

Jan. 15, 1952

J. W. ROBERTSON

2,582,281

ELECTRIC FIELD HEAT TREATMENT OF LIQUIDS

Filed April 12, 1946

Fig. 1.

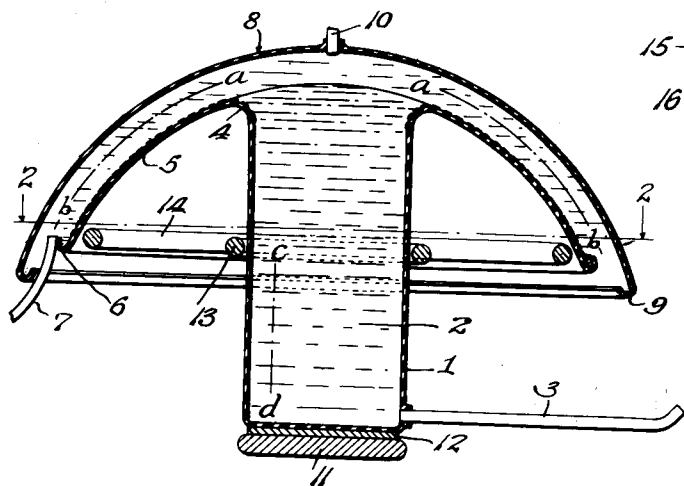
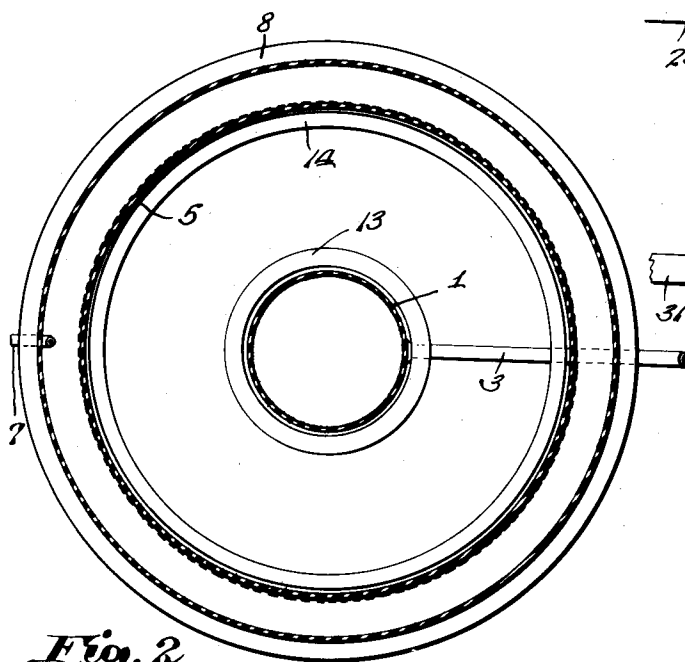
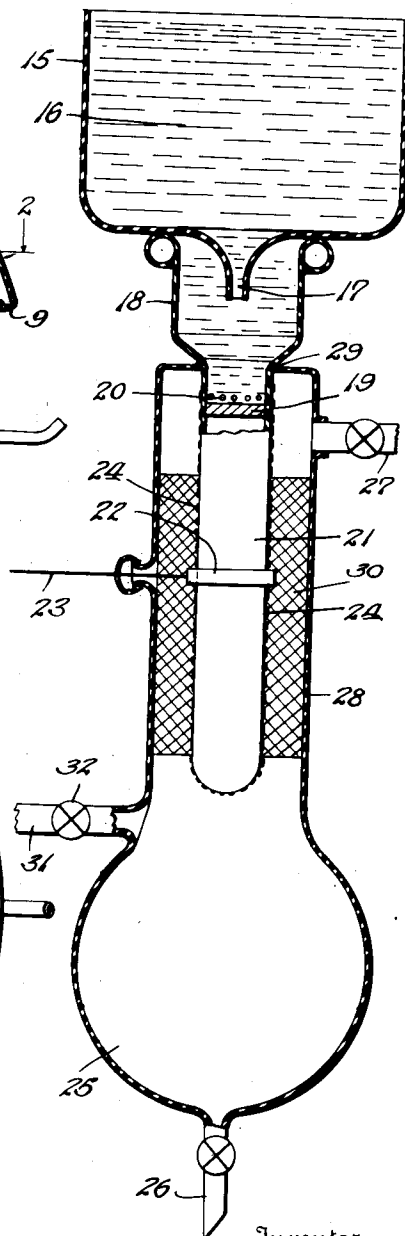


Fig. 2.

