March 19, 1968 B. R. HOPKINS 3,374,334

HIGH FREQUENCY HEATING SYSTEM

Filed April 29, 1963

FIG. 1

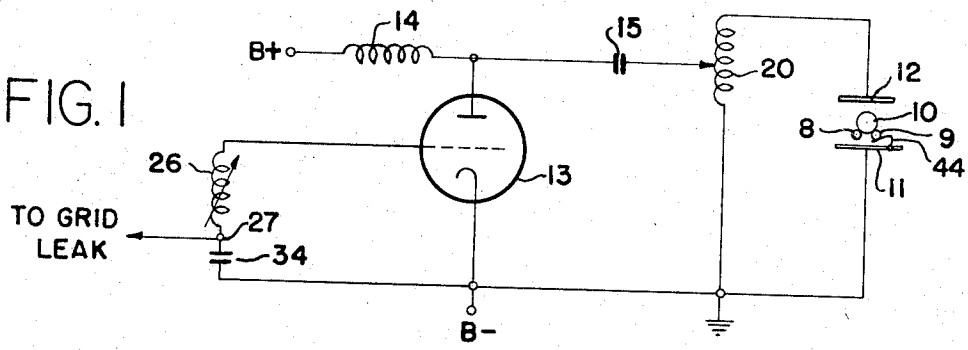



FIG. 4

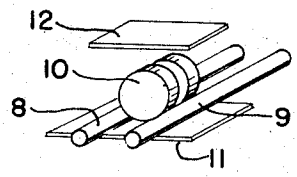



FIG. 5

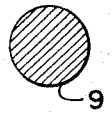



FIG. 6




FIG. 2

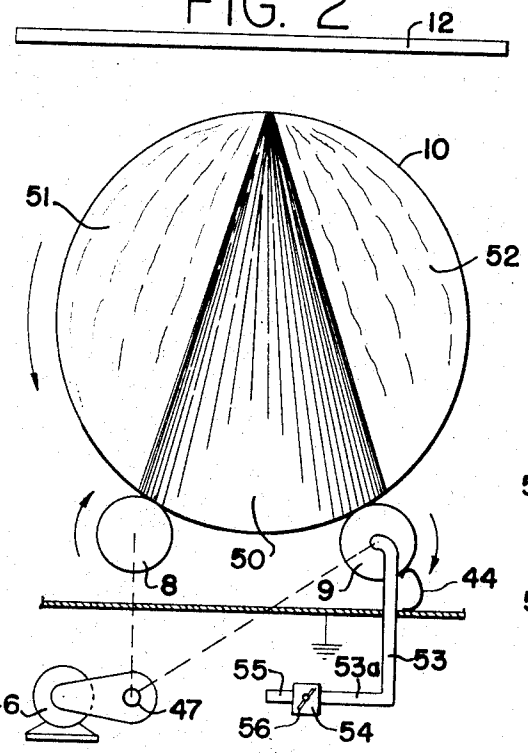



FIG. 3

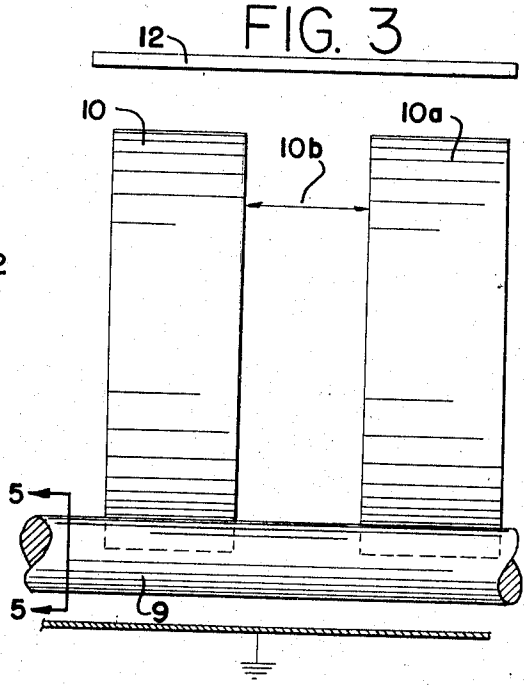
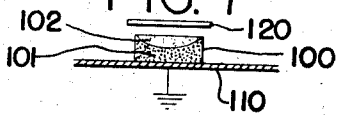



FIG. 7




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# HIGH FREQUENCY HEATING SYSTEM

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1 Claim. (Cl. 219—10.69)

This invention relates to high frequency heating, and more particularly to a method of and system for high frequency dielectric heating.

