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MICROWAVE APPARATUS FOR EVAPORATING LIQUID MIXTURES

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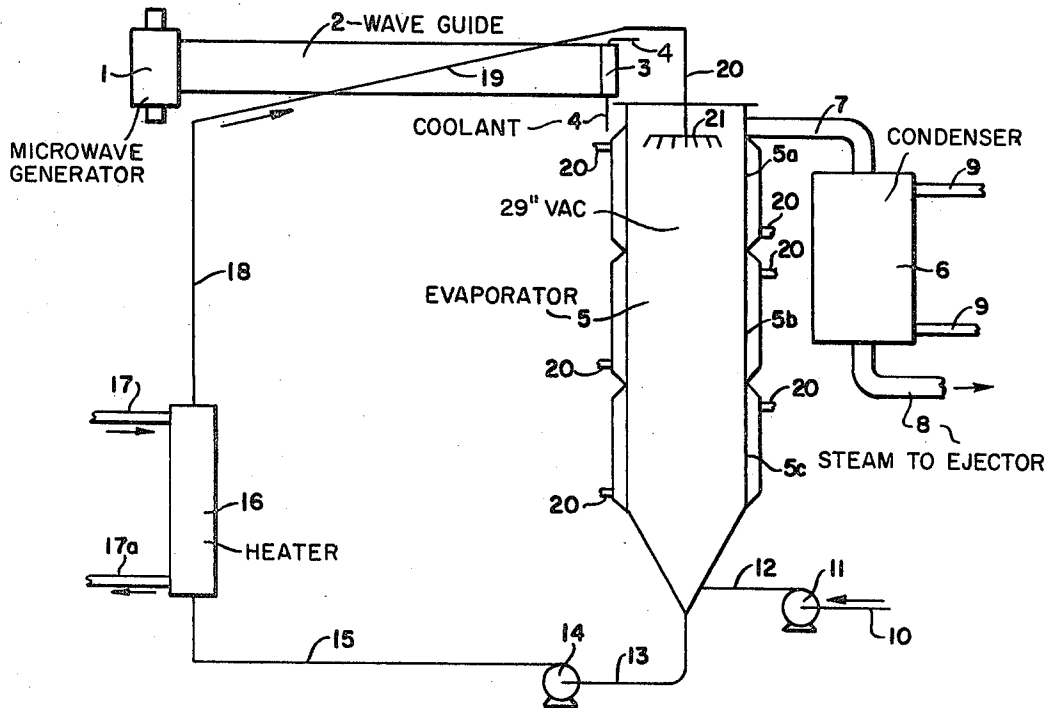


FIG. 1.

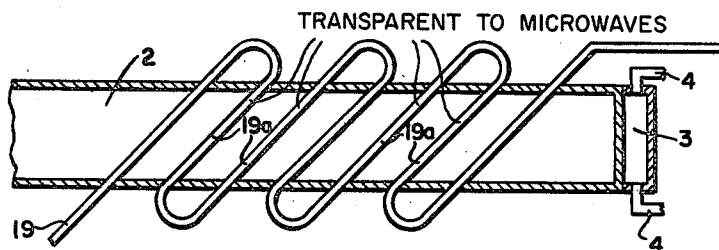


FIG. 2.

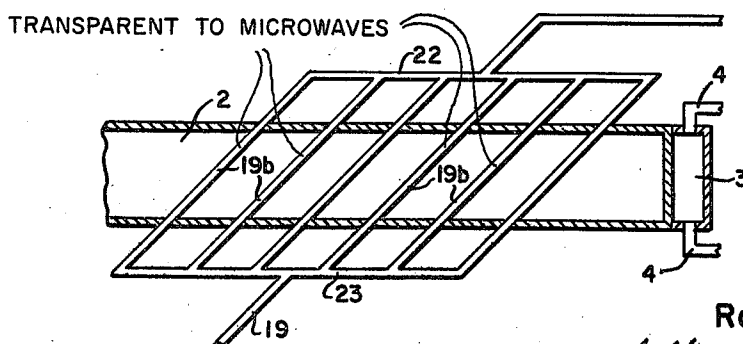


FIG. 3.

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MICROWAVE APPARATUS FOR EVAPORATING LIQUID MIXTURES

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7 Claims

ABSTRACT OF THE DISCLOSURE

An evaporator for liquids comprises a wave guide and a microwave generator feeding thereinto. A microwave-transparent tube conveying preheated liquid passes thru the wave guide at an angle to its axis thus further heating the liquid which is then sprayed into a heated, evacuated chamber wherein the liquid is flash evaporated. The released vapor is withdrawn and condensed and the un-evaporated liquid is mixed with feed and recycled.