Fig. 3.



Inventor
John W. Robertson

By

Sol Shappirio

Attorney

UNITED STATES PATENT OFFICE

2,582,281

ELECTRIC FIELD HEAT-TREATMENT OF LIQUIDS

John W. Robertson, Englewood, N. J., assignor, by direct and mesne assignments, of one-half to Ellis-Foster Company, a corporation of New Jersey, and one-half to Montclair Research Corporation, a corporation of New Jersey

Application April 12, 1946, Serial No. 661,793

7 Claims. (Cl. 219-47)

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This invention relates to the heat treatment of liquids and apparatus therefor and is particularly concerned with the utilization of high frequency or radio frequency power applied in the heat treatment of liquid materials.

While radio frequency power for heating "dielectric" types of materials by placing the material between condenser plates has developed in recent years, little has been done in the development of the utilization of such types of heating with liquids, particularly to utilize the various factors which enter into such operations in the efficient treatment of liquid materials.

Among the objects of the present invention is the utilization of high frequency or radio frequency power in the heat treatment of liquids.

Further objects include the utilization of such methods and apparatus therefor in the treatment of liquids while the latter are in the form of a thin film.

Still further objects and advantages of the present invention will appear from the more detailed description set forth below it being understood that such detailed description is given by way of illustration and explanation only, and not by way of limitation, since various changes therein may be made by those skilled in the art, without departing from the scope and spirit of the present invention.

In connection with that more detailed description, there is shown in the accompanying drawings, in

Figure 1, an elevation in section of one form of apparatus that can be utilized in carrying out the present invention; in

Figure 2, a plan view of the apparatus of Figure 1; and in

Figure 3, a modified form of apparatus shown in section, that may be utilized in carrying out the present invention.

In accordance with the present invention, liquids of any desired type but particularly those which are relatively poor conductors electrically, are passed as a thin film through a heating zone in which they are subjected to high frequency or radio frequency power in order to heat the liquid for any desired purpose.

In carrying out the heating operations in accordance with this invention, the heating effects obtained by the use of a high voltage electrode in proximity to a liquid surface is employed. It has been found that the heating effects on liquids of varying conductivity indicates that vapors above the surface of the liquid may behave in much the same manner as sharp edges or points

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of metal in initiating corona discharges (visible or invisible). So that when such surface is at high potential, these discharges start (usually invisibly) and cause rapid heating of the surface as they discharge into the air. The heating of such liquids is complicated under the stated conditions by various factors including the effect of displacement currents (true dielectric loss), conduction currents (resistance loss), "skin effect" phenomena, corona discharges, and possibly other unknown effects. In some cases the corona effects are no doubt present during the conditions which produce "skin effect" heating. Utilization of these phenomena has been found quite useful in quickly heating thin films of liquids for various purposes, as for example, for evaporation, distillation, pasteurization, producing chemical reactions, drying, etc.

The present invention utilizes forces which come into play at higher voltages, particularly those above 5000 volts, and more particularly above 10,000 volts and more specifically when these voltages are applied to materials which are neither dielectrics nor conductors in the best known sense of those words. In other words the stated materials will not heat effectively as a dielectric because they are too good as conductors and they will not heat effectively by induction because they are too good as insulators.

