Aug. 23, 1960 H. J. CAMERON 2,949,677

DIELECTRIC DRYING OF MATERIALS

Filed July 30, 1956

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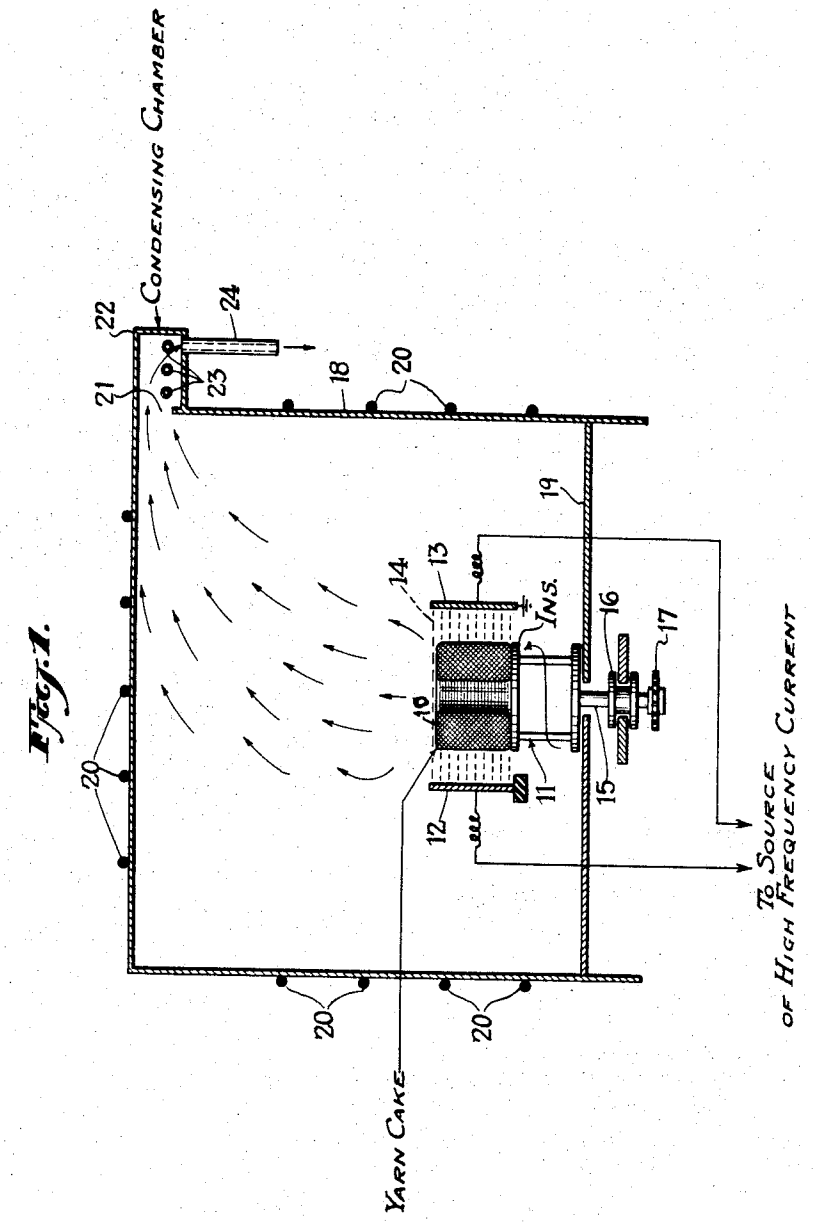


Fig. 1.

