

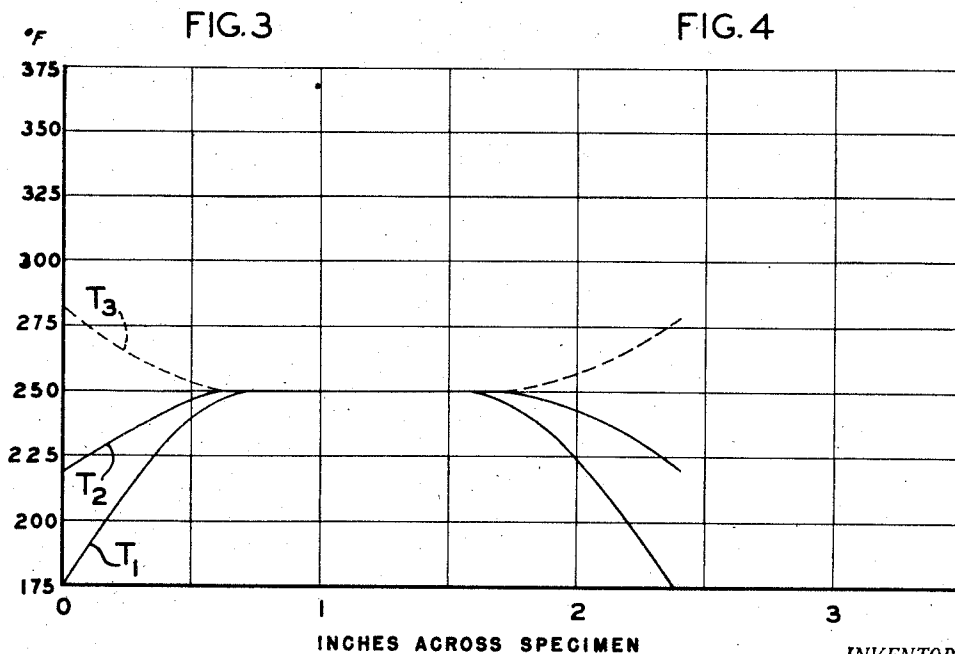
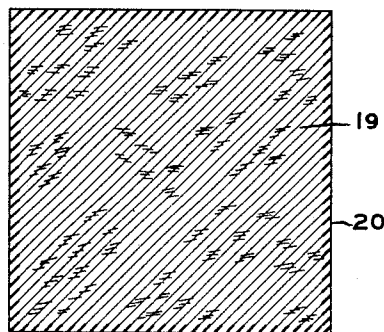
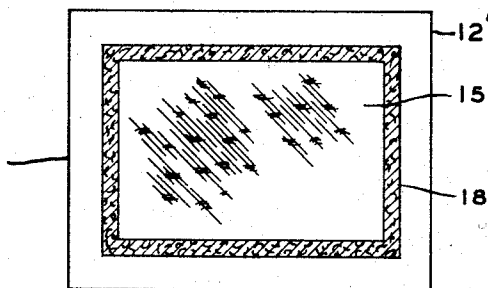
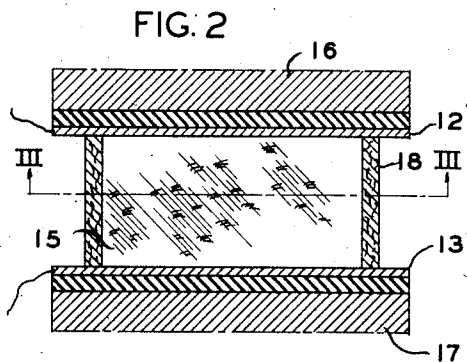
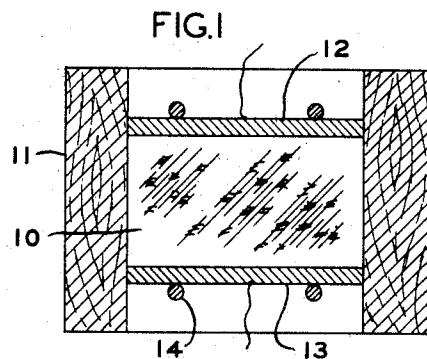
Oct. 24, 1950

