

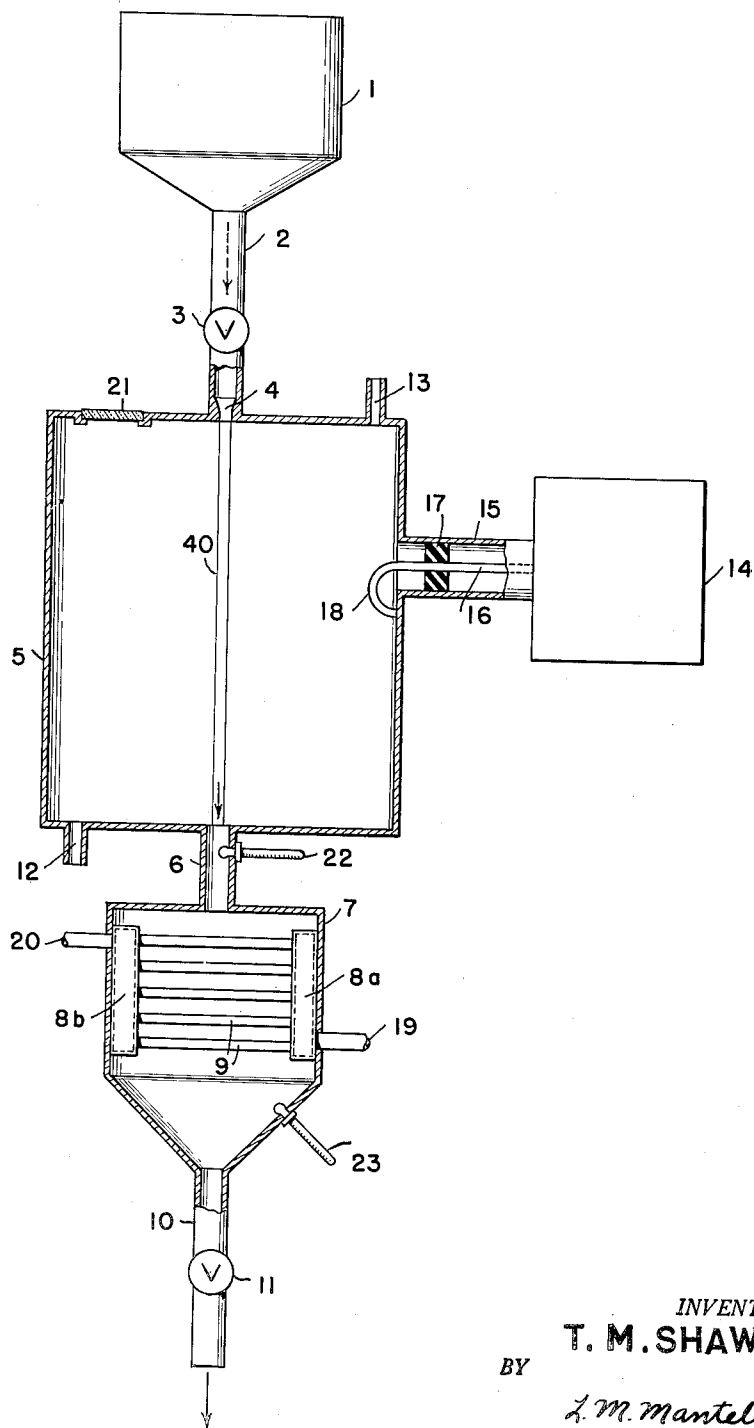
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METHOD AND APPARATUS FOR HEATING FLUIDS

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METHOD AND APPARATUS FOR HEATING
FLUIDS

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This application is made under the act of March 3, 1883, as amended by the act of April 30, 1928, and the invention herein described, if patented in any country, may be manufactured and used by or for the Government of the United States of America for governmental purposes throughout the world without the payment to me of any royalty thereon.

This invention relates to a method and apparatus for heating fluids, particularly liquid foodstuffs, by means of ultra high-frequency dielectric heating.

The invention utilizes the principle of exciting a conductive cavity with a source of high-frequency electromagnetic waves, the size of the cavity being such that the cavity is in resonance with the high-frequency generator. A fluid or divided solids are then passed, in a freely-falling stream, through the cavity at the region or regions where the standing waves in the cavity are at maximum voltage. In this manner the material is subjected to the maximum electrical energy available in the system and is heated by the action of the electromagnetic waves.