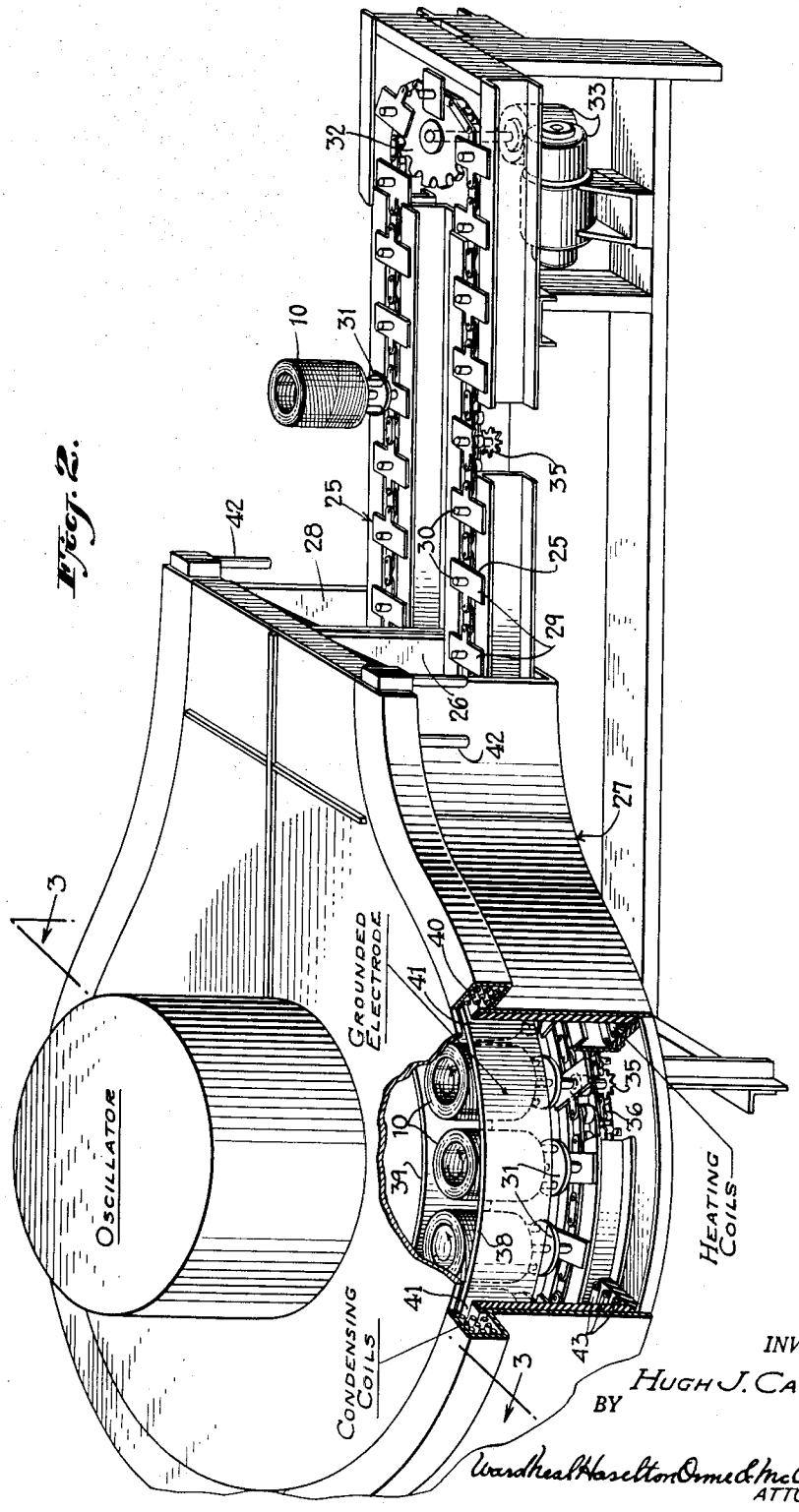
INVENTOR.
HUGH J. CAMERON.
BY
Ward, Heal, Haselton, Orme & McElhannon
ATTORNEYS.

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Fig. 2.



INVENTOR.
HUGH J. CAMERON.
BY
Ward Neal Haselton Ormel & McElhannon
ATTORNEYS.