The term dielectric heating is generally used to describe the process of heating a dielectric material in a rapidly alternating electric field. This field is generally produced between two parallel metallic plate electrodes, at least one of which is insulated so that a high alternating voltage may be applied. Although this heating effect is apparent at all radio frequencies, the frequencies generally employed fall in the range from $10^7$ to $10^8$ cycles.

In the dielectric heating of a cylindrical object in the past it has been customary to place the cylindrical object with its axis perpendicular to the electrodes employed. In this position the heating of the object although not uniform, is the most uniform possible by previously known methods without recourse to specially shaped electrodes which compensate for the distortion of the dielectric field due to the presence and shape of the object being heated. However, such shaped electrodes are generally considered to be impractical for industrial application since they are limited to use with one particular size and shape of dielectric material.

When a dielectric body is heated in the field between two electrodes, the presence of the dielectric in the field between the electrodes causes distortion of the uniform field. If the body or object being heated is cylindrical, this distortion results in the upper central areas of the cylindrical object being heated less than the outer edges. The extent of such uneven heating is increased as the width of the mass of dielectric is increased. If two cylindrical objects are placed closely adjacent each other with their respective circular faces in side-by-side relation and with their axes parallel to the plane of the electrodes, the width of the mass of dielectric material is approximately the sum of the widths of the two objects. Therefore, the extent of uneven heating is much greater than if only one of the cylindrical objects was in the field.

It is, therefore, an object of the present invention to provide a high frequency dielectric heating method and system producing more rapid and more uniform heating of cylindrical sections than previously obtainable.

Another object of the present invention is to provide a high frequency dielectric heating method and system for uniformly heating a cylindrical body by rotating it while it is being heated.

A further object of the present invention is to provide a high frequency heating method and system for heating a plurality of cylindrical objects at the same time.

Briefly stated, in accord with the illustrated embodiment of the present invention, there is provided two parallel rollers disposed between the plate electrodes of a dielectric heating system and adjacent to the earthed one of these plate electrodes. The electrode, insulated from ground, to which the alternating potential is applied, is parallel to this earthed electrode and placed above it sufficiently to clear the cylindrical dielectric object to be heated when it is disposed upon these two parallel rollers with its axis parallel to the axes of the rollers and the plane of the plate electrodes. Means are provided for driving the rollers at a uniform slow speed so that the cylindrical object slowly turns about its axis as it is exposed to the dielectric field. In such a system there is a tendency to produce the greatest heat along curved lines between the upper electrode and the two rollers, with a lowest degree of heat about a line between the upper and lower electrodes located intermediate the rollers, and a minimum amount of heat in the areas near the perimeter of the cylindrical object and between the rollers and the upper electrode. However, since the cylinder is in constant rotation, the heat is uniformly generated throughout the material.



For heating two or more cylindrical objects simultaneously in the same field, the cylindrical objects are placed on the rollers side-by-side with an air space provided between each pair of them. By such spacing of the cylindrical objects, only narrow masses of dielectric are presented to the field, thus minimizing the distortion of the field and resulting in uniform heating of even the top central areas of the cylindrical objects.

The invention, both as to its organization and method of operation, together with further objects and advantages, will best be understood by reference to the following description taken in connection with the accompanying drawing in which:

FIG. 1 diagrammatically shows a dielectric heating system including means for rotating cylindrical objects undergoing heating in accordance with the invention;

FIG. 2 is a diagrammatic elevation view showing details of the electrode and roller arrangement of a portion of FIG. 1.

FIG. 3 is a side elevation view of a portion of the electrode and roller arrangement of FIG. 2;

FIG. 4 is a simplified perspective view further illustrating the electrode and roller arrangement of the system of FIG. 1;

FIG. 5 is a sectional view taken along the line 5—5 of FIG. 3 showing the internal structure of the roller shown in FIG. 3;

FIG. 6 is a sectional view showing the internal structure of another form of roller; and

FIG. 7 is a fragmentary elevation view, partially in section, showing a cylindrical object being dielectrically heated according to a prior art method.