One way that may be utilized herein to define the nature of conductors can be based on the behavior of salt solutions. "Poor conductors," especially in the nature of salt solutions (or acid or alkali) comparable in dielectric and corona behavior with sodium chloride solutions stronger than about .05% will be affected by the "electrical field" or "corona discharge field" selectively, faster than surrounding media of "dielectric" behavior such as that of sodium chloride solutions below about .03% as set forth and further established. References herein to "corona discharge field," "invisible corona," "invisible discharges" and other corona phenomena are not to the visible corona discharge which is familiar to all but rather to the ionized field surrounding high voltage electrodes under suitable conditions and which apparently actually dissipates energy at levels too low to discharge through a concentrated, visible path in the well known corona phenomenon.

Principally in connection with the present invention "poor conductors" are subjected to treatment in a zone within the discharge field of high frequency power where such poor conductors possibly act more as metallic particles would and

become focal points for the initiation of such invisible discharges themselves, thus causing overheating, and other effects which are not yet well understood but which are often instantaneous in their action. The principle in use is to cause concentration of the electrical field or discharge on particles which may be "conductors" or "poor conductors" in that field.

In carrying out the operations of the present invention, the effects of a high voltage electrode in proximity to the object to be affected is employed. For this purpose as stated, voltages of the order of 5000 above ground potential are useful but for best effectiveness, voltages of over 10,000 are employed. These voltages bring into play more effectively, the phenomenon referred to herein and which will be referred to herein as corona discharge effect or invisible corona discharge effect. In so doing, no limitation is intended as the phenomenon may be described in other ways by physicists. It has been noted that at these voltages, visible corona discharges start from sharp metallic points and, surprisingly enough, from the surface of a conductive liquid such as a salt or acid or alkali solution. It appears then that vapors above the surface of the liquid behave in much the same manner as sharp edges or points of metal in initiating corona discharges (visible or invisible). These same solutions (all too conductive to heat effectively as a dielectric) will also heat in a partially enclosed space if placed in the vicinity of an electrode at high potential and particularly at frequencies above 1 mc. Lower frequencies may be useful at higher voltages but practical industrial considerations call for frequencies of the order of 30 mc. and above and at such voltage that a field of desired strength and extent is made for the proposed use. As pointed out above, effective use of the method is particularly concerned with the voltages as described above and more desirably voltages above 10,000 (electrode potential). It has been further noted that the effect of increasing frequency is rather pronounced due possibly to the fact that higher frequencies, it is believed, tend to leave such terminal surfaces as described above, more readily than lower frequencies. This tendency to corona at lower voltages in the high frequencies may thus be emphasized in connection with the present invention and the increasing effects of high frequencies in the disclosed method supports the corona discharge theory. But as explained, the phenomena are not to be restricted by the use of such terms as corona discharge because definite effects have been obtained whatever may be the explanation therefor or whether such explanation may lie along other lines.

While voltages have been particularly emphasized above with respect to the effects obtained, it may be pointed out that frequencies of less than 30 mc. are effective but it is preferred to utilize frequencies above 30 mc. It has been shown that salt solutions heat inductively with increasing usefulness as frequency is increased but at frequencies below 1000 mc. this effect is not pronounced enough for certain uses. Mc. is used to designate megacycle.

To explain phenomena involved herein, the following example showing the range of concentration of salt solutions which can be effectively heated as a dielectric is given. Dielectric heating apparatus operating at about 20 mc. and 5000 volts between electrodes is set up so as to give a substantially uniform dielectric field through

a quartz test tube containing the solution to be studied. The time required to boil various concentrations of sodium chloride solutions was determined and the relative heating rate of surface compared to body of liquid was noted.

NaCl Conc.	Time to boil	Comments
None—distilled water—	15° C. rise in 30 min.	Uniform heating.
.001%—	240 seconds—	Do.
.005%—	80 seconds—	Do.
.01%—	47 seconds—	Do.
.02%—	40 seconds—	Surface heats faster.
.03%—	43 seconds—	Do.
.04%—	43 seconds—	Do.
.05%—	49 seconds—	Do.
.10%—	75 seconds—	Do.
.50%—	215 seconds—	Surface heats faster and boils first.
1.00%—	1,000 seconds—	Do.