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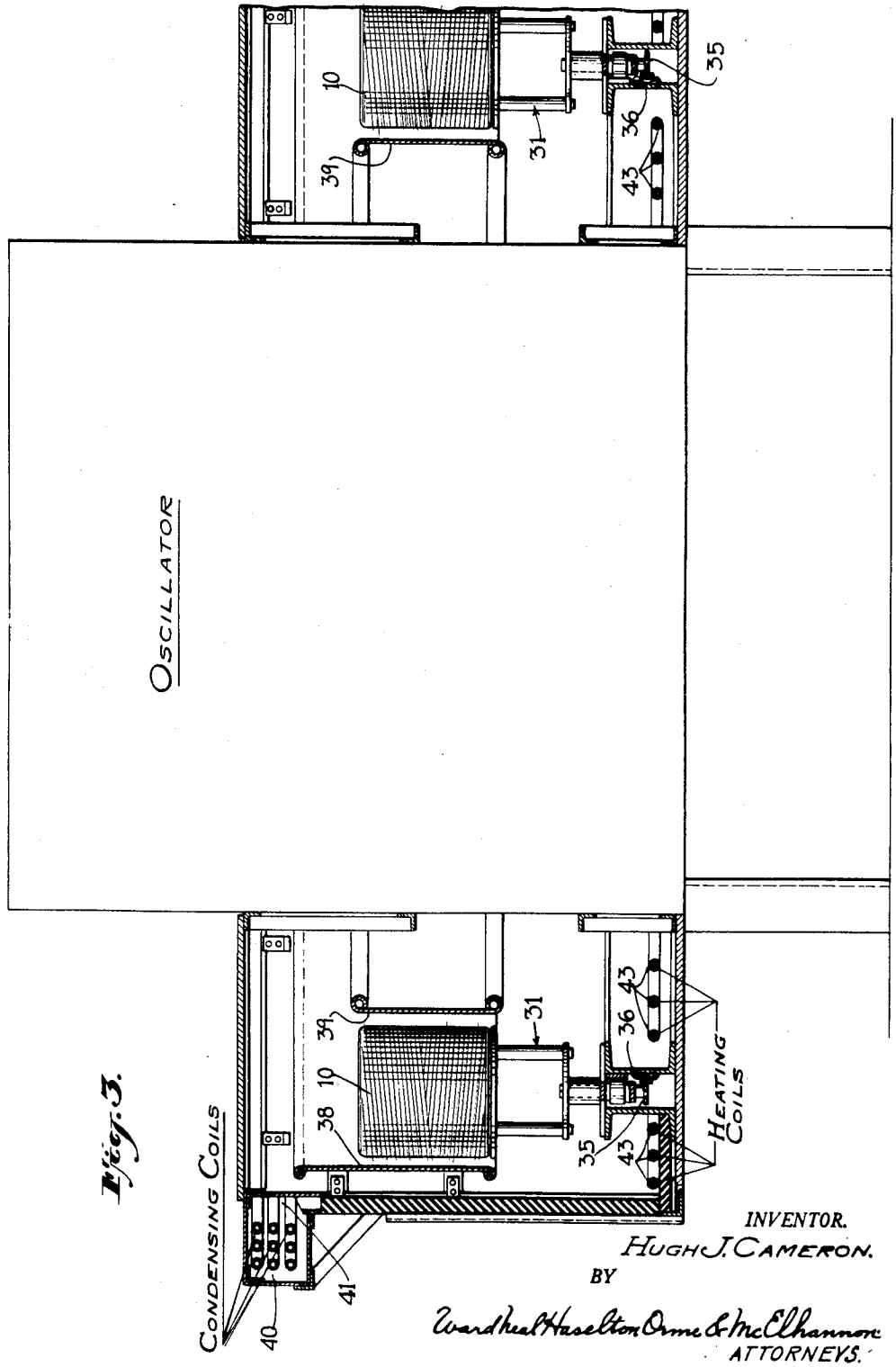


Fig. 3.

INVENTOR.
HUGH J. CAMERON.
BY
Ward Neal Haselton Orme & McElhannon
ATTORNEYS.