Referring now to the drawing, and particularly to FIG. 1, the invention in one form has been shown as it is employed in a high frequency dielectric heating system utilized for elevating the temperature of a cylindrical dielectric load or work piece **10** such as a plastic preform, carried by a pair of rollers **8** and **9**, mounted above an earthed or grounded electrode **11**. Above the dielectric load **10** is a second electrode **12**.

The source of high-frequency power, which may be taken as representative of typical power generators, includes a power tube **13** of the thermionic type having the customary electrodes therein, which has an anode circuit including a source of anode current whose positive and negattive terminals have been identified as B+ and B—. A radio frequency choke coil **14** is included in the direct-current anode circuit and the high-frequency output of the tube **13** is fed by way of a capacitor **15** to a tank coil **20** having one end thereof connected to the electrode **12** and the other end connected to ground.

The grid circuit includes a variable inductance coil **26** having one end connected to a junction point **27**, which is connected, in turn, to the grid leak, and to a bypass condenser **34** connected to the ground.

The cathode is connected to B—. Although not shown for simplicity, it will be understood that the circuit may also include suitable protective devices such as an overcurrent relay, and suitable switching devices and metering equipment.

The use of high frequency fields for rapidly heating dielectric materials such as molding compounds to shorten the molding cycle has been employed for many years and is now widely accepted, especially where thermosetting plastics are involved. These materials are thermo-

plastic when first heated; however, after a short period of time they convert to a solid which does not re-soften upon additional heat. The higher the degree of preheat, the shorter is this period of plasticity during which the material may be molded. Consequently, high speed molding technique requires fast preheating and transfer of the heated material to the mold. The hotter the preheat, the shorter the over-all cure cycle will be. It is important that no portion of this preheated load be so hot that curing occurs before the mold is properly closed. Conversely, it is important that no portion be too cool since this would result in uncured sections in the finished piece. As a consequence, the degree of uniformity of the preheat determines a minimum production cycle time for satisfactory results. Obviously the time required for transfer of the preheated material to the mold is also important due to the short period of plasticity.

Automation advances in the molding industry have eliminated the need for a preheating period compatible with the variations normally encountered in manual operation. As a consequence automatic molding can take advantage of rapid uniform high temperature preheat of the molding material, rapid transfer of the material to the press, and fast operating presses, all on a fast over-all cycle that repeats itself at a uniform rate.

The molding compounds are commonly subjected to preheating prior to molding while in the form of cylindrical preforms. A typical preform might be three inches in diameter by one and one half inches thick.

Referring now particularly to FIGS. 2 and 4, rotatable means comprising a pair of horizontal, parallel rollers **8** and **9** are provided for supporting the preform **10** between the spaced electrodes **11** and **12** with its axis parallel to them. Means for driving the rotatable means comprising a suitable drive motor **46**, and a suitable gear train, driven by motor **46** and enclosed within a housing **47** are also provided. As indicated in FIG. 2 the driving means is connected to drive rollers **8** and **9**. The gear train and drive motor **46** are selected to provide a uniform, slow rotation speed for the rollers **8** and **9**, and the cylindrical preform **10** rotated on edge between them. The preform **10** thus slowly turns about its axis as it is exposed to the field between the electrodes **11** and **12** during the heating cycle in order to attain a predetermined desired temperature throughout the preform.

As indicated by the lines on the preform **10** in FIG. 2, the greatest heat is concentrated along curving lines between the upper electrode **12** and the rollers **8** and **9**, with a lowest degree of heat directly about a line between the upper and lower electrodes located intermediate the rollers at **50**, and a minimum amount of heat in the areas near the perimeter of the cylindrical object and between the rollers and the upper electrode at **51** and **52**. However, since the cylindrical preform **10** is being constantly rotated during the cycle in which it is being heated to the predetermined desired temperature, it is uniformly heated throughout.