From these results it is seen that salt solutions under .04% concentration exhibit rapid heating as dielectrics but those over .04% do not heat so well as dielectrics and in fact the surfaces of stronger solutions heat so much faster than the under surface liquid, that boiling first takes place at the surface while the lower layers may still be 10° or 20° below boiling temperatures, thus indicating that the effective heating is not caused by dielectric heating but by other high frequency effects in which invisible corona discharge plays an important part.

Similar charts on phosphoric acid, hydrochloric acid, sodium sulfate, and p-toluene sulfonic acid all show maximum heating rate as dielectrics at concentrations below .05%. It would be expected that there would be obtained much more rapid and selective heating when placed near an electrode at high radio frequency voltage, than would take place at a point say half way between two plates of a dielectric heating condenser at the same electrode voltage.

This behavior may be demonstrated by vertically suspending two flat plates, for example 5 inches square, as electrodes in a kerosene bath. Kerosene is a good dielectric and heats very slowly in a dielectric field. With 10,000 volts across the plates, spaced at 8 inches, the kerosene will rise in temperature about 1° C. in 30 minutes. Five Pyrex test tubes filled with 0.1% salt solution suspended at equal spacings on a center line between the electrodes were subjected to the application of the radio frequency power. In five minutes the temperature of the salt solution in the tubes nearest the electrodes had increased 15° C. at the surface and 5° C. at the bottom, and the temperature in the tube half way between the plates had not increased measurably.

The liquid to be treated may be conveyed or caused to pass over a dielectric surface or body having such surface where it is subjected to such high frequency or radio frequency power. The nature of the material undergoing treatment, the nature of the surface over which it flows, and the positioning of the electrodes which apply the power from a conventional type of radio frequency generator system, determine the type of heating effects which are obtained. Thus the thin film of liquid may be the chief resistance (considering any medium in which heating takes place) between electrodes properly positioned and the film heated rapidly due to its resistance when a suitable voltage and frequency is impressed between the electrodes. Or the positioning of the electrodes may be so effected that both resistance effect and dielectric effect are employed in producing the heating. If the voltage impressed at

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the surface of the film is high enough, corona discharge may also take place and affect the heating which is carried out.

The resistance and corona discharge effects may be augmented by varying the surface of the area covered by the thin liquid film. Thus if such surface is covered completely or discontinuously with a thin metal film such as of silver, platinum, etc., the film may be utilized as an electrode and serve as such, and especially at a high voltage, will cause an increase in corona discharge effect.

It is further possible to increase the evaporation rate from such surface or otherwise affect the heating function obtained by variation in the character of the surface employed. For example, such surface over which the liquid film is flowing may be made of a woven glass cloth. An irregular surface may thus be produced or in other ways. It is not clear whether this improvement is due to the irregular surface of the cloth offering more protruding points for corona discharge or more paths for resistance currents. But at any rate in such utilization, as for example, a glass cloth as the surface over which the thin film of liquid flows, proves to be a useful procedure under many conditions whether one or two electrodes are employed. There particularly may be use for other uneven surfaces of large area in small volume of space employing such materials as sintered glass or other ceramic materials.

Such cloth or other uneven surface may furthermore be metallized with one of the metals as set forth above for the purposes there described to produce a double effect and also where chemical reactions are taking place, such metal may act catalytically.

Furthermore these operations may be carried out within a closed chamber in order to control the type of atmosphere in which the heat treatment takes place. In such closed chamber the atmosphere may include an inert gas or vapor with respect to the liquid undergoing treatment or on the other hand, a gas or vapor which reacts chemically with said liquid may be introduced into such closed space to contact with the liquid during the heat treatment. Where chemical reaction is being employed, unreacted gas or vapor from the heating zone may be withdrawn and recycled to said zone.

Also by the utilization of such enclosed chamber within which the apparatus is employed, the pressure under which the heat treatment is carried out may be controlled and either vacuum of any desired degree may be employed, or super-atmospheric pressures may be maintained during such heat treatment. The apparatus may under such circumstances be utilized for distillations and where a very high vacuum is employed, molecular distillation may be carried out employing a suitable spacing between electrode area and outside walls.

