjustable. That is, the end of the arm 33 is in the form of a socket in which a fixture 55 is mounted. A spherical washer 56 holds the fixture 55 in its socket, the washer being held under pressure against the fixture 55 by means of a coil spring 58 mounted on a screw 59 between the washer and a nut 60. The fixture 55 has an opening therein through which the screw 59 passes, the opening being several times the diameter of the screw. This construction provides a ball and socket joint support for the electrode 17 which is attached to the fixture 55 by means of thumb screws 62 mounted on studs 63 attached to the electrode 17 and passing through holes in the fixture 55. The electrode 17 is now tiltable in any direction relative to the arm 33 and permits the surface of the electrode 17 to accommodate itself to the upper surface of the material positioned between the electrodes 16 and 17 as illustrated by the dotted lines 65. The particular shape of electrodes is also illustrated in Fig. 5 and show them with a large edge radius ($\frac{3}{8}$ inch). All sizes of the electrodes have this large edge radius so as to keep the potential gradient low and thus lessen the power loss due to corona discharge. This construction also lessens the

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chance of voltage flash-over between electrodes.

By making the surface electrode 17 adjustable and its mounting such that it will not only be independently stable in any position when the cage 10 is open, but at the same time move up and down with the opening and closing of the cage, loading and unloading of the generator has been particularly simplified. It is only necessary for the operator to place a preform on the electrode 16 and close the cage to connect the generator to the load in its most efficient manner. However, if the operator desires to make a preliminary adjustment of electrode 17 to the surface of the material to be heated, he may do so without moving the cage, and may either leave the electrode 17 in position on the material or in a raised position. After the heating cycle, the coil 23 is energized to release the latch 22 which permits the cage openers 40 to raise the cage along with the electrode 17. The electrodes are weighted so that all sizes have the same weight so the counter balancing mechanism need not be readjusted when changing from one size electrode to another.

If it is desired to limit the lower position of electrodes 17 with respect to the surface of the electrode 16, the stop screw 3 may be adjusted to the proper position. In this manner, if small preforms well within the capacity of the generator are being heated, and these preforms vary considerably in surface irregularity, it will be unnecessary for the electrode 17 to adjust itself to each preform.

As mentioned above, a series of electrodes of various sizes may be used at 16 and 17, and the use of several sizes of electrodes is for the purpose of accommodating various sizes of load specimens. In general, both operating electrodes should be no larger than necessary to cover the end areas of the work specimens, and equal in size if the diameter of the end area of the specimen is large, as compared with its thickness. However, because of the cage and other surrounding elements being at ground potential, it is necessary to use a high voltage electrode of larger diameter than that of the grounded electrode, if the spacing between them is appreciable. In this way, the field strength is increased at the grounded electrode and decreased at the high voltage electrode thus offsetting the distortion of the field in the work due to the proximity of grounds.

Mounted in the front corners of the sink 8 are a pair of infrared lamps 67 and 68 which are provided to supply heat to the electrodes 16 and 17 and the surface of the material 65 to offset the loss of heat by air and metallic conduction and thus maintain an even temperature throughout the material. The lamps 67 and 68 may be energized at all times or only during the heating period depending upon the amount of heating required to be applied to the electrodes and surface of the material.

Referring now to the control panel shown in Fig. 1, a meter is shown at 70 under which are three push-buttons 71, which may be actuated for reading the cathode current of each of the vacuum tubes or the combined grid current thereof. A control knob 72 is for regulating the power output of the generator while a green signal lamp 73 indicates that the filaments of the vacuum tubes are energized and a red signal lamp 74 indicates that the plates are energized. Buttons 76 and 77 are on and off buttons, respectively, while a main power switch 79 is mounted

to the right. An interval timer is shown at 80, which, after a predetermined interval, will energize the coil 23, thus removing the end of the locking lever from the notch in the latch 22 permitting the cage 10 to rise. On the left-hand side of the panel is a control knob 82 for the purpose of adjusting the resonance of the load and coupling inductor as described in detail in the above-identified Young and Miller copending application. Under the control knob 82 is a switch push-button 83 which activates a motor to vary the inductance of the coupling inductor as also described in the above-mentioned copending application. These controls are mounted on a sloping panel for ease of observation and operation.

The sequence of operation of the above-described high frequency power generator is as follows:

1. If the cage 10 is not already opened, it may be opened by either pressing the off button 77 or by merely lifting it by the handle 20.

2. Preform material is then centrally positioned on the lower electrode 16.

3. The upper adjustable electrode is now manually pulled down to permit it to adjust its angle to conform with the top surface of the preform.

4. The cage 10, by means of handle 20, is closed, the projection 25 closing the power switch and energizing the heating lamps 67 and 68, the latch 22 locking the cage in closed position.

5. The interval timer is set to the desired time interval unless it has been previously set to the proper period.

6. The radio frequency heating interval is started by pressing the on button 76 which causes the timer to start the measurement of the preset interval.

7. At the end of this interval, the timer energizes the coil 23, releasing the cage 10, which also raises the electrode 17, and disconnects the high voltage from this electrode. This action also de-energizes the interval timer and may extinguish the heating lamps 67 and 68.

8. The heated preform is then removed from the apparatus and placed in the mold after which a new preform is placed on the lower electrode.

I claim as my invention:

1. In a high frequency dielectric heater, a pair of electrodes adapted to be connected to a source of high frequency potential; means fixedly supporting one of said electrodes in a position to receive dielectric material to be heated; means movably supporting the other electrode for movement into and out of cooperative relation with said one electrode; a shielding cage mounted for movement into and out of shielding relation with respect to said electrodes, and frictional means responsive to the movement of said cage for similarly moving said other electrode, said other electrode also being operable independently of the movement of said cage.

2. In a high frequency dielectric heater, a pair of electrodes adapted to be connected to a source of high frequency potential; means fixedly supporting one of said electrodes in a position to receive dielectric material to be heated; a shielding cage mounted for movement into and out of shielding relation with respect to said electrodes; and means movably supporting the other

electrode for movement into and out of cooperative relation with said one electrode including a friction clutch connected between said other electrode and said cage for bringing said electrodes into cooperative relation when said cage is moved into shielding position while permitting said other electrode to be moved independently of the movement of said cage.

3. In a high frequency dielectric heater, an upper and a lower electrode adapted to be connected to a source of high frequency potential; means fixedly supporting said lower electrode in a position to receive dielectric material to be heated; a shielding cage pivotally mounted for movement into and out of shielding relation with respect to said electrodes; supporting means rotatable from a substantially vertical to a substantially horizontal position for supporting said upper electrode in cooperative relation with said lower electrode when in its horizontal position; and a friction clutch for transmitting the movement of said cage to said supporting means providing sufficient torque to cause said supporting means to follow said cage when moved into and out of shielding position while permitting free movement of said supporting means independently of said cage.

4. A device of the character described in claim 3 which includes, in addition, spring means for partially overcoming the force of gravity on said upper electrode, said spring means tending to raise said electrode and said supporting arm to the vertical position.

5. A device of the character described in claim 4 which is further characterized in that said spring means also provides pressure on said friction clutch.

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