Aug. 23, 1960 H. J. CAMERON 2,949,677

DIELECTRIC DRYING OF MATERIALS

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4 Sheets-Sheet 4

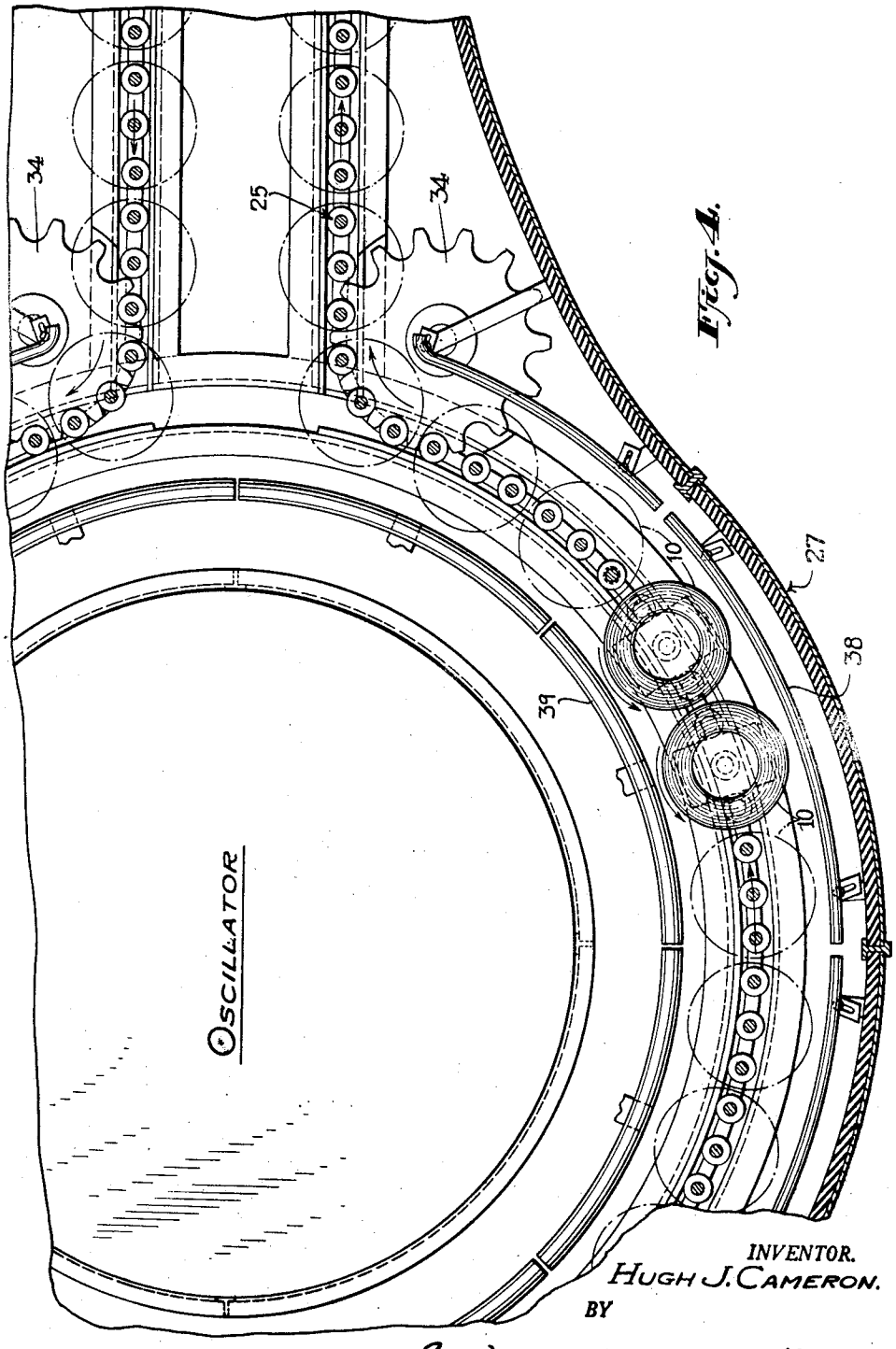


Fig. 4.

INVENTOR.
HUGH J. CAMERON.
BY
Ward Neal Haselton Orme & McElhannon
ATTORNEYS.

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DIELECTRIC DRYING OF MATERIALS

Hugh J. Cameron, New Rochelle, N.Y., assignor to Magnetic Heating Corp., New Rochelle, N.Y., a corporation of New York

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6 Claims. (Cl. 34—1)

This invention relates to methods and apparatus for separating volatile liquids from other material by dielectrically heating the material to cause evaporation of the liquid therefrom. The invention is particularly adapted for the removal of water from porous or absorbent solids.

The invention will be herein described in a form particularly adapted for the drying of so-called "cakes" of rayon yarn, but it will be understood that the invention in various of its aspects is well adapted for the drying of other materials, such as textiles, wood, sponge rubber and the like, paper and pulp materials and the baking of articles such as foundry cores.

The drying of materials by dielectric heating involves the reducing of the water content of the material by the internal generation of heat therein, produced by subjecting same to a high frequency electrical field maintained between a pair of spaced electrodes. In order that such high frequency field may be sufficiently effective for the purpose, it is in practice necessary to apply to the electrodes a potential high enough such as to be liable to generate arcs and cause dielectric breakdown of the air space about the electrodes. The presence of water in the form of mist or as droplets on any conducting surface in the vicinity, greatly increases the liability of arc formations and destructive electrical discharges. Thus a major problem has involved the prompt and effective removal of the moisture vaporized by the high frequency heating, to prevent condensation on the electrodes or other parts of the apparatus. To this end, it has been customary to provide sensible heat to the electrodes and to force a considerable volume of air over the electrodes so as to reduce the dewpoint to a point below that of the temperature of the condensing surfaces. However, such a procedure is uneconomical as it involves an extensive waste of heat and the continuously introduced volumes of air, as same become moisture-laden, must be exhausted by the use of extensive duct work and the operation of exhaust fans. In cold weather, quantities of air equal to the amount exhausted must be preheated. The blowing of air onto the drying material, especially in case of cakes of rayon, also has the objection that it may cause uneven drying and consequent uneven shrinkage and stretching of the yarn or filament in the cake, with the result that when same is dyed, different portions will present contrasting appearances. In fact all of the above difficulties of blowing preheated air onto the drying material are increased in cases where the material being dried has a relatively large percentage of water, as do cakes of rayon. Furthermore, it is necessary to have screening located immediately above the rayon cakes, carrying high frequency current, and if even small amounts of condensation form on such screening, it might not only induce arcs, but also cause transfer in droplets of moisture of microscopic but injurious quantities of metallic salts from the screening to the rayon.