This invention relates to means for evaporating and concentrating liquid mixtures containing water and more particularly for concentrating fruit juices and other heat-sensitive liquids by means of electromagnetic wave energy.

In Patent No. 3,072,090, Ralph G. Sargeant teaches the concentration of such liquid mixtures by subjecting them, while flowing in a closed path, to the action of radio frequency energy, and discloses a special electrode structure for accomplishing this.

In carrying out this Sargeant method, it was found to be necessary to apply the radio frequency energy to the flowing stream of liquid while under substantial hydraulic pressure. If the juices are subjected to radio frequency energy, in accordance with the Sargeant method, while under atmospheric or sub-atmospheric pressure, arcing will be likely to occur, with the result that the product may be burned where it comes into contact with the electrode.

I now find that practically the same concentrating result can be achieved by using microwave energy instead of radio frequency energy, and that, by employing improved apparatus, it is possible to successfully concentrate the juices while at atmospheric or sub-atmospheric pressures, as distinguished from substantial hydraulic pressure.

The general object of the invention is to provide an effective arrangement of apparatus for carrying out such microwave treatment for concentrating the fruit juices.

In order that the invention may be readily understood, reference is had to the accompanying drawing, forming part of this specification, and in which:

FIG. 1 is a diagrammatic view showing one arrangement of my novel apparatus;

FIG. 2 is a fragmentary sectional view on an enlarged scale, showing a modified construction; and

FIG. 3 is a similar view, showing still another modification.

Referring to the drawings in detail, 1 designates any desired form of microwave generator. It is arranged to discharge directly into one end of an elongated wave guide 2. This is in the nature of a metallic conduit, which may have a rectangular cross-section. The opposite end is preferably terminated by a "water load" 3, to absorb the excess energy. This "water load" comprises a closed chamber through which cooling water is caused to circulate by means of pipes 4.

My apparatus includes an evaporating chamber 5, which is shown as an elongated, vertically disposed cylinder. A suitable vacuum is maintained in this chamber by means such, for example, as a steam-operated air ejector (not shown), operating through pipe 8, a suitable condenser 6, and pipe 7, tapping the top of the chamber 5. The

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air ejector, condenser, and other associated parts, may be similar to what is shown in the Sargeant patent, above referred to, and in the operation of my apparatus, a partial vacuum and temperatures substantially the same as in said Sargeant patent are maintained. A suitable product discharge means may be provided in the pipe 15.

The liquid mixture to be evaporated may be delivered into the chamber 5, by a pump 11, and pipes 10 and 12.

From the lower end of the evaporator 5 which preferably has a conical bottom, with cylindrical sides, extends a pipe 13, to a circulating pump 14, which delivers into a pipe 15, preferably connected with one end of an auxiliary heat exchanger 16, supplied with heating fluid which enters by pipe 17, and is discharged through pipe 17a.

From the other end of the heat exchanger 16 extends a pipe 18, which is connected at its upper end with one end of a special tube element 19. This tube element passes through the sides of the wave guide into and transversely across the same. After it emerges from the wave guide it is connected by pipe 20 with a spray head 21, disposed near the top of the evaporating chamber, substantially the same as shown in said Sargeant patent.

The tube element 19 must be formed of material which is transparent to microwaves. An excellent material for this purpose is the well known plastic sold under the name "Teflon." Other hard plastics, as well as certain types of glass, may also be successfully employed.

The liquid mixture to be evaporated is circulated by means of the pump 14 from the bottom of the chamber 5, up through the pipes 15 and 18, with or without being pre-heated by the auxiliary heat exchanger 16, into and through the tube element 19, and thence by pipe 20 and spray head 21, into the evaporator. In its passage through the tube element 19 the liquid mixture is heated by the microwave energy inside the wave guide, which energy permeates the tube element and the liquid flowing through the same. This microwave energy may produce other effects on the liquid mixture in addition to heating. It is not known with certainty just what other effects the microwave energy has on the liquid mixture. In any event, when the heated liquid mixture issues from the spray head and is discharged into the evaporator, which is maintained under partial vacuum, as described, the water present in the mixture flashes into vapor, and is drawn off and condensed, as in the Sargeant patent.

The microwave energy employed may have a frequency of anywhere from 915 to 22,000 megacycles, or more. The precise frequency range appears to be unimportant.