G. E. GARD

2,526,699

METHOD OF COMPENSATING FOR OR PREVENTING HEAT LOSSES
FROM MATERIAL DURING DIELECTRIC HEATING THEREOF

Filed June 21, 1946



INVENTOR.
GEORGE E. GARD

FIG. 5

by
Stebbins, Blenko & Webb
ATTORNEYS

UNITED STATES PATENT OFFICE

2,526,699

METHOD OF COMPENSATING FOR OR PREVENTING HEAT LOSSES FROM MATERIAL DURING DIELECTRIC HEATING THEREOF

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

Application June 21, 1946, Serial No. 678,217

10 Claims. (Cl. 219—47)

1

This invention relates to a method of processing material by dielectric heating and, in particular, to a method of heating a mass of amorphous particles to a substantially uniform temperature, despite the loss of heat from the surfaces of the mass by conduction or otherwise.

When a mass of dielectric material is subjected to a high-frequency electric field for heating it by the dielectric effect, the curve of temperature distribution throughout the mass rises from the outside toward the interior thereof. This results from the loss of heat from the exterior due to conduction or radiation or both. This condition is aggravated where the material being heated is of such shape that its exposed surface area per unit of volume is large. In such instances, the temperature which is attained by the material adjacent the electrodes and that at the lateral surfaces of the mass under treatment are substantially less than that existing in the center of the body. This may prevent activation of the binder adjacent the surface areas. If the length of the heating period is increased in order to attain the necessary temperature at such surfaces, overcuring or overactivation may occur on the interior of the mass. As an example, in the curing or setting of a cork-composition block made from a mass of cork granules coated with a heat-activatable binder such as a mixture of glue, glycerin and paraformaldehyde or plasticized phenol-formaldehyde resin, the outer portions of the block which are in contact with the mold surfaces have a tendency to be substantially undercured as evidenced by crumbling of the block adjacent such surfaces upon removal of the mass from the mold. Such portions, of course, must be trimmed from the block and scrapped prior to cutting the block into sheets such as those used in making cork gaskets.

The heat generated by the dielectric effect varies with the loss factor of the material, $K \tan \delta$, K being the dielectric constant and $\tan \delta$ the dissipation factor of the material. I take advantage of this fact to cause a greater amount of heat to be generated in the portions of the mass adjacent the surfaces thereof than in the interior.

Specifically, I sheath the mass under treatment with material having a loss factor greater than that of the mass of material under treatment. This may be accomplished by choosing for the wall of the mold surrounding the mass under treatment, a material having a higher loss factor than the material under treatment. In another practice of my invention the same effect is obtained by actually coating the surface of

2

the mass under treatment with a material having a higher loss factor than the material composing the mass so that the surface, even though it be only a few thousandths of an inch thick, actually attains a higher temperature than the remainder of the mass and thus acts as a heat barrier or heat wall preventing heat losses which ordinarily occur there.

It must be borne in mind that the nature of the material composing the mold wall or the surface coating which has a higher loss factor, will have an appreciable effect on the amount of energy required to effect the heating of the surface portions to a higher temperature. This may be expressed by the formula

$$(\text{loss factor})_{\text{wall}} \geq (\text{loss factor})_{\text{mass}} \times \frac{Q_w}{Q_d}$$

where Q_w and Q_d are the heat capacity of the mold wall and the mass to be heated, respectively.

Where a coating of material having a higher loss factor is applied to the surface of the mass under treatment, the coating material may form part of the finished article or, if desired, may be a fugitive material which is consumed or dissipated in the dielectric heating of the mass. For example, in the dielectric heating of a phenol-formaldehyde composition including a filler of wood-fiber, a coating may be applied to the surfaces of the articles which are normal to the plane of the electrodes. By choosing a coating material possessing a higher loss factor than the mass, the surface portions will be heated to a higher temperature than the interior of the mass and when final curing has been effected, both the coating on the surface and the binder within the body will be heat set. Where preforms for molding are under treatment, partial activation may be accomplished and the final setting of the binder accomplished in a conventional molding press.

The rate of dielectric heating increases as the temperature of the mass rises due to the increase in the numerical value of the loss factor ($K \tan \delta$) with increased temperature. For example, in the molding of a block of cork composition as previously described, if the mold in which the material is confined is heated to a temperature greater than the temperature of the mass of material under treatment, the rate of heating of the mold will be proportionately greater than the rate of heating of the mass of cork composition. Thus the mold may have an initial loss factor the same as that of the cork composition or even less,

and still heat up faster than the mass, giving a higher rate of heating at the surfaces where the greatest heat losses occur.