Many methods and devices are known and used for the heating of liquid foodstuffs. The most common method is to heat the liquid in a vessel or heat-exchanger by thermal contact with steam or other hot medium. In such processes the liquid film that is close to the heated surface does not move, hence this portion of the liquid is heated to a higher temperature than the remainder of the liquid. As a result, development of off-flavors occurs because of the overheating of a portion of the material. Besides this surface effect, overheating also results because it is impossible to achieve heating at a reasonable rate without employing a heating medium at a temperature much higher than the final temperature desired. Thus if it is desired to heat a body of liquid to 80°, the temperature of the heating medium must be considerably higher than 80° in order that the temperature gradient be high enough to obtain heat transfer at a reasonable rate. As a consequence it is unavoidable that portions of the liquid closest to the heating medium will have a higher temperature than more remote portions. This situation is, of course, aggravated with viscous materials or materials which become viscous on heating, in which cases agitation is difficult and often impossible. It is also known to heat materials including foods by induction heating. Such type of heating involves passing a high-frequency current through a cylindrical coil and passing the foodstuff along a

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path coincident with the axis of the cylinder. This method has the disadvantage that the electromagnetic field established by the coil is widely dispersed, whereby different portions of the material are heated to different temperatures. Further, in such type of heating, only the magnetic force of the current is utilized since the electric forces are very weak in the region of the axis of the cylinder.

The method and apparatus of this invention are not subject to the disadvantages set forth above. The fluid is not in contact with any surface while undergoing heating, hence no overheating occurs. There is no temperature gradient involved; hence no overheating is caused by this phenomenon. The electrical energy acts upon and heats all the particles in the fluid stream to the same extent regardless of their position in the stream. Further, the fluid is passed through a region in the cavity where the electrical field is uniform and has its maximum value. Thereby uniform heating is obtained and the maximum of energy available in the system is utilized. Further, the invention utilizes not only the magnetic but also the electrical energy available in the system.

In the figure annexed herewith is illustrated an embodiment of the apparatus of this invention. This embodiment comprises hopper 1 at the lower end of which is attached pipe 2. Valve 3 is provided in pipe 2 to regulate the flow of liquid from hopper 1 to treating chamber 5. A nozzle 4 having a circular cross-section is disposed at the point where pipe 2 is attached to chamber 5. The purpose of this nozzle is to cause the fluid 40 to flow into chamber 5 in a smooth downward-flowing stream, preferably as a pencil or cylindrical stream of narrow cross-section compared to the diameter of chamber 5. Chamber 5 is a cylindrical vessel made of material which is a good conductor of electricity—copper or silver, for example. The horizontal cross-section of this chamber is critical and preferably should be about one-half wave length in diameter. Thus, if the chamber is excited with a current of 600 megacycles, the diameter of the chamber should be about 35 centimeters. Further data on the correlation of frequency and size of the cavity is set forth hereinafter. As shown in the drawing, the nozzle 4 is situated in the middle of chamber 5 so that the fluid flowing through the chamber will pass through the points in the chamber where the electromotive field is at a maximum. Light-glass 21 is provided in the top of chamber 5. A high-frequency generator 14 of

conventional type feeds high-frequency current into chamber 5 via coaxial cable 15, 16. Coaxial members 15 and 16 are, of course, made of a material which is a good conductor of electricity. Annulus 17 is made of insulating material and serves to prevent contact of the coaxial members 15 and 16. The middle coaxial conductor 16 is formed into a loop 18 within chamber 5 and is fastened to the chamber wall at its extreme end. By means of this arrangement, the high-frequency current from generator 14 is impressed upon chamber 5, the dimensions of which are adjusted so that it will be in resonance with the generator. The fluid or liquid 40 which has been exposed to the high-frequency field flows directly into pipe 6 provided with thermometer 22. This pipe, in turn, conducts the fluid into cooler 7. Cooler 7 is a vessel equipped with cooling means comprising chests 8a and 8b and pipes 9. A suitable refrigerant such as cold brine is pumped through pipe 19, chest 8a, pipes 9, chest 8b, and pipe 20. Thermometer 23 is installed in the bottom of cooler 7. Fluid which collects in cooler 7 can be withdrawn through pipe 10 by suitable operation of valve 11. Vent 13 is provided to release gases such as steam which are released when the device is operated. Inert gases such as nitrogen may be introduced through pipe 12 to flush out air from chamber 5 to prevent oxidation or other undesirable reactions from taking place during processing. If desired, a slight pressure of inert gas may be employed during processing to flush air entrained in the liquid and steam out of the system through vent 13.