In accordance with an important feature of the present

invention, all these difficulties have been avoided by covering the space where the product is being dielectrically treated with an enclosure or hood, and in case it is water vapor that is being separated from the product, such vapor is preferably allowed to rise to the top of the hood, since at a given temperature and pressure it has a density substantially less than that of air; hence an exit for the evolved vapor is preferably provided at the upper portion of the hood and at some point in such exit or connected thereto, means is provided for condensing the vapor at the same rate as evolved from the product under treatment and the resulting condensate is carried away from the presence of the space within the hood and its contents. It may be noted, however, that such condensing means need not necessarily be physically located outside the hood and connected thereto by a vapor exit, since such means might in effect be located within the space in the hood proper, if means is provided for catching and conducting away the condensed liquid without allowing same to drip or flow into the region of the electrodes.

Also, with the method of the invention, preferably in order to insure against condensation of water vapor on the walls of the hood or other parts, sensible heat is supplied to the space within the hood or to the walls thereof, but this needs to be only sufficient to compensate for the heat losses from the walls of the hood. This may be done by preheating the enclosure by steam coils or other heaters to a temperature just in excess of 212° F. Such addition of sensible heat may be continued during the operation of the method and will result in superheating of the vapor evolved from the product under treatment, but such superheating will remain only slight at the points where the vapor reaches the condensing means.

While, of course, water in the liquid state is a poor dielectric, yet as not generally appreciated, water in the form of vapor only, has dielectric properties which approach those of dry air, and accordingly with the method above outlined, the atmosphere in the hood comprising air plus water vapor maintained above its temperature of condensation, not only eliminates the problem of condensation of droplets at any point where not desired, but also makes possible a highly efficient dielectric heating field.

With this invention, it will be appreciated that the condensing means in the vapor exit from the hood, will in effect provide means for constantly evacuating the water vapor evolved from the drying product without evacuating any stream of air. Thus the maintenance of any continuous intake of air into the hood to blow away the vapor, is avoided. This not only avoids the heavy heat losses heretofore necessary for preheating such air, but also avoids the drafts of air past the drying product which heretofore tended to cause the undesirable nonuniform drying above mentioned.

It may be mentioned that in case the invention is applied to the problem of expelling from a product under treatment vapors which have a density greater than air under the temperature and pressure conditions present, then the exit for the evolved vapor may preferably be located at a relatively low point in the hood instead of in the upper portion thereof. It may be noted, however, that the condensing means or the vapor exit thereto, if used, need not necessarily be located at a particular elevation depending upon the relative density of the vapor as compared with air, since the vapor at the condensing means will ordinarily be condensed with sufficient rapidity to tend to lower the pressure at the condenser enough to cause the vapor as evolved from the drying material to flow into the condensing means.

Another feature of the invention involves an arrange-

ment of the hood, such as above described, in a generally arcuate or circular form, so that same may contain a conveyor for conveying a continuous series of articles or products to be heated around along an arcuate or circular path, at one end of which same are removed in treated or dried condition. In this case, the path at each side may be flanked by dielectric heating electrodes of arcuate form and arranged coaxially with the path, one being positioned preferably internally of the path and the other externally thereof. Such an arcuate or circular arrangement not only provides for an efficient and continuous method of operation, but also enables the source of the high frequency current, such as an electrical oscillator, to be arranged concentrically of the path whereby such oscillator may be concentrically located.

Various further and more specific objects, features and advantages of the invention will appear from the description given below, taken in connection with the accompanying drawings illustrating by way of example certain preferred forms of the invention.

In the drawings:

Fig. 1 is a somewhat schematic vertical sectional view illustrating one simple form of apparatus for carrying out the invention;

Fig. 2 is a perspective view of the form of apparatus for carrying out the invention by conveying workpieces about a generally circular path arranged coaxially with respect to an oscillator surrounded by such path;

Fig. 3 is a vertical sectional view taken substantially along line 3—3 of Fig. 2, showing certain of the parts within the apparatus in elevation or vertical section; and

Fig. 4 is a horizontal sectional view, partly broken away, the section being taken along beneath the cover portions of the apparatus of Fig. 2.