The liquid to be treated in the form of a thin film as set forth above may first be subjected to heating to raise its temperature to a point at which such heat treatment in the thin film condition may desirably be carried out. For such purpose a body of the liquid may be heated by high frequency or radio frequency power dielectrically and the liquid withdrawn from such heated body in the form of a thin film and subjected for treatment as explained above.

One form of apparatus utilizing these features is illustrated in Figures 1 and 2. As there shown, a container or vessel 1 for the liquid to be treated contains a body of such liquid 2, the inlet 3 serv-

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ing to introduce such liquid into the container 1. The feed of such liquid through the inlet 3 may be either continuous or discontinuous. Such vessel or container 1 while illustrated as cylindrical, may take any desired shape and may be oval, octagonal, etc. Attached at 4 to the upper end of the container 1 is a downwardly depending dome shaped member 5 over which the liquid from container 1 may overflow in the form of a thin film where it is subjected to the heat treatment in accordance with the present invention. The liquid which flows over the dome shaped surface 5 may be received in a trough member 6 attached to the outer peripheral edge of the dome shaped member 5 and removed through the outlet 7 connected to such trough 6. The dome shaped surface 5 may be curved or straight and at almost any angle and the distance over which the thin film of liquid flows on the surface 5 may be any desired distance within the limits of processing equipment.

Desirably a hood of either glass or metal depending upon the particular utilization, as shown at 8 may be positioned over the dome shaped member 5, desirably equidistant from it at all points. This hood member 8 may serve as a condensing area for vapors which are to be collected after separation from the body of the liquid. The hood 8 may also at its peripheral edge have a trough portion 9 for collection of the liquids which condense from the vapors in contact with the hood member 8 and suitably withdrawn through any desired outlet from such trough 9. An outlet 10 may also be supplied for removal of vapors which may be valved.

In the form of apparatus shown in Figures 1 and 2, electrodes with proper connections to a source of radio frequency power are employed for producing an initial dielectric heating of the body of liquid in the container 1 and also heating of the thin film of liquid which overflows from the liquid 2 in container 1 along the dome shaped surface 5. One arrangement of electrodes that may be utilized is illustrated in Figures 1 and 2. As there shown, the bottom of the container 1 is placed adjacent to an electrode 11, and the container 1 may rest on the electrode 11, or be spaced therefrom with an air spacing between, or a block of insulating material may be placed between the electrode 11 and the bottom of the container 1.

To overcome localization of heating or possible overheating of the bottom of such vessel, the container 1 is desirably spaced from this plate electrode 11. Air spacing may be employed, but under commercial conditions may offer mechanical difficulties. When the container 1 is placed adjacent to such plate electrode 11, as for example, in being placed directly on such electrode, it is found desirable to utilize a material of low power loss factor between the bottom of the vessel or container 1 and the plate electrode 11. Such low power loss factor material is indicated at 12. The type of material to be used depends on the particular conditions of the operation being carried out. A block of sintered Pyrex glass of suitable thickness is fairly useful where the conditions are not such that there is rapid heating of such block of material. More desirably a material of lower loss factor may be employed such as sintered or porous "Nonex" glass or "Vycor" (96% silica) glass or quartz or volcanic rock or pumice stone or fibers of these materials. A simple means that may be employed, particularly in the heat treatment of smaller vessels or contain-

ers, consists in employing a piece of "Mycalex" (mica and glass) sheet together with a folded piece of glass cloth to provide added spacing with a large percentage of air insulation. Such insulation between the container 1 and the plate electrode 11 sufficiently controls the heating operations with respect to the container 1 and electrode 11. This bottom electrode 11 may be grounded, depending upon the effect being utilized and the design of the radio frequency apparatus.