The dielectric load **10** is illustrated in FIGS. 2, 3, and 4 in the form of a cylinder. However, the rollers **8** and **9** could obviously be utilized for rotating dielectric material in another round form such as a sphere.

As is often necessary to accommodate dielectric loads of different sizes, means are provided for adjusting the spacing between the rollers **8** and **9** so that round objects of different diameters can be carried by the rollers. In one form the adjustment means comprises an L shaped support **53** for supporting a hub portion of roller **9**, a block **54** having a passage **55** through it sized to accommodate a leg **53***a* of support **53**, and a thumb screw **56** in threaded engagement with block **54**. Screw **56** can be tightened against leg **53***a* to lock the support **53** in a selected position. To adjust the spacing between rollers **8** and **9** in order that a preform **10** may be properly supported and rotated by the rollers, the thumb screw **56** is loosened, freeing leg **53***a*. The roller **9** is then moved



to the desired location relative to roller **8**, and screw **56** is tightened against leg **53***a*, locking roller **9** in the desired position.

The rollers **8** and **9** may be made of metal, as shown in FIG. 5 which is a section view of roller **9**, or a low loss dielectric material such as Teflon (E. I. du Pont and Company trade name for polytetrafluoroethylene), or a combination of both as is the roller **9***a* shown in section in FIG .6 which comprises a metal core **9***b* having a non-conducting outer layer **9***c*. Metal rollers such as the roller **9** decrease the effective air gap and allow a faster heating. One the other hand rollers have an outer layer of a non-conducting material such as Teflon have advantages in that the material is easier to clean than some metals, and there is less likelihood of arcing as there is less voltage gradient at the surface of the roller.

The preferred embodiment shown in FIGS. 1 and 2 is provided with metal rollers **8** and **9**. The rollers **8** and **9** are connected to the ground electrode **11** by a ground strap **44**.

In some applications it is advantageous to heat two or more cylindrical dielectric objects simultaneously while rotating them in the same field as shown in FIG. 3. The cylindrical preforms **10** and **10***a* are disposed in side-by-side relationship on the rollers **8** and **9** with their axes concentrically aligned and substantially parallel to the planes of the electrodes **11** and **12**. The adjacent cylindrical preforms **10** and **10***a* are spaced so that there is a substantial space **10***b* between them. A spacing equal to the width of the preform has been found satisfactory. By spacing each preform, only narrow masses of dielectric material are presented to the field between the electrodes, thus minimizing the distortion of the field, and by continuously rotating the preforms about their axes while they are being heated, even the top central areas of the preforms are uniformly heated.

The advantages of the present invention described above may be more readily appreciated by briefly referring to the prior art method of heating cylindrical objects in a high frequency dielectric heating system.

FIG. 7 shows a cylindrical plastic preform **10** being dielectrically heated according to the prior art method with the axis of a preform **100** perpendicular to high frequency heating system electrodes **110** and **120** and with the preform maintained stationary during the heating operation. Due to the presence of the dielectric **100** in the field, the field is distorted, resulting in uneven heating. As illustrated in FIG. 7 the lower portion **101** of the preform **100** is darker in color than the upper central portion **102** indicating that portion **102** is cooler than portion **101**. If portion **101** is hot enough for molding, portion **102** will be too cool, resulting in uncured sections in the finished piece. On the other hand, if heating is continued until portion **102** is hot enough, portion **101** may cure before the mold is closed. These prior art problems are overcome by the method and system of the present invention.

While there has been described what is at present considered to be the preferred embodiment of the invention, it will be understood that various modifications may be made therein and are intended to be included within the scope of the appended claim.

What is claimed is:

**1.** In a high frequency dielectric system for heating cylindrical dielectric material to a predetermined desired temperature between a pair of spaced electrodes in a high frequency dielectric heating system, the combination comprising a roller forming an electrode and an additional electrode defining spaced electrodes, an additional roller defining a pair of elongated rollers with said first roller for supporting said material in heating position between the electrodes with the axis of said material and of said rollers parallel to each other and to said additional electrodes; drive means for rotating at least one of said rollers to rotate said material continuously about its axis

while maintaining said axis in place in heating position; and high frequency power means connected to said electrodes for heating said material to said predetermined desired temperature.


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