The operation of the device may be explained as follows:

The fluid to be treated is placed in hopper 1 with valve 3 closed. The generator 14 is then switched on to energize chamber 5. The refrigerant is circulated through cooler 7. Valve 3 is then opened to permit the fluid to flow in a stream through chamber 5 into pipe 6. The opening of valve 3 is adjusted to obtain the proper heating of the fluid in its passage through the chamber as measured by thermometer 22. The rate of flow will, of course, be governed by the temperature increase desired and by the electrical power available in the generator-chamber system. After obtaining a proper rate of flow, it is advisable to adjust the frequency of generator 14 since the stream in the chamber will, to some extent, detune the system. By slight adjustment of the frequency of the generator the chamber can be brought back into resonance. This fact can easily be determined by the use of electrical probes and other instruments well known to those skilled in high frequency work. The hot fluid entering pipe 6 descends into cooler 7 where it is instantaneously cooled thereby to prevent undesired reactions which would cause development of off-flavors, etc. The treated, cooled fluid collecting in cooler 7 may be canned, frozen, or otherwise prepared for use or sale.

The source of high-frequency electromagnetic waves may be any of the devices available in commerce for communications and/or radar purposes. A generator suitable for the purposes of this invention is described by R. B. Nelson in *Journal of Applied Physics*, vol. 18, page 356 (1947). Other generators with which those skilled in the art are familiar are equally operative. The frequency of the generator may be varied over a wide range. In general, any frequency employed in radio communications can be used. It is to be noted that the frequency of

the generator controls the size of the cavity because the generator and cavity must be in resonance; the higher frequencies requiring a cavity of smaller cross-section. Thus for practical purposes it is preferred to use a frequency in the range from about 500 to about 5000 megacycles per second. Where it is desired to treat a very fine thread-like stream of liquid the frequency can be increased to as high as 30,000 megacycles per second. As stated above, the generator and cavity must be in resonance to obtain the full effect of the electrical output of the generator. As well known in the field of high-frequency currents, the shape and size of the cavity determine its resonant frequency. Although we prefer to use a cylindrical cavity having an inner diameter approximately equal to one-half wavelength because the standing waves therein are of simple character, being at a maximum along the longitudinal axis thereof, other shapes or sizes may be used such as squares or rectangles having dimensions of one-half, one or other multiples of one-half wavelengths. In any case the point or points of maximum voltage can be easily determined mathematically or by the use of electrical probes. Resonance can also be determined mathematically or by experimentation using an electrical probe to ascertain the adjustments necessary to obtain resonance. Data on the determination of maximum points and calculation of proper sizes to obtain resonance are set forth in the textbook *Hyper and Ultra High Frequency Engineering*, by Sarbacher and Edson at pp. 364-396 and in the article by Horner et al. in *Journal of the Institution of Electrical Engineers (London)*, vol. 93, p. 53 (1946). It is obvious that where a size or shape of cavity is used such that there is more than one maximum point, one may pass the fluid through the cavity in several streams, one stream passing through each point of maximum voltage.

The method and apparatus of this invention are of wide versatility and can be employed for the heating of any fluid, this term being used to include any material capable of flowing. Thus the invention can be applied to any normally liquid material, to solutions of solids in normally liquid materials, to emulsions or suspensions of liquid or solid materials in a liquid medium, to sludges, and slurries. The fluid may also be a material which en masse has fluid characteristics. Thus the fluid may be granular or powdered material which is capable of flowing. Thus the invention can be utilized for the sterilization or heat treatment of seeds, powdered or granular foods or chemicals. The device can thus be employed for feeding heated powdered or granular materials into reaction systems. In other applications, the chamber can be used as the reaction vessel itself. Thus a catalyst in divided condition is fed into the chamber as the fluid to be heated, while simultaneously gases are fed into the chamber through vents 12 or 13 for reaction in the presence of the catalyst. The purpose of the heating in regard to any fluid may be heating to cause chemical reaction, heating to cause evaporation either to concentrate the non-volatile components or to recover the volatile component or both, heating merely to raise the temperature for further processing or use of the liquid, heating to pasteurize, sterilize or to inactivate enzyme components. Our invention is particularly adapted to the heating of liquid foodstuffs such as fruit or vegetable juices, soups, gravies, fruit or vegetable purees, milk, sugar so-

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lutions or syrups, egg meats, meat juices, liquid cereal preparations such as malt extracts, worts, and cereal broths. In particular our invention is adapted to the heating of liquid foodstuffs for the purpose of sterilizing the material so that it is in condition for packaging as by canning, bottling, or freezing.

