

July 1, 1952

G. E. GARD

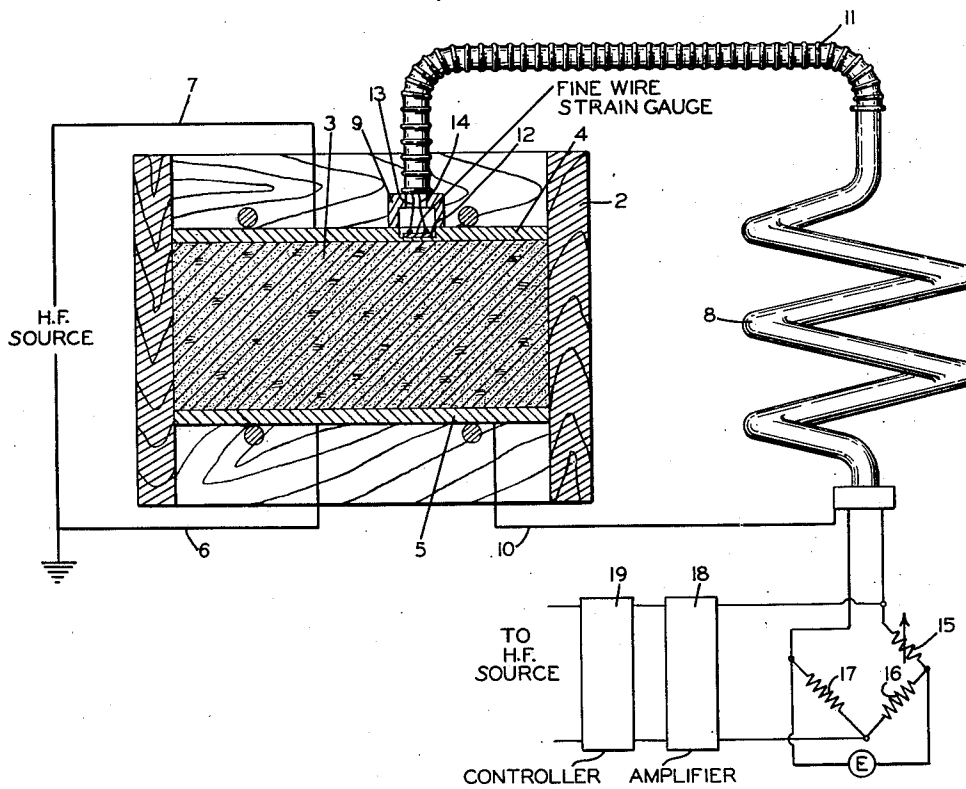
2,602,133

METHOD AND APPARATUS FOR HEATING MATERIALS DIELECTRICALLY

Filed May 23, 1950

2 SHEETS—SHEET 1

Fig. 1



INVENTOR
GEORGE E. GARD

by
Wright & Conner
ATTORNEY

July 1, 1952

G. E. GARD

2,602,133

METHOD AND APPARATUS FOR HEATING MATERIALS DIELECTRICALLY

Filed May 23, 1950

2 SHEETS—SHEET 2

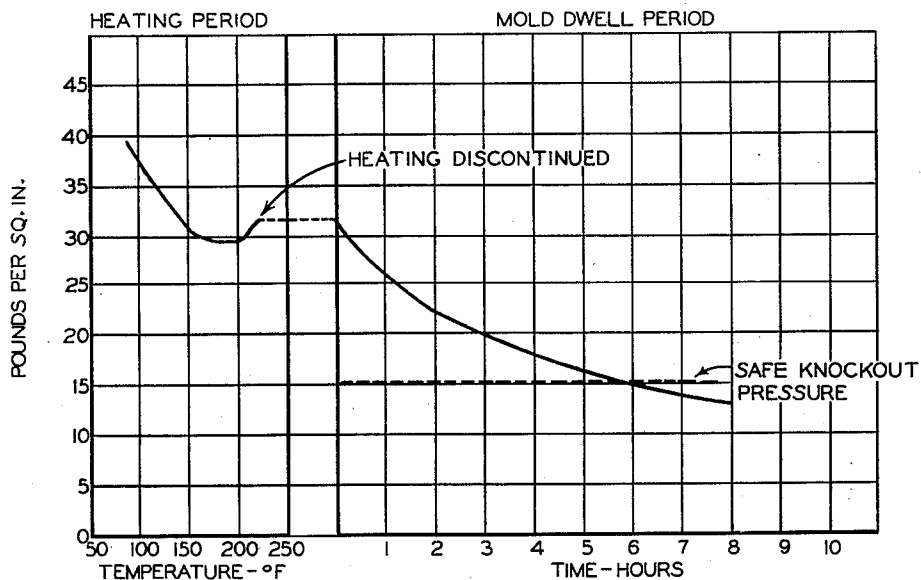


Fig. 2

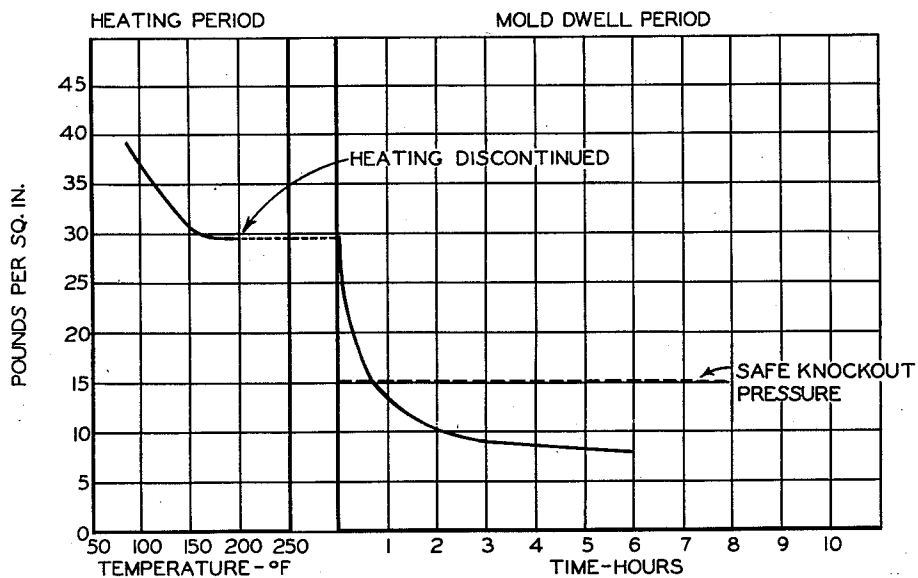


Fig. 3

INVENTOR
GEORGE E. GARD

W. H. & H. J. H. H.

ATTORNEY

UNITED STATES PATENT OFFICE

2,602,133

METHOD AND APPARATUS FOR HEATING
MATERIALS DIELECTRICALLY

George E. Gard, Lancaster, Pa., assignor to Armstrong Cork Company, Lancaster, Pa., a corporation of Pennsylvania

Application May 23, 1950, Serial No. 163,747

5 Claims. (Cl. 219—47)

1

This invention relates to a method and apparatus for heating materials dielectrically and is concerned particularly with a method and apparatus for dielectrically heating materials such as cork compositions and the like while held under confinement within a mold.

In the manufacture of cork compositions utilizing a heat-activatable binder, common practice is to coat the granules with the binder material and charge the coated granules into a mold. The mass is compressed and then heated while under compression to activate the binder. Where dielectric heating is employed, a high-frequency alternating electric field is established within the mass, and this causes the temperature thereof to be elevated rapidly. Thereafter, the mass is maintained in the mold until the cork particles have been substantially completely stress-relaxed and the binder activated to bind the cork granules together.

As pointed out in my copending application Serial No. 152,057 filed March 27, 1950, and entitled "Cork Composition Manufacture," the attainment of too high a temperature within the mass may result in an undesirable increase in vapor pressure which militates against the rapid stress-relaxation or setting of the cork granules, causing the mold dwell time to be increased; for substantially complete stress-relaxation is desirable before the mass is removed from the mold in order to avoid objectionable swelling of the mass upon such release. This is more fully explained in my copending application referred to.

It is also important in the manufacture of cork composition and the like utilizing dielectric heating to discontinue the application of the high-frequency field when the mass attains a desired maximum temperature in order to avoid binder degradation and possible charring of the mass. The temperature can be determined as disclosed in my copending application Serial No. 702,559 filed October 10, 1946, and entitled "Method and Apparatus for Dielectric Heating," now Patent No. 2,508,382, by inserting a heat-responsive device, such as a thermocouple, directly within the mass and using this heat-responsive device for discontinuing the application of the field upon the attainment of the desired predetermined temperature within the mass.