More specific reference will now be made to Fig. 1, which illustrates somewhat schematically and in simplified form, fundamental features of the invention. Here there is shown at **10** an article or product to be dried or heated, such as a rayon yarn cake, resting upon a rotatable insulated support **11** at a position intermediate between a pair of electrodes **12** and **13**, which are connected as indicated to a source of high frequency current so as to establish an electrical field as at **14** extending between the electrodes and through the product being heated. The support or stand **11** may be carried on a suitable spindle means as at **15**, extending through bearing means as at **16** and adapted to be rotated as by a gear **17**, such rotation permitting the various cross-sectional portions of the cake **10** each to be subjected to approximately the same amount of heating action in the field **14**. The portions of the arrangement of Fig. 1 as thus far described, are well known in the art.

As further shown in Fig. 1, the space surrounding the electrodes **12**, **13** and the product being dried, is enclosed in a chamber **18**, which forms a hood covering the electrodes and extending down to the lowest level of the product or lower, and if desired, such chamber may have a bottom piece as at **19**, which, however, need not be airtight. The walls of the chamber **18** are preferably made of some suitable heat insulation material or covered or lined with such material, as in the case of another embodiment of the invention hereinafter described in connection with Fig. 2. At various points at or adjacent the walls of the chamber **18**, suitable heating means, such as steam pipes **20**, are mounted. The rate of flow of heating medium through such pipes is preferably adjusted so as to maintain the walls of the chamber and the gases within the chamber at a temperature at least just above 212° F. in case water vapor is being driven off from the product **10**. In case some other fluid is being evaporated from the product, the walls in the chamber should similarly be heated to a temperature just above the point of vaporization thereof.

At or near the top of the chamber, preferably along one side thereof, a vapor exit opening **21** is provided and a condensing chamber **22** is positioned at any suitable point to receive the vapors coming out of exit **21**. The condensing may be accomplished as by the use of conduits **23** carrying streams of cooling fluid and these conduits are positioned so that the resulting condensate drips to the bottom of the condensing chamber and is conducted away as through a conduit **24**. Preferably the flow of cooling fluid in the conduits **23** is adjusted as by suitable manual control valves or otherwise and by trial, so as to cause condensation of vapor in this chamber at approximately the same rate as the vapor evolves from the product **10**. The resulting condensate will comprise a hot liquid, the heat of which may be economically utilized in the plant, either for space heating purposes or for process heating.

As the product **10** becomes heated to a point at or above the vaporization point of the liquid to be separated therefrom, the resulting vapor, as indicated by the arrows in the chamber (Fig. 1) will in the case of water vapor at least, flow up to the top of the chamber, displacing downwardly the air originally contained in the chamber. Furthermore, this vapor will be drawn through the exit **21** into the condensing chamber **22** by reason of suction through the exit arising from the decreased vapor pressure within the condensing chamber occurring as the result of the condensing action. The condensing chamber, exit **21**, and the top of the chamber **18**, are preferably arranged in such manner, for example as shown, so that the condensing chamber in normal operation of the apparatus will be filled with the vapor substantially to the exclusion of air and the condensing action is carried out as above indicated at a rate preferably just fast enough substantially to stabilize the amount of the vapor within the upper portions of the chamber **18** so that the condensing chamber will not contain any substantial amount of air and at the same time so that the body of vapor in the chamber **18** will not become so large as to cause vapor to be displaced downwardly from the bottom of the chamber or to any very substantial degree through any openings other than exit **21**.

Thus with the arrangement shown, the product may be dielectrically heated without blowing or conducting any streams of air past same to carry away the vapors, but instead the vapors are in effect withdrawn from the region of the drying product substantially independently of air and in effect by the action of the partial vacuum created in the condensing chamber. Consequently, uneven drying of the product due to currents of air is avoided, as is also the necessity of preheating any air currents, and furthermore, a considerable part of the heat of the evolved vapor may be recovered by utilizing the hot condensate for other purposes. Air ducts and blowers and all such equipment for providing air streams are also avoided.

With the more elaborate embodiment of the invention shown in Figs. 2–4 inclusive, a series of articles or products to be dried, such as the rayon cakes **10**, are carried by conveyor means **25** around a generally circular path starting from an entrance **26** through a generally circular chamber **27** which has an outlet **28**. That is, an operator, standing near the inlet **26**, may successively place the articles to be dried on the conveyor **25**, so that same will pass in and around the circular chamber **27** and after they have become dried in the chamber and emerge through the outlet **28**, same may be removed from the conveyor.