A complete understanding of the invention may be gained from the following description and accompanying drawings. In the drawings,

Figure 1 is a vertical sectional view through a mold constructed in accordance with the principles of the present invention, containing a mass of material to be heated dielectrically;

Figure 2 is a similar view showing the invention applied to the heating of a body of dielectric material in a platen press;

Figure 3 is a sectional view substantially on the plane of line III—III of Figure 2, showing how the lateral surfaces of a block under treatment are arranged to accomplish the results sought for in the present invention;

Figure 4 is a view similar to Figure 3 showing high-loss material incorporated in the exterior surface or shell of the mass of material under treatment; and

Figure 5 is a set of curves showing the temperature distribution through a mass of material under treatment.

Referring first to Figure 1, a mass 10 of dielectric material such as cork composition or the like which is to be heated dielectrically is confined within a mold 11 of suitable material, e. g., wax-impregnated wood, such as that more particularly described and claimed in the copending application of George W. Scott, Jr., Serial No. 678,215, filed June 21, 1946. The mass is held under pressure between metal plates 12 and 13 which serve as electrodes and are held in position by pins 14 passing through the walls of the mold.

When high-frequency voltage is applied to the electrodes 12 and 13, the mass 10 and mold 11 are heated by the dielectric effect. The wall of the mold 11 has a higher loss factor than the cork granules and binder composing the mass 10 under treatment. This may be obtained by using a material for the mold wall which possesses such higher loss factor or by heating the mold to cause an increase in its normal loss factor. The material used for the mold 11 must satisfy the equation set forth above, in which the loss factor of the mold wall is equal to or greater than that of the mass times the quotient of the heat capacity of the mold divided by the heat capacity of the material under treatment. As a result, the surfaces of the mass in contact with the mold 11 attain a temperature at least as great as the interior of the body of the mass and may, if desired, be caused to reach a higher temperature. In either event, compensation for heat loss is obtained. In the manufacture of certain products, it may be found desirable to have the mold 11 reach a temperature substantially higher than the mass under treatment and thereby cause the surfaces of the mass where greatest heat loss is occasioned to have a correspondingly higher temperature. This makes it possible to maintain safely a minimum temperature within the body of the mass for a greater period of time than if the mass were heated uniformly throughout. For example, in curing a mass of cork composition where the minimum curing temperature is in the order of 220° F., the portions adjacent the peripheral surfaces may be heated to a temperature of 250° F. and the whole mass will be maintained above the minimum temperature until such time as the peripheral surfaces dissipate heat to the atmosphere in an

amount sufficient to reduce their temperature from 250° F. to 220° F.

The problem of reducing heat loss from masses of material under treatment in platen presses is aggravated because the peripheral edges of the mass are exposed and subject to greater radiation than where they are confined within the mold. This loss may be compensated by the scheme shown diagrammatically in Figure 2 where the mass of material 15 being heated is disposed between press platens indicated at 16 and 17. I provide layers 18 surrounding the lateral surfaces of the mass having a loss factor higher than that of the mass 15. Electrodes 12' and 13' are provided between which the mass of material 15 and the layers 18 are electrically connected in parallel. Heat loss from the portions adjacent to the lateral surfaces of the mass will be compensated substantially in the same manner as in Figure 1. The layers 18, however, also serve to limit loss of heat by radiation and convection. This is clearly apparent from Figure 3, a horizontal section showing how the exterior of the mass 15 is protected against undesired heat losses when heating is being carried out in a press such as that shown in Figure 2.

As stated above, the principles of the present invention may be applied by treating the exterior surface of the mass with a coating material having a higher loss factor than that of the mass, so that the heat compensation actually takes place as a result of heating the exterior shell of the mass to a higher temperature than the interior of the mass. An example of this is shown diagrammatically in Figure 4, where the mass 19, composed of material such as cork composition or the like, is treated over its exterior surface with a high-loss material indicated at 20. Figure 4 shows all of the lateral surfaces coated. This may be a coating of material in liquid form which penetrates the surface of the mass to a desired distance and upon evaporation of the solvent forms an integral part of the mass to be heated. On the other hand, this material may be of fugitive form so that during the heating it is volatilized and lost to the atmosphere or it may be material which performs an added function; for example, serves as a surface binder or finish for the mass which is to be heated. The mass 19, treated as indicated in Figure 4, is susceptible of being subjected to preliminary heating in the manner specified above in connection with the scheme of Figure 1.

