

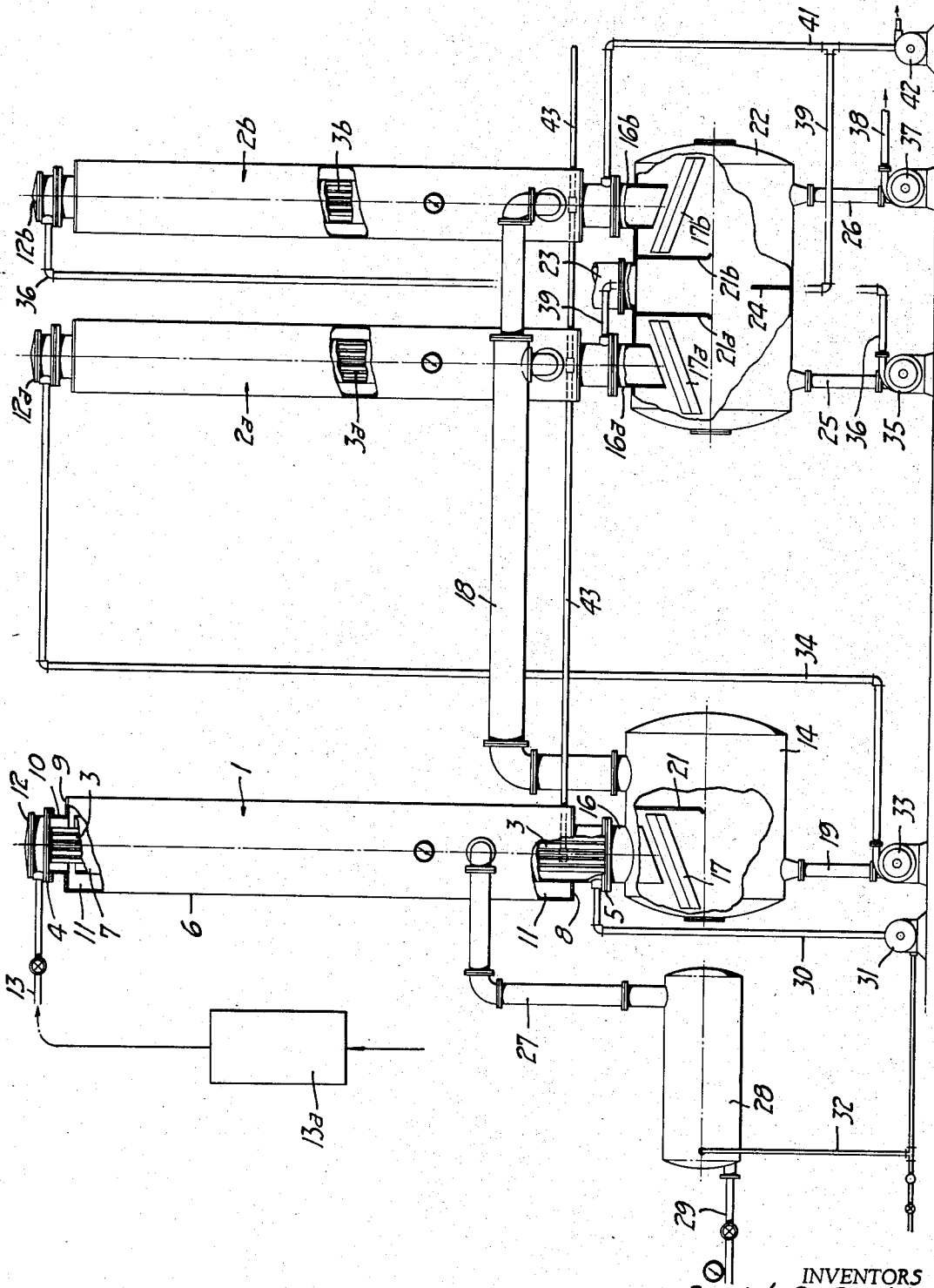
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D. D. PEEBLES ET AL

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EVAPORATING APPARATUS AND METHOD

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INVENTORS
David D. Peebles
Paul D.V. Manning

BY

Paul D. Flehr
ATTORNEY.

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EVAPORATING APPARATUS AND METHOD

David D. Peebles, Eureka, and Paul D. V. Manning, Berkeley Woods, Calif.

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6 Claims. (Cl. 159—17)

This invention relates generally to apparatus and methods for the concentration of various liquid materials containing one or more vaporizable components, in two or more evaporating effects or stages. It has particular application where the liquid material to be evaporated contains organic ingredients, such as milk or milk products, fruit juice, and the like.

It is an object of the invention to provide an apparatus and method of the above character which will be characterized by efficient evaporation in a second or subsequent evaporating effects, irrespective of the fact that the liquid material being handled is more concentrated than the liquid fed into the first effect.

Another object of the invention is to provide a multiple effect evaporator of the "vapor-mist" type, which maintains the desired character of evaporating action as the liquid becomes more concentrated.

Another object of the invention is to provide an evaporating apparatus and method which will be characterized by the existence of a relatively small amount of liquid being concentrated in the system at any one time. This characteristic is of advantage in handling material such as milk products or fruit juices, which are apt to be injured by prolonged heating.

Another object of the invention is to provide a multiple effect evaporator in which a single pass of the liquid through the different effects will suffice to produce a relatively high degree of concentration.