The conveyor may comprise chain-like means having links, some of which comprise small spaced platform-like members **29**. Rotatable spindles as at **30** may extend up through these members, each of these spindles being adapted to carry a rotatable insulation support as at **31**, like the support **11** above referred to in Fig. 1, and adapted to rotatably support the rayon cakes. The chain-like conveyor means may be driven as by a sprocket **32**, which in turn is driven as by motor and gear means

indicated somewhat schematically at **33**. At points where the conveyor chain enters and leaves the chamber **27**, it will deviate from the circular path around within the chamber into the straight paths externally of the chamber as indicated in Fig. 4, and at these points of entrance and exit of the conveyor chain means, idler pulleys as at **34** may be provided for suitably guiding the same.

At the lower end of each of the spindles **30**, pinion gears as at **35** may be mounted, these being adapted to be turned either regularly or intermittently as by engaging a suitable stationary sprocket chain-like member as at **36**.

As will be apparent from Figs. 2–4, the space in the chamber **27** through which the conveyor conducts the product to be dried, may comprise a generally annular enclosure or hood preferably with walls of insulation material covered with metal foil or other suitable conductive screening material for preventing high frequency radiation from the chamber. A vertical cross-section of a portion of this enclosure appears at the left hand side of Fig. 3 and the similarity thereof to Fig. 1 will be noted. The electrodes which are connected to a suitable source of high frequency current, are indicated at **38** and **39**, these being preferably positioned vertically and concentrically with the chamber **27**, the electrode **38** extending around the outside of the path of the product being treated and the electrode **39** extending along coaxially with such path at the inside thereof.

As indicated in Fig. 2, the central space within the chamber **27** may be occupied as by an electrical power oscillator, the output terminals of which respectively are connected to the electrodes **38** and **39**. Such oscillator may be of a suitable known construction.

As best shown in Figs. 2 and 3, a condensing chamber **40** of annular shape is provided and positioned to extend around the upper outer rim of the chamber **27**, there being an annular exit opening thereto from the chamber **27**, as indicated at **41**. It will be understood that the function of this condensing chamber **40** and of the exit opening **41** is comparable to the chamber **22** and exit opening **21** in Fig. 1. Condensate pipes as at **42** for draining condensate from the chamber **40** may be positioned at suitable locations.

On the walls or within the lower portion of the annular enclosure within chamber **27**, suitable heating coils as at **43** are located, these being for the same purpose as heating means **20** as shown in Fig. 1.

Although for clearness, the apparatus as shown in Fig. 2 is indicated as being mounted in a generally horizontal position, this equipment, if desired, may be so mounted as to be tilted upwardly somewhat at the left hand end as viewed in this figure, so as to insure that the vapor evolved from the drying product will substantially all be withdrawn through the annular exit **41** by the action of the condenser, instead of escaping from the inlet **26** or the outlet **28**.

Although certain particular embodiments of the invention are herein disclosed for purposes of explanation, various further modifications thereof, after study of this specification, will be apparent to those skilled in the art to which the invention pertains. Reference should accordingly be had to the appended claims in determining the scope of the invention.

What is claimed and desired to be secured by Letters Patent is:

1. Apparatus for separating a volatile liquid from solid material by dielectric heating, said liquid in the vapor phase having a density different from that of air, which comprises: an enclosure; means mounted in said enclosure for supporting the material; material heating means mounted in said enclosure and comprising a pair of spaced-apart electrodes between which the material is supported, said electrodes being adapted to be connected to the terminals of a high frequency power source, whereby the material may be heated by the electrical field maintained therein between the electrodes and to a temperature causing vaporization of the liquid in the material and the emission of vapor from said material; and means for maintaining a separate layer of air at atmospheric pressure adjacent and in contact with said vapor during the heating of said material for causing said vapor to flow along a predetermined path without substantial circulation of air past said material comprising a condensing means having an inlet opening into said enclosure, which inlet is disposed vertically of said material supporting means and in said path of said vapor for receiving and condensing said vapor evolved from the heated material, said condensing means also having means for discharging the condensed vapor and said enclosure having an air inlet opening therethrough to the surrounding atmosphere, said last mentioned opening being separate from said inlet opening, whereby said vapor is caused to flow between said material and said condensing means because of the layer of air in contact with said vapor and the difference in vapor pressure produced by said material heating means and said condensing means.