The copending application of George W. Scott, Jr., Serial No. 678,214, filed June 21, 1946, and entitled "Dielectric Heating Method and Apparatus," now Patent No. 2,526,697, discloses that as the temperature of a mass under dielectric treatment increases, its rate of heating increases; and

2

thus there is a so-called "snow balling" or "avalanche" effect which causes an accelerated rate of heating which may rapidly become uncontrollable. It is desirable under such circumstances to have the control equipment responsive instantaneously and continuously to the temperature of the mass. Where there is a tendency for certain portions of the mass to heat at a different rate than other portions, it is desirable to effect the control of the field in accordance with the average temperature of the whole of the mass which is not possible with the probe type thermocouple arrangement, for it is responsive to local temperatures at or adjacent to the area into which the probe is inserted. Where vapor pressure has a material effect on stress-relaxation, as in the manufacture of cork compositions utilizing a binder of glue, glycerine, and formaldehyde, a difference in the temperature of the mass of 20° F. at the time of discontinuance of the application of the field may have a substantial effect on the duration of the mold dwell period.

An object of this invention is to provide a method and apparatus for dielectric heating in which the pressure exerted by the mass is employed to control the dielectric heating. The pressure will vary in accordance with the average temperature of the mass.

Another object of the invention is to provide a method and apparatus for dielectric heating in which the application of the dielectric field to the mass will be discontinued prior to any substantial increase in the pressure exerted by the mass during the heating cycle. The pressure will initially decrease as stress-relaxation occurs in the mass but will increase when the vapor pressure of the binder becomes a measurable factor.

A further object of the invention is to provide a method and apparatus for dielectric heating in which the control of the heating will be responsive substantially instantaneously to the average temperature of the mass measured by the pressure exerted by the mass.

Other objects of the invention will become apparent from a consideration of the description of a preferred embodiment of the invention which follows.

According to this invention, changes in pressure exerted by the mass with temperature changes therein are utilized to control the application of the high-frequency field. The dielectric heating is so controlled that the application of the field is discontinued prior to any substantial increase in vapor pressure which would affect materially the stress-relaxation charac-

teristics of the cork granules. With any given cork composition mass to be cured, the vapor pressure of the mass can be readily determined, and the total force or pressure exerted by the mass at any given temperature can be predicted. It is thus possible to control accurately the average temperature of the mass in accordance with the pressure exerted by the mass. Where the vapor pressure is not known or may vary from batch to batch depending upon the accuracy of binder compounding, automatic control may not be desirable. In such circumstances, a recording meter may be utilized and manual control effected.

In order that the invention may be readily understood, a preferred embodiment will be described in conjunction with the attached drawings, in which:

Figure 1 is a diagrammatic and schematic view of a mold arrangement for dielectrically heating a mass of cork composition and controlling the application of the field to the mass in accordance with the present invention; and

Figures 2 and 3 are graphs showing the relationship between the pressure exerted by a mass and the temperature thereof and the relationship between mold dwell period and pressure exerted by the mass.

Referring to Figure 1, there is shown a mold 2 having walls of wood which may be impregnated with a waterproofing impregnant such as ceresin wax as more fully described and claimed in the copending application of George W. Scott, Jr., Serial No. 678,215 filed June 21, 1946, and entitled "Mold for Confining Material During Dielectric Heating," now Patent No. 2,526,698. A mass of cork composition 3 is disposed within the mold 2 and is held under compression by electrodes 4 and 5. These electrodes are connected to a suitable source of high-frequency current by leads 6 and 7. A tuning coil 8 is provided which is connected across the electrode plates 4 and 5 by a connector 9 and a lead 10. The coil 8 is formed of tubular conductor, and there is a flexible section 11 which permits the upper electrode 4 to be removed to facilitate charging and discharging of the mold 2. It is recognized that high-frequency current will flow in the outer skin surface of a conductor, and it is thus possible to dispose control leads within the tubular conductor 8 where they will be completely shielded from the high-frequency current. Thus a fine wire strain gauge element 12 may be cemented to the upper electrode 4, and the leads 13 and 14 from the strain gauge may then be passed through the tubular conductor 8, emerging therefrom at ground potential. The fine wire strain gauge may be of the type disclosed in Burr Patent No. 2,415,082. The electrode 4 may be recessed as shown to increase the sensitivity of the gauge.