In the manufacture of articles such as jar covers from molding compositions of the usual type, including a binder of phenol-formaldehyde, for example, where dielectric preheating is used, it has been found desirable to compensate for heat losses which occur at the surface of the preforms in order to permit as rapid article formation as possible. Assuming that the temperature desired in the preform is in the neighborhood of 250° F., it has been determined that, by preheating dielectrically, this temperature can be attained quite rapidly at the interior of the body, but the surfaces which are exposed to the atmosphere during preheating are at a substantially lower temperature in the neighborhood of 175° F., for example. A substantially shorter molding cycle can be obtained if the preforms are heated more nearly to the desired temperature throughout. I have found, in accordance with my invention, that the preforms may be coated on their outer surfaces and dielectrically heated, and the heat losses at the surface compensated for by reason

of the higher loss factor in the surface coating. As a specific example, I have taken preforms of phenol-formaldehyde molding powder suitable for use in the manufacture of molding jar covers, and have treated them with a concentrated acetone extract of the binder of phenol-formaldehyde. This I have applied to the surfaces of the preforms and have then dielectrically preheated them, elevating the interior of the preforms to 250° F. The temperature at the outer surface has thus been raised to 195° F., whereas without such coating the temperature at the surface will be in the neighborhood of 175° F., when the interior is at 250° F. By this practice, the molding cycle may be shortened materially since it is not necessary in actual molding to bring the temperature to 250° F. from 175° F., but only from 195° F. A noticeable saving in time is represented by the difference between the temperature at the outer surface in the two cases. There is, of course, a temperature gradient within the mass from the interior which is at 250° F., to the exterior which is at 195° F.

In a modified practice, I have coated the surface of molding composition preforms with a coating of resorcin and formaldehyde in equal parts. This coating was melted and then applied to the preforms. Upon preheating, the temperature of the preforms at the interior was raised to 250° F. and the exterior attained a temperature of 220° F. With this coating, an even shorter molding cycle is possible. Since the molds in which the preforms are actually formed into the desired finished article are heated, it is not necessary that the exterior surface attain a temperature higher than the interior, although this may, in some instances, be desirable, and can be obtained in accordance with my invention. For example, in the automatic molding of bottle closures, it may be desirable to preheat the preforms to a higher temperature at the outer surface, particularly where there is a considerable time lapse between the time of preheating and the time of actual insertion of the preform into the mold and the closing thereof.

In the modification shown in Figure 4 as in the other illustrated embodiments of the invention, the lateral surface portions 20 of higher loss factor will be electrically connected in parallel with the body portion 19 between the electrodes during dielectric heating.

A similar problem is involved in the manufacture of cork composition blocks as mentioned above, and in tests which I have made in the treatment of cork composition dielectrically, I have coated the mold surfaces which are in engagement with the cork granules and binder during molding with a resorcin-formaldehyde coating composition. This has proved effective to increase the temperature at the outer surface of the block under treatment. In the particular case referred to, the resorcin-formaldehyde material was actually mixed with the mold lubricant, which was applied to the surfaces of the mold in contact with cork composition.

Figure 5 illustrates the variations in temperature across the width of a mass of material being subjected to dielectric heating. Curve T₁ shows conditions normally existing and curve T₂ shows the effect of my invention. As indicated by the curve T₁, the temperature of a mass of material subjected to dielectric heating as in the second example given above, may vary from 250° on the interior to 175° on the exterior because of the loss of heat to surrounding media.

This results in undercuring of the surface portions of the mass. The curve T₂ shows the effect of my invention in reducing the temperature differential between the surface portions of the mass and the interior. Curve T₃ represents conditions which might be desired in some cases, i. e., the surfaces of the mass at a higher temperature than the interior.

Those skilled in the art will recognize that the loss factor of the material from which the mold or other confining element is made must not be so high as to short-circuit the electrodes yet it should be sufficiently high so as to obtain the desired accelerated rate of heating to accomplish the end result sought for. The material must further be of such a nature as to withstand the applied voltage.

It will be apparent from the foregoing that my invention possesses advantages not realized in the prior practice of dielectric heating. The invention provides a simple, inexpensive manner of compensating for the heat lost from the exterior of a mass of material undergoing heating and makes possible a product having a higher degree of uniformity without the danger of overheating or overcuring the interior portion thereof.