2. Apparatus for separating moisture from solid material by dielectric heating, said moisture in the vapor phase having a density different from that of air, which comprises: an enclosure; means mounted in said enclosure for supporting the material; material heating means mounted in said enclosure and comprising a pair of spaced-apart electrodes between which the material is supported, said electrodes being adapted to be connected to the terminals of a high frequency power source, whereby the material may be heated by the electrical field maintained therein between the electrodes and to a temperature causing vaporization of the moisture in the material and the emission of vapor from said material; means for maintaining a separate layer of air substantially at atmospheric pressure adjacent and in contact with said vapor during the heating of said material for causing said vapor to flow along a predetermined path without substantial circulation of air past said material comprising condensing means having an inlet opening into said enclosure, which inlet is disposed vertically of said material supporting means and in said path of said vapor for receiving and condensing said vapor evolved from the heated material, said condensing means also having means for discharging the condensed vapor and said enclosure having an air inlet opening therethrough to the surrounding atmosphere, said last mentioned opening being separate from said inlet opening, whereby said vapor is caused to flow between said material and said condensing means because of the layer of air in contact with said vapor and the difference in vapor pressure produced by said material heating means and said condensing means; and further heat generating means for supplying heat to said electrodes sufficient to maintain said electrodes at a temperature above the temperature of condensation of said vapor.

3. Apparatus for separating moisture from solid material by dielectric heating, said moisture in the vapor phase having a density different from that of air, which comprises: a generally arcuate enclosure having entrance and exit openings therein; conveyor means extending through said openings and into said enclosure for conveying the material along a path into, through and out of said enclosure and generally concentrically therewith; material heating means mounted in said enclosure and comprising a pair of electrodes extending respectively in spaced relation and with said path therebetween, said electrodes being adapted to be connected to the terminals of the high frequency power source, whereby the material being conveyed therebetween may be heated by the electrical field maintained between the electrodes to a temperature causing vaporization of the moisture in the material and the emission of vapor from said material; means for maintaining a separate layer of air at

substantially atmospheric pressure adjacent and in contact with said vapor during the heating of said material for causing said vapor to flow along a predetermined path without substantial circulation of air past said material comprising condensing means having an inlet adjacent and opening into the upper portion of said enclosure and in the path of said vapor for receiving and condensing said vapor evolved from the heated material, said condensing means also having means for discharging the condensed vapor, whereby said vapor is caused to flow between said material and said condensing means because of the layer of air in contact with said vapor and the difference in vapor pressure produced by said material heating means and said condensing means; and further heat generating means for supplying heat to said enclosure and to said electrodes sufficient to maintain the walls of said enclosure and said electrodes at a temperature above the temperature of condensation of the moisture.

4. A method for removing a volatile liquid from solid material in air at atmospheric pressure, said liquid in the vapor phase having a density different from that of said air, said method comprising generating heat in said material sufficient to cause said vapor to be evolved from said material by subjecting said material to a high frequency electric field between electrode means, said vapor being urged away from said material and toward a point vertically spaced therefrom due to the difference in densities of said vapor and said air, condensing said vapor at said point and removing the condensate, and controlling the rate at which the material is heated dielectrically with respect to the rate at which said vapor is condensed so that vapor, substantially free of air, is maintained between said material and said air, and so that a layer of said air is maintained separate from but adjacent and in contact with said vapor without substantial circulation of air past said material during the heating thereof.

5. A method for removing water from a rayon cake in air at atmospheric pressure, said water in the vapor phase having a density less than that of said air, said method comprising generating heat in said cake sufficient to cause water vapor to be evolved from said cake by subjecting said cake to a high frequency electric field between electrode means, said vapor being urged upwardly from said cake toward a point vertically spaced therefrom due to the difference in densities of said vapor and said air, condensing said vapor at said point and removing the condensate, controlling the rate at which said cake is heated dielectrically with respect to the rate at which said vapor is condensed so that a vapor pressure is provided at said point which is lower than the vapor pressure adjacent said cake and so that vapor, substantially free of air, is maintained between said cake and said air and between said cake and said point and a layer of said air is maintained separate from but adjacent and in contact with said vapor without substantial circulation of air past said cake during the heating thereof, and supplying heat, in addition to the heat generated dielectrically in said cake, to the space surrounding said cake to maintain said air and said vapor at a temperature above the temperature of condsensation of said vapor.

6. A method for removing water from solid material in air at atmospheric pressure, said water in the vapor phase having a density less than that of said air, said method comprising generating heat in said material sufficient to cause said vapor to be evolved from said material by subjecting said material to a high frequency electric field between electrode means, condensing said vapor at a point spaced from said material and removing the condensate, controlling the rate at which the material is heated dielectrically with respect to the rate at which said vapor is condensed so that vapor, substantially free of air, is maintained between said material and said air, and so that said air is maintained in spaced relation to but adjacent said material and in contact with said vapor during the heating of said material, and preventing the absorption of heat from said vapor by supplying heat, in addition to the heat generated dielectrically in said material to the space surrounding said material sufficient to maintain said vapor at a temperature at least equal to the boiling point of the water during the heating of said material dielectrically.

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