The strain gauge 12 constitutes one leg of a Wheatstone's bridge including a variable resistance member 15 and two fixed resistance members 16 and 17. A source of energizing voltage E is applied to the system in the conventional manner, and the output is fed through an amplifier 18 into a controller 19 which may include a relay effective for controlling the application of current to the electrodes 4 and 5 from the high-frequency source. This may be accomplished in any number of ways as, for instance, by interrupting the input to the high-frequency oscillator or by interrupting the output to the electrodes. The bridge circuit will be so arranged and set that upon reduction of the pressure exerted on

the electrode 4 by the mass to a predetermined value, the controller will be initiated and the supply of current to the electrodes discontinued. For instance, in the production of a cork composition made of the following formulation, it may be desirable to interrupt the supply of high-frequency current when the mass attains a pressure in the order of 29 to 30 pounds per square inch, assuming the initial pressure of the charged mass compressed in the mold to be in the order of 38 to 40 pounds per square inch. With this composition the temperature of the mass will be in the order of 190 to 200° F. when the pressure falls to about 29 pounds.

	Parts by weight
5 to 9 mesh cork (U. S. Standard) -----	100
Glycerin -----	20
Glue -----	6.5
Water -----	2.5
Paraformaldehyde -----	.52

Referring to Figure 3 which includes in the left-hand portion a graph of temperature vs. pressure for the above-identified cork composition, it will be noted that as the temperature of the mass initially increases, the pressure drops, and that when the temperature approaches 190° F., the pressure tends to level off at about 29 pounds per square inch. Referring now to Figure 2, which is a similar graph showing the identical cork composition, it will be noted that as the temperature increases from the range between 180 and 190° F., the pressure then tends to rise. This may be explained in accordance with the theory expressed in my copending application Serial No. 152,057, referred to above as an initial decrease in pressure due to partial setting or stress-relaxation of the cork granules and an increase due to the development of a vapor pressure component within the mass. The stress relaxation of the cork is materially inhibited by the vapor pressure as is evidenced from a comparison of Figures 2 and 3. In Figure 3 where the heating was discontinued when the pressure fell to about 29 pounds, the mold dwell period was relatively short and the stress relaxation was rapid, falling from 29 pounds to below 15 pounds in slightly less than one hour. As my application Serial No. 152,057 points out, when the pressure is less than about 15 pounds per square inch the mass may be removed from the mold without danger of excessive "swelling" of the mass, provided, of course, the binder has been satisfactorily heat-activated in such period. Longer mold dwell periods are required for some cork compositions to insure satisfactory binder conversion. With the composition given above, a dwell period of two hours will be adequate where the maximum temperature at the time of discontinuance of the high-frequency heating is about 200° F. From Figure 3 it will be seen that the pressure will have dropped to about 10 pounds per square inch at the end of a two-hour dwell period—below the safe pressure at which the mass may be removed from the mold and the mold made ready for reuse.

In Figure 2 where the high-frequency field is not discontinued until after the pressure has commenced to increase and has reached about 32 pounds per square inch, the mold dwell time will be much longer and the pressure will not fall to the safe limit of 15 pounds until the mass has been in the mold for a period of about six hours.

From the foregoing it will be observed that it is advantageous to control the application of the field so as to interrupt the heating prior to any

substantial increase in vapor pressure as evidenced by an increase in pressure exerted by the mass as a whole. The entire dielectric heating cycle may require only three minutes or less; and in only a few second's time after the mass has been elevated to about 200° F., it will rise to 220° F. This small difference in temperature, and concomitant increase in pressure, causes a major increase in mold dwell time as shown in the graphs of Figures 2 and 3.

As previously mentioned, in place of having an automatic control on the dielectric heating equipment, such as indicated in Figure 1, manual control may be effected. This may be accomplished by coupling the amplifier 18 to a meter which may be calibrated to read pressure in pounds per square inch. With this arrangement an operator can follow the visual indication of pressure and can interrupt the application of the high-frequency field to the mass prior to any important increase in pressure. This is particularly desirable where the initial molding pressure, the moisture content of the cork, the size of the cork granules, the distribution of the binder, or other variable factors which affect the pressure exerted by the mass through stress-relaxation, vapor pressure, or otherwise may make automatic control impracticable. The control may be effected manually with great accuracy by providing a recording device on the meter. As the curve of pressure tends to flatten out before it starts to rise, due to the vapor pressure component, the supply of energy to the electrodes may be interrupted. The operator can very quickly perceive the trend in the curve as it is formed and may actually anticipate the levelling off by a short period and further reduce the mold dwell time, in instances where this may be commercially important, for there is undoubtedly a period when vapor pressure is approaching a force equal to the diminution in total force due to stress-relaxation of the cork granules. Where initial pressure, binder formulation, and the other possible variable factors mentioned above are constant, the automatic control will be set by arranging the bridge circuit to actuate the control when the pressure has fallen to the desired value, taking into account any such desirable anticipation of a pressure increase.