Since a vacuum of approximately 29 inches of mercury is maintained in the evaporating chamber, and since the pressure required to force the liquid mixture through the tube element is very small, there being no restriction between this tube element and the evaporator, it is obvious that the liquid mixture will be subjected to the microwave energy while flowing through the tube element at sub-atmospheric pressure.

In FIG. 1 I have shown the tube element 19 as comprising only a single straight portion passing through the side walls of the wave guide and extending transversely across the interior thereof at an acute angle to the axis of the same. This is a rather inefficient arrangement, since the single run of the tubing can absorb only a relatively small part of the microwave energy passing through the wave guide, the major part of such energy by-passing the tube element and being absorbed by the water load at the far end.

In FIGS. 2 and 3 I have shown more efficient arrangements.

FIG. 2 illustrates an arrangement in which the tube element 19 comprises a plurality of portions 19a, formed

by a number of loops, all connected in series and all passing through the opposite side walls of the wave guide and extending transversely across the interior thereof at an acute angle to the axis of the same. Here, the microwave energy passing through the wave guide impinges successively on the plurality of portions 19a of the tube element, and the effect is cumulative, the total absorption of energy by the liquid mixture being treated, being much greater than with only a single run of tubing exposed to the energy, as in FIG. 1.

In FIG. 3 is illustrated a generally similar idea, except in this case I provide a plurality of tube portions 19b all connected in multiple or parallel between two manifolds 22, interposed in the tube element 19. In this case also, these portions 19b of the tube element each passes through the side walls of the wave guide, and extends transversely across the interior thereof at an acute angle to the axis of the same. The microwave energy traveling along the wave guide impinges successively on the tube portions 19b, and the effect is multiplied. Here again, the total absorption of energy is much greater than in FIG. 1.

Referring again to FIG. 1, I preferably surround the evaporator 5 with a series of separate jackets, three such jackets being shown and designated 5a, 5b and 5c. Each of the jackets is equipped with inlet and outlet pipes 20, through which heating mediums of different temperatures may be caused to flow. Thus one portion of the evaporator may be maintained at a higher or lower temperature than other portions. Jackets 5a and 5b, for example, might be used to supply the heat of vaporization, and jacket 5c to heat the product, or jacket 5a might be used for the heat of vaporization, and jackets 5b and 5c to heat the product.

This jacket arrangement might be used to take the place of the heat exchanger 16, or may be used in conjunction with it.

What I claim is:

1. Apparatus for evaporating liquid materials comprising an evaporating chamber maintained under partial vacuum, a microwave generator, an elongated wave guide into one end of which said generator discharges, a tube element transparent to microwaves having a portion extending at least once through the sides of said wave guide into and transversely across the same at an acute angle with the wave guide axis, one end of said tube element being connected with said evaporating chamber and the other end with a liquid feed supply, and means for causing the liquid to be evaporated to flow through said tube element into said chamber.

2. Apparatus in accordance with claim 1 in which the evaporator is in the form of an elongated, vertically disposed chamber, and in which a spray head is mounted

within said chamber adjacent the top thereof, said tube element being connected with said spray head.

3. Apparatus in accordance with claim 1 in which said tube element has a plurality of portions each extending through the sides of said wave guide into and transversely across the same.

4. Apparatus in accordance with claim 3 in which said plurality of portions of the tube element are connected in series

5. Apparatus in accordance with claim 3 in which said plurality of portions of the tube element are connected in parallel.

6. Apparatus for evaporating liquid materials comprising an elongated, vertically disposed chamber, means for generating microwave energy and a wave guide confining same along a closed path, a tube element transparent to microwaves disposed in the path of said microwaves, one end of said tube element being connected with said evaporating chamber and the other end with a liquid feed supply, said tube element being inclined at an acute angle to the axis of said wave guide, means for causing the liquid to be evaporated to flow through said tube element into said chamber, a plurality of independent jackets surrounding different, vertically spaced portions of said chamber, and means for causing a heating medium of a different temperature to circulate through each of said independent jackets.

7. Apparatus for evaporating liquid materials comprising an elongated, vertically disposed evaporating chamber, means for causing the liquid to be evaporated to be heated, said means comprising a microwave guide and a heating tube transparent to the microwaves passing through said guide at an acute angle thereto, said liquid then being discharged into the top of said chamber, a plurality of independent jackets surrounding different vertically spaced portions of said chamber, and means for causing a heating medium of a different temperature to circulate through each of said independent jackets.

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