Although I have illustrated and described but a preferred embodiment and certain modifications of my invention, it will be understood that changes in the procedure described may be made without departing from the spirit of the invention or the scope of the appended claims.

I claim:

1. In a method of dielectrically heating a mass of dielectric material having lateral surfaces subject to surface cooling, the steps including: disposing said mass within a mold of dielectric material having a higher loss factor than that of said mass with the lateral surfaces of said mass in contact with the walls of said mold; positioning said mass between a pair of plate electrodes with said mass and said mold walls in contact with the lateral surfaces of the mass electrically connected in parallel between said electrodes; and simultaneously subjecting said mass and said mold walls to a high-frequency alternating electric stress by impressing a high-frequency alternating electric voltage between said electrodes to generate heat simultaneously within both said mass and said mold walls, said mold walls, having a higher loss factor than that of the mass and being disposed in a parallel circuit therewith between said electrodes, heating at a rate faster than the rate of dielectric heating of said mass during the application of said high-frequency alternating electric stress thereto.

2. In a method of dielectrically heating a mass of dielectric material having lateral surfaces subject to surface cooling, the steps including: disposing said mass in a mold with the lateral surfaces of the mass in contact with mold wall surfaces having a dielectric loss factor greater than that of the mass; disposing said mass and said mold within a high-frequency electric field between a pair of plate electrodes, with said mass and said mold wall surfaces electrically connected in parallel between said electrodes; and simultaneously subjecting said mass and mold to high-frequency alternating electric stress by impressing a high-frequency alternating electric voltage upon said plate electrodes to generate heat simultaneously within both said mass and said mold, said mold wall surfaces in contact

with the lateral surfaces of the mass having a dielectric loss factor greater than that of the mass and being disposed in a parallel circuit therewith between said electrodes heating at a faster rate than the rate of dielectric heating of said mass.

3. In a method of dielectrically heating a body of dielectric material having lateral surfaces subject to surface cooling, the steps including: contacting said lateral surfaces of said body of dielectric material subject to surface cooling with a second dielectric material having a higher loss factor than that of said body of dielectric material; disposing said body of dielectric material so contacted between a pair of plate electrodes, with said body of dielectric material and said second dielectric material electrically connected in parallel between said electrodes; and simultaneously subjecting said body of dielectric material and said second dielectric material to high-frequency alternating electric stress by impressing a high-frequency alternating electric voltage upon said plate electrodes to generate heat simultaneously within both said body of dielectric material and said second dielectric material, said second dielectric material, having a higher loss factor than that of said body of dielectric material and being disposed in a parallel circuit therewith between said plate electrodes, heating at a rate faster than the rate of dielectric heating of said body of dielectric material during the dielectric heating of said body of dielectric material.

4. In a method of offsetting or preventing heat losses due to thermal conduction, convection or radiation from the lateral surfaces of a body of dielectric material, the steps including, applying a second dielectric material to the lateral surfaces of said body of dielectric material, said second dielectric material having a dielectric loss factor and heat capacity productive upon dielectric heating of a higher temperature at said surfaces than within said body of dielectric material, dielectrically heating said body of dielectric material and said second dielectric material between electrodes, said body of dielectric material and said second dielectric material being electrically connected in parallel between said electrodes during said dielectric heating, whereby the higher temperature of said second dielectric material at said surfaces is effective in maintaining a desired temperature at said lateral surfaces relative the temperature maintained within the interior of said body of dielectric material.

5. In a method of offsetting or preventing heat losses due to thermal conduction, convection or radiation from the lateral surfaces of a body of dielectric material, the steps including, positioning said body of dielectric material between electrodes, applying a sheath-like layer of a second dielectric material to the lateral surfaces of said body of dielectric material, said lateral surfaces being those extending between said electrodes, said second dielectric material having a higher rate of dielectric heating than said body of dielectric material, dielectrically heating said body of dielectric material and said second dielectric material by applying a high-frequency voltage across said electrodes, with said body of dielectric material and said second dielectric material electrically connected in parallel between said electrodes, whereby the higher rate of dielectric heating of said second dielectric material is effective

in substantially preventing any outward loss of heat from said lateral surfaces.