In its preferred form, the outlet 6 of chamber 5 is of such size and so placed with respect to orifice 4 that the line stream or thread of liquid or divided solids 40 drops into it with no accumulation or a minimum of accumulation, of the material in the bottom of chamber 5. This assists in avoiding fluctuations in the characteristics of the dielectric in chamber 5.

Having thus described my invention, I claim:

1. A high-frequency resonant cavity heater for liquid foodstuffs comprising an axially elongated chamber of electrically conductive material disposed with its axis in a vertical plane, means for feeding liquid foodstuffs to be heated into said chamber in the form of a cylindrical line stream substantially coincident with the axis of said chamber, the means for feeding liquid including a vessel for the liquid, a liquid outlet conduit for the vessel, a valve in said conduit, and a restricted axial orifice having a circular cross-section at the point where the conduit enters the chamber, means for establishing a high frequency electric field within said chamber the electric field being parallel to the axis of the chamber and the region of maximum and uniform electrical intensity being coincident with the axis of the chamber whereby the line stream of liquid is subjected to the maximum and uniform energy of the electrical field existing in the chamber, an outlet in the bottom wall of said chamber, said outlet being of sufficient size to admit the line stream and to avoid accumulation of fluid on the bottom wall of the chamber, a vent in the chamber wall to release gases released from the liquid, and cooling means connected with said outlet to instantaneously cool the foodstuff to prevent undesired reactions.

2. A method of heating a liquid foodstuff which comprises passing the liquid foodstuff in a free-falling line stream, in the form of a narrow cylindrical pencil unconfined at its side boundaries, through a cylindrical cavity excited by and in resonance with a source of high-frequency electromagnetic waves, the line stream being passed through the cavity along a path coincident with the axis of the cavity, this path being coincident with the region in the cavity where the standing waves are substantially at constant maximum voltage, the electric field being parallel to said stream, the stream being thereby sub-

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jected throughout its passage to the maximum and uniform energy of the electric field existing in the cavity, the diameter of the stream being at least several times less than the diameter of the cavity, most of the space in the cavity being vacant of liquid material, and in which process the heated material is not permitted to accumulate in the cavity, being immediately removed from the cavity.

3. A method of heating a liquid foodstuff which comprises passing the liquid foodstuff in a free-falling line stream, unconfined at its side boundaries, through an elongated cylindrical cavity excited by and in resonance with a source of high-frequency electromagnetic waves, the line stream being passed through the cavity along a path coincident with the axis of the cavity, this path being coincident with the region in the cavity where the standing waves are substantially at constant maximum voltage, the electric field being parallel to said stream, the stream being thereby subjected throughout its passage to the maximum and uniform energy of the electric field existing in the cavity, the line stream being a narrow cylindrical pencil substantially confined to the axial region, the liquid foodstuff being fed to the cylindrical cavity through a restricted orifice having a circular cross-section, and in which process the heated liquid foodstuff is not permitted to accumulate in the cavity, being immediately removed from the cavity for cooling.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,166,207	Clark	July 18, 1939
2,188,625	Dufour et al.	Jan. 30, 1940
2,364,526	Hansell	Dec. 5, 1944
2,398,606	Wang	Apr. 16, 1946
2,446,557	Schutz et al.	Aug. 10, 1948
2,480,679	Spencer	Aug. 30, 1949
2,495,170	Kinn	Jan. 17, 1950
2,495,435	Welch	Jan. 24, 1950
2,497,670	Hanson et al.	Feb. 14, 1950
2,500,752	Hanson et al.	Mar. 14, 1950
2,508,365	Bierwirth	May 23, 1950
2,545,106	Parker	Mar. 13, 1951

OTHER REFERENCES

Terman, "Radio Engineer's Handbook," 1943, pp. 251-273, particularly pp. 265, 266.
 "Heating with Microwaves," Electronics, March, 1947, pages 82-85.