A second ring electrode 13 encircles the container 1 and is positioned at a distance from the plate electrode 11. The utilization of the ring and plate arrangement as described enables ready control of the heating effect of the body of liquid 2 in container 1 to be carried out. The plate electrode 11 may be a flat circular plate of metal while the ring electrode 13 is also of metal. Desirable connections are made to supply the power to such electrodes from a conventional radio frequency power source. The ring electrode 13 may be positioned at various points distant from the electrode 11 to control the heating effect obtained. Instead of an arrangement of a ring electrode and plate electrode as described, two adjustable rings may be used, each such ring electrode encircling the container 1. The positioning of the ring electrode 13 with respect to the material undergoing heat treatment must be taken into account and are highly important in producing the particular results desired. In order to obtain the best field distribution for uniform heating, the ring should be as high as possible, even above the surface of the batch of material undergoing treatment. But this is undesirable in those cases where too much surface heating takes place and in such cases the ring should be lowered until it is in a position as illustrated, all of the factors involved depending on the conductivity of the batch and the desirability of heating one portion of the body more rapidly than another.

If it is desired to heat one portion of the body of material 2 in container 1 more rapidly than other portions thereof, expedients may be employed for that purpose. Thus blocks of high dielectric loss material, especially of larger surface area, such as sintered, high loss glass may be positioned in the container at the point where the greatest heating effect is desired. By adjustment of the fact just discussed above, almost any reasonable degree of control of temperature can be obtained for given processing or treatment, especially for liquids and homogeneous materials. And even for non-homogeneous materials undergoing treatment, the control of temperature may be readily carried out by the expedient set forth.

A third electrode 14 is shown positioned under the outer periphery of the dome shaped surface 5 under the lower edge of that overflow area. This electrode 14 may be spaced from or in contact with the material of the overflow area and may in fact be placed on top of the dome shaped member 5 and in contact with or above the liquid film. The power connection to this electrode 14 is made conventionally in a manner not shown.

The liquid to be treated, enters the bottom of the container 1 from the inlet 3, fills the container 1 at any suitable speed, and passes upwardly past the ring electrode 13. At this point we have heating in this area indicated at c—d largely due to dielectric loss.

Continuing to rise, the liquid 2 reaches the top of the column and overflows at all points around the circumference of the top of the container 1

and flows downwardly at an angle, spread out in a thin film over the surface of the dome shaped member 5 at the portions indicated as a—b.

The film of liquid at the portions a—b can be the chief resistance between the electrodes 13 and 14 or 11 and 14 and heating will be rapid due to the resistance of such film when a suitable voltage and frequency is impressed. Voltages of the order of 10,000 and frequencies of the order of 20 megacycles may be employed, the particular voltages and frequencies depending on the materials undergoing treatment and the character of treatment to be carried out.

A combination of resistance effect and dielectric effect takes place when electrode 14 is working against electrode 11 or ground, the distance between electrode 14 and the side of the cylinder or container 1 regulating this dielectric effect. If the voltage impressed at the surface of the film is high enough, corona discharge also takes place.

As indicated above, the resistance and corona discharge effects may be augmented by varying the character of the surface over which the thin liquid film flows. It may be metallized as indicated above or it may be an uneven surface as further described above or a combination of metallized uneven surface material may be employed.

The processed liquid which flows over the dome 5 is collected in the trough 6 and removed through the outlet 7. If the hood member 8 is employed any vapors which are condensed on that hood 8 may be removed from the collecting trough 9. Any residual vapors or gases may be withdrawn through the exit 10.

The whole unit or cell may be enclosed in a vacuum chamber in which event the apparatus may serve as a molecular still or low pressure evaporator. By applying a D. C. voltage through suitable circuits to the hood and film layer it is possible to use this force to move molecules of vapor more rapidly across the space between them utilizing what may be called a "cathode sputtering effect."

If the liquid being fed in falls in the class of a "poor dielectric" as described above, it will heat more rapidly as a dielectric than by skin effect and corona discharge. Incidentally, it will be very hard to separate the latter two effects, especially at voltages over 3000 or 4000. An example of such a solution would be a sugar solution which contains enough ionizable salts to make it "absorb" power dielectrically at a speed in the class of .005% to .05% salt solutions. A pure sugar solution in pure distilled water is a very good dielectric and will not heat effectively by any of the methods disclosed. To heat sugar solution containing .03% salts the electrode 13 would be spaced as close to the cylinder wall as possible to prevent arcing, perhaps one inch or less at voltages of 10,000 or less, assuming the electrode is so designed as to have no sharp edges or contours. If this electrode is so located as to boil the liquid just as it overflows in a thin film, much evaporates and concentration will take place, especially under a vacuum, and because the boiling liquid and vapor above it are at a high potential due to proximity of the electrode 13 and because they are better conductors when hot than when cold, and because vapors above slightly conductive solutions appear to act to initiate invisible corona discharges, further heating effects are produced at the surface and along the surface of the thin film. Voltages impressed on electrode 13 should be on the order of 10,000 or more in

order to raise the surface voltage high enough to get corona effects.