6. In a method of offsetting or preventing heat losses from the lateral surfaces of a body of dielectric material during dielectric heating thereof, the steps including, positioning said body of dielectric material between electrodes in substantially close contact therewith, applying a second dielectric material to the lateral surfaces of said body substantially normal to the planes of said electrodes, said second dielectric material having a dielectric loss factor higher than the dielectric loss factor of said body of dielectric material, dielectrically heating said body of dielectric material and said second dielectric material by applying a high-frequency voltage across said electrodes, with said body of dielectric material and said second dielectric material electrically connected in parallel between said electrodes, whereby the higher rate of dielectric heating of said second dielectric material is effective in substantially preventing any outward loss of heat from said lateral surfaces.

7. In a method of offsetting or preventing heat losses due to thermal conduction, convection or radiation from the lateral surfaces of a body of dielectric material, the steps including, coating said lateral surfaces of said body of dielectric material with a second dielectric material, said second dielectric material having a dielectric loss factor higher than the dielectric loss factor of said body of dielectric material whereby said second dielectric material reaches a higher temperature upon being dielectrically heated than the temperature reached by said body of dielectric material, subjecting said body of dielectric material and said coating of said second dielectric material to dielectric heating between electrodes across which a high-frequency voltage is impressed, said body of dielectric material and said coating on said lateral surfaces being electrically connected in parallel between said electrodes during said dielectric heating, whereby the higher temperature reached by said coating of said second dielectric material is effective in maintaining a substantially uniform temperature throughout said body of dielectric material for the thermal activation of said body.

8. In a method of offsetting or preventing heat losses due to thermal conduction, convection or radiation from the lateral surfaces of a body of dielectric material, the steps including, coating said lateral surfaces of said body of dielectric material with a second dielectric material, said second dielectric material also being a surface binder or finish coat material and having a dielectric loss factor higher than the dielectric loss factor of said body of dielectric material, and subjecting said body of dielectric material and said coating of said second dielectric material to dielectric heating between electrodes across which a high-frequency voltage is impressed, said body of dielectric material and said coating on said lateral surfaces being electrically connected in parallel between said electrodes during said dielectric heating, whereby the higher rate of dielectric heating and consequent temperature of said coating of said second dielectric material is effective in maintaining a substantially uniform temperature throughout said body of dielectric material during thermal activation of said body and said coating serves as a surface binder or finish coat for said body of dielectric material.

9. In a method of dielectrically heating a mass of dielectric material having lateral surfaces

9

subject to surface cooling, the steps including: depositing said mass within a mold of dielectric material with a coating having a higher loss factor than that of said mass interposed between the mass and the mold; positioning said mass between a pair of plate electrodes with said mass and said coating electrically connected in parallel between said electrodes; and simultaneously subjecting said mass and said coating to a high-frequency alternating electric stress by impressing a high-frequency electric voltage between said electrodes to generate heat simultaneously within said mass and said coating, said coating, having a higher loss factor than that of the mass and being disposed in a parallel circuit therewith between said electrodes, heating at a rate faster than the rate of dielectric heating of said mass during the application of said high-frequency alternating electric stress thereto.

10. In a method of dielectrically heating a mass of dielectric material having lateral surfaces subject to surface cooling, the steps including: disposing said mass within the walls of a mold of dielectric material heated to a temperature above the temperature of the mass and having a higher loss factor than that of said mass, with the lateral surfaces of said mass in contact with the heated walls of said mold; positioning said mass between a pair of plate electrodes with said mass and said mold walls in contact with the lateral surfaces of the mass electrically connected in parallel between said electrodes; and simultaneously subjecting said mass and said mold walls

10

to a high-frequency alternating electric stress by impressing a high-frequency alternating electric voltage between said electrodes to generate heat simultaneously within both said mass and said mold walls, said mold walls, having a higher loss factor than that of the mass and being disposed in a parallel circuit therewith between said electrodes, heating at a rate faster than the rate of dielectric heating of said mass during the application of said high-frequency alternating electric stress thereto.

GEORGE E. GARD.

REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,280,771	Dufour et al.	Apr. 28, 1942
2,303,341	Dufour et al.	Dec. 1, 1942
2,304,958	Rouy	Dec. 15, 1942
2,308,995	Miess	Jan. 19, 1943
2,341,617	Hull	Feb. 15, 1944
2,388,824	Brown	Nov. 13, 1945
2,413,003	Sherman	Dec. 24, 1946
2,421,101	Lasko	May 27, 1947
2,463,054	Quayle et al.	Mar. 1, 1949

FOREIGN PATENTS

Number	Country	Date
517,798	Great Britain	Feb. 8, 1940