While preferred practice is to have the fine wire strain gauge or other pressure-sensitive device attached to one or the other electrodes 4 or 5, the strain gauge or its equivalent may be positioned in other locations. For instance, the strain gauge could be positioned in a wall of the mold 2 adjacent the inner surface thereof, and the leads from the strain gauge could be led out through a shielding arrangement into the tubular conductor 8 in a manner similar to that disclosed for the thermocouple leads in my copending application Serial No. 702,559, now Patent No. 2,508,382, referred to above or for the resistance lead in my application Serial No. 163,748 filed concurrently herewith and entitled "Method and Apparatus for Dielectric Heating." The need for shielding may be eliminated where the application of the field is intermittent as in a "keying" system. The pressure-measuring and/or controlling equipment will be so arranged as to be brought into operation either manually or automatically when the high-frequency field is intermittently interrupted.

I claim:

1. Apparatus for dielectrically heating a confined mass of material which initially decreases

in pressure exertion upon heating but which thereafter increases in pressure exertion as the temperature thereof rises comprising: a pair of electrodes disposed in fixed spaced relationship; a mold for receiving said mass to be treated under confinement between said electrodes; means connecting said electrodes to a source of high-frequency alternating voltage; and means responsive to reduction in pressure exerted by said mass against said electrodes as the temperature thereof rises for discontinuing the application of high-frequency alternating voltage to said electrodes at substantially said point of minimum pressure exertion by said mass during heating.

2. In a method of dielectrically heating a confined mass of material which initially decreases in pressure exertion upon heating due to stress relaxation within the mass but which upon reaching a point of minimum pressure exertion thereafter increases in pressure exertion due to increase in vapor pressure within the mass as the temperature thereof rises, the steps comprising confining the mass under applied compression, applying a high-frequency alternating electric field to the mass from a source of high frequency voltage to heat said mass and cause the pressure exerted by said mass to decrease, and discontinuing the application of the field to the mass at substantially the point of minimum pressure exerted by said heated mass during heating and prior to any increase in pressure exertion above said point of minimum pressure exertion which would affect substantially the stress relaxation characteristics of said mass.

3. In a method of dielectrically heating a confined mass of cork composition including cork granules and a heat-convertible binder, which mass initially decreases in pressure exertion upon heating due to stress relaxation within the mass of cork granules but which upon reaching a point of minimum pressure exertion thereafter increases in pressure exertion due to increase in vapor pressure within the mass as the temperature thereof rises, the steps comprising confining a mass of cork composition within a mold under applied compression, applying a high-frequency alternating electric field to the mass from a source of high-frequency voltage to heat said mass and cause the pressure exerted by said mass to decrease, and controlling the application of said field to said mass of cork composition confined within said mold in accordance with the pressure exerted by said confined mass to bring said mass to substantially the point of minimum pressure exerted by said heated mass during heating and without any increase in pressure exertion above said point of minimum pressure exertion which would affect substantially the stress relaxation characteristics of said mass.

4. In a method of dielectrically heating a confined mass of cork composition including cork granules and a glue binder, which mass initially decreases in pressure exertion upon heating due to stress relaxation with the mass of cork granules but which upon reaching a point of minimum pressure exertion thereafter increases in pressure exertion due to increase in vapor pressure within the mass as the temperature thereof rises, the steps comprising confining a mass of said cork composition within a mold under applied compression between spaced electrodes, applying a high-frequency alternating electric field to the mass from a source of high-frequency voltage, thereby heating said mass to a temperature at which stress relaxation in said cork granules will

7

be accelerated and the pressure exerted by said mass will be decreased, and discontinuing the application of the field to the mass at substantially the point of minimum pressure exerted by said heated mass during heating and prior to any increase in pressure exertion above said point of minimum pressure exertion which would affect substantially the stress relaxation characteristics of said mass.

5. Apparatus for dielectrically heating a confined mass of material which initially decreases in pressure exertion upon heating but which upon reaching a point of minimum pressure exertion thereafter increases in pressure exertion as the temperature thereof rises comprising a pair of electrodes disposed in fixed spaced relationship, means confining the mass to be treated while disposed between said electrodes, means connecting said electrodes to a source of high-frequency voltage, and means responsive to reduction in pressure exerted by said mass as the temperature thereof rises for discontinuing the application of high-frequency alternating voltage to said electrodes at substantially said point of minimum pressure exertion by said mass during heating.

8

GEORGE E. GARD.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
451,240	Dewey	Apr. 18, 1891
2,252,464	Kearns et al.	Aug. 12, 1941
2,316,251	Kahle et al.	Apr. 13, 1943
2,467,783	Sears	Apr. 19, 1949