As the diameter of electrode 13 is expanded toward 14, and it could preferably be raised at the same time to be in proximity of under surface 5 as it expands, the dielectric effect will become less at the same electrode voltage and additional effects of skin effect conductivity and corona discharge come into stronger play. Obtaining greater effects from these phenomena is best done when the ionizable salt concentration is such as to be too conductive for best and most efficient heating dielectrically. The position of the ring electrode around the cylinder insures some heating of the liquid body by dielectric effect, its proximity to the film area insures some corona effect, and the partially conductive film insures some leakage current to flow along its surface to get to the ground via the body of liquid. Thus all three effects are useful here. At a point, 14, which may for example, be 6 inches from 13, the dielectric effect may be rather small at the same electrode voltage of 10,000 and the corona and skin effect heating will be predominant.

A further type of still or evaporator of a design particularly suited to heating by corona discharge effects is shown in Figure 3. It may be noted in this connection that liquids and solutions of higher electrical conductivity, heat faster from corona effect at any given voltage than do liquids of very low conductivity.

As shown in Figure 3, the reservoir 15 contains liquid 16 which flows through the outlet 17 therefrom into the passage or pipe 18, the lower end of which is sealed as shown at 19 but is provided with a series of openings 20 that permits the liquid to overflow downwardly along the outside surface of the tube or thimble 21. During such flow downwardly over the tube 21, the liquid is in the form of a thin film and either is vaporized or removed from the lower end of the tube 21 during which time it is subjected to heat treatment.

A high voltage, radio frequency electrode 22 connected through the conductor 23 to a suitable source of power, brings the power to the center of the heating surface indicated by the dotted lines 24. Such surface may be a glass surface because the liquid layer is usually conductive enough to act as its own electrode and to carry the potential to all parts of the surface.

Unvaporized liquid collects in the receiver 25 and may be removed through the valve outlet 26. Gases or vapors which are formed may be removed through the valved outlet 27.

The heating effect with this single electrode connection appears to be due to the corona discharge effect described above and partly to "skin effect" conductivity from the electrode contact point out to either end of the heating area. Steam forms rapidly when a slightly conductive liquid flows over the surface of the tube 21 under suitable conditions of voltage, rate of flow, and conductivity.

Many modifications of the described apparatus are possible, for particular functions. A slight roughening of the outside surface of the tube 21 tends to help prevent breaks in the liquid film especially when a thin film is desired. Arcing and sparking may occur when the liquid film is not complete.

One method of assuring a substantially continuous film at almost any rate of flow is to cover the surface of the tube 21 with a "wick" of fibrous material such as glass cloth in a manner similar

to that described above in connection with the covering of the surface of the dome shaped member 5 over which the thin film of liquid flows in the apparatus of Figure 1. The very rapid evolution of steam with almost any desired amount of liquid passing through without being evaporated as in the concentration of solutions, may be attained at voltages substantially under 10,000 at 20 megacycles on dilute solutions of electrolytes such as sodium chloride.

This glass fiber "wick" may be metallized as described above, if desired to obtain other operating characteristics including catalytic effects which are characteristic of such metals as thin platinum films, silver, etc. The surface of the glass may also be metallized under the wicking if desired.

The receiver 25 has its upper cylindrical portion 28 carried upwardly to receive the lower portion of the tube or pipe 18 and to form a seal at 29. The neck portion 28 of the receiver 25 may be filled with material either in part or completely filling the space between the neck 28 and the tube 21 to provide a surface over which the liquid may flow in thin film form. Thus this space may be filled with a solid piece of sintered glass having desirably fairly large pores, or helices, or other still packing or filling may be employed. This is illustrated in Figure 3, where the packing or filling 30 is shown between the neck 28 and the tube 21. The utilization of such pieces of material gives much more surface for vaporization or reaction in the same volume of space but, of course, demands more power from the radio frequency generator.

In the device shown in Figure 3, an inlet 31 having a valve 32 may be supplied for passing in gases such as carbon dioxide or nitrogen for maintaining an inert atmosphere depending on the nature of the liquid undergoing treatment or for passing in a gas which is to react with the liquid that is flowing down in the thin film over the catalytic or plain surface of the tube 21. Unreacted gas or the gas introduced for purposes of creating the particular atmosphere within the apparatus may be withdrawn as indicated above through the valved outlet 27 and may be recycled to the inlet 31 if desired.

The features as to procedures carried out under reduced or increased atmospheric pressures may be applied to the apparatus of Figure 3 just as in connection with that of Figure 1 as explained above. The apparatus is compact and readily made tight. Molecular distillation may be carried out and all of the other features described above in connection with the apparatus of Figure 1 apply also to the apparatus of Figure 3.

There are many variables in setting up and operating apparatus such as is described in this specification but they will be readily recognized by those skilled in the art from the disclosure herein. Thus the circuits per se employed are those fully understood and used in the art, but hundreds of modifications electrically, in them are possible. Thus some dielectric heating equipment is made with two high voltage outlet connections from a balanced or "push-pull" circuit and others with one high voltage outlet to be worked against the ground. Two tubes are necessary for the push-pull circuit and one or more in parallel can be used for the other. Both have strong supporters among radio men. The chief advantages in this work is with one grounded electrode where possible because it increases operating safety factors in many cases. In the

case of Figure 1, the bottom electrode 11, and the feed-in line 3, and storage tank are safer by being at ground potential.

This application is a continuation-in-part of application Serial No. 626,860, filed November 5, 1945, entitled Heating Apparatus and Method, now Patent #2,485,658.

Having thus set forth my invention, I claim:

1. Apparatus for heating a liquid that is a relatively poor conductor electrically which poor conductor has the electrical conducting properties of an aqueous sodium chloride solution of from .04% to .10% and is a liquid that will not heat effectively as a dielectric because of its electrical conducting properties and will not heat effectively by induction because of its electrical insulating properties, which apparatus comprises a film forming member having a surface of extended area of a material that is conducive to surface heating effects in the liquid under conditions of use, a heating zone in which said member is placed, means for flowing said liquid as a film over the surface of said member of extended area, and means for subjecting said film in a high frequency electric field to high frequency power at high voltage to heat the liquid by skin effect phenomena, said last named means including a single electrode only which electrode is adjacent said member of extended surface area and through which power is supplied.

2. Apparatus as set forth in claim 1 in which the film forming member has an uneven surface affecting the invisible discharge characteristics of said surface.

3. Apparatus as set forth in claim 1 in which the film forming member has a metallized surface affecting the invisible discharge characteristics of said surface.

4. Apparatus as set forth in claim 1 in which the film forming member includes a glass cloth over which the film of liquid flows during heating.

5. Apparatus as set forth in claim 1 in which the film forming member includes a body of packing material over which the film of liquid flows during heating.

6. Apparatus as set forth in claim 1 in which the member of extended area is an elongated cylinder and the electrode encircles the cylinder between the ends thereof.

7. Apparatus for heating a material that is a relatively poor conductor electrically which poor

conductor has the electrical conducting properties of an aqueous sodium chloride solution of from .04% to .10% and is a material that will not heat effectively as a dielectric because of its electrical conducting properties and will not heat effectively by induction because of its electrical insulating properties, which apparatus comprises means for moving said material in a relatively thin layer through a heating zone, and means for subjecting said material in a thin layer in said heating zone in a high frequency electric field to high frequency power at high voltage to heat the material by skin effect phenomena, said last named means including a single electrode only which electrode is adjacent said first named means and through which power is supplied.

JOHN W. ROBERTSON.

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