Further objects of the invention will appear from the following description, in which the preferred embodiment of the invention has been set forth in detail in conjunction with the accompanying drawing.

The apparatus as illustrated in the drawing affords two evaporating effects or stages, each of which utilizes evaporating tubes through which the liquid material being evaporated is caused to pass. A vapor-mist type of evaporation is utilized, such as is disclosed in our co-pending application Serial No. 14,300, filed April 2, 1935. The first effect utilizes one heater 1, while the second effect utilizes the two heaters 2a and 2b.

Heater 1 consists of a plurality of evaporating tubes 3, which have their ends secured to the upper and lower tube sheets 4 and 5. The tubes 3, for substantially their entire length, are surrounded by the steam jacket 6. Within the jacket 6 the tubes 3 are surrounded by a conduit 7 forming in effect a cylindrical baffle. The lower annular end wall 8 of the jacket 6 is attached to

conduit 7, and a lower extension of the conduit 7 is attached to the tube sheet 5. The upper annular end wall 9 of the steam jacket is shown attached to an extension 10, which in turn is secured to the tube sheet 4. The upper end of conduit 7 terminates short of the annular end wall 9, whereby steam introduced into the jacket flows upwardly through the space 11, and then downwardly through the conduit 7 and about the evaporating tubes 3. The space above tube sheet 4 is enclosed by the head 12, which forms a primary expansion chamber communicating with the upper ends of the evaporating tubes 3. Pipe 13 is shown for introducing liquid to be evaporated into the head 12, and is shown connected to the outlet of a preheater 13a.

The mist of liquid and vapor discharged from the lower ends of the evaporating tubes 3 is delivered into a separating and collecting receiver 14. Depending conduit 16, which extends downwardly from the lower tube sheet 5, serves to connect this receiver with the heater 1. Immediately below the lower end of conduit 16 there is an inclined entrainment tray 17 which aids in effecting separation between liquid and vapor. Vapor is removed from receiver 14 by conduit 18, while liquid is removed by the depending pipe 19. A baffle 21 tends to minimize entrainment of liquid particles in the vapor removed through conduit 18.

The heater 2a can be constructed in a manner similar to the heater 1 described above. However, for reasons to be presently explained, the cross-sectional flow area afforded by the tubes 3a is made substantially less than the cross-sectional flow area of the tubes 3 for heater 1. This can be done by utilizing tubes of the same internal diameters for both heaters, with a substantially fewer number of tubes 3a so that the combined cross-sectional flow area will be substantially less. It can also be accomplished by using substantially the same number of tubes as compared with the number of tubes for heater 1, but with the tubes 3a being of a substantially smaller internal diameter. In this connection, good results have been secured by making the total cross-sectional flow area afforded by tubes 3a about 60% of the cross-section flow area afforded by the tubes 3 for the first heater. Heater 2b can be a duplicate of heater 2a. Because of the smaller cross-sectional flow area afforded by the tubes 3a and 3b of these two heaters, it is evident that the remaining parts of these heaters can be of reduced size, as compared with the heater 1.

Instead of providing separate collecting and

separating receivers for the two heaters 2a and 2b, a single receiver 22 is provided. This receiver receives liquid and vapor from the two heaters, through the conduits 16a and 16b, and is provided with entrainment trays 17a and 17b. Baffle plates 21a and 21b are also shown, to prevent entrainment of liquid particles with the vapor withdrawn through conduit 23. A baffle 24 segregates liquid collected in the lower part of receiver 22, whereby the liquid components discharged from the tubes 3a and 3b are not allowed to intermix, but are separately collected and separately withdrawn through the pipes 25 and 26.

The additional equipment and connections illustrated in the drawing are as follows:—Steam is admitted to the jacket 6 of the first heater 1 through pipe 27. Where it is desired to utilize steam from a high pressure source, with admission of steam to the heater 1 at a relatively lower pressure, a de-superheater 28 is employed, which is connected to a high-pressure steam pipe 29, to suitable pressure reducing means. Condensate is shown being withdrawn from the first heater 1 through pipe 30 and condensate pump 31. A part of this condensate can be sprayed into the de-superheater 27, as indicated by pipe 32. Pipe 19, which receives liquid from the receiver 14, is shown connected to the inlet side of a pump 33 which has its discharge side connected by pipe 34 to the head 12a of heater 2a. Conduit 18, through which vapor is withdrawn from the receiver 14, is shown connected to the jackets of the two heaters 2a and 2b. Thus the supply vapor to the heaters 2a and 2b is vapor evolved from the liquid being evaporated in the first effect, and is vapor under like temperature and pressure conditions. Such an arrangement can be termed parallel heating, of the second effect heaters.

Pipe 25, through which liquid collected from the heater 2a is withdrawn, is shown connected to the inlet side of a pump 35, the discharge side of which is connected by pipe 36 to the head 12b of heater 2b. Pipe 26, which receives liquid discharged from heater 2b, connects to the inlet side of a pump 37, the discharge side of which connects with a pipe 38 for final delivery. Condensate from both the heaters 2a and 2b is shown being withdrawn through pipe 39 and 41 to the condensate pump 42. Pipe 43 is shown communicating with all of the heaters 1, 2a and 2b, and leads to suitable evacuating means for the removal of non-condensables. Vapor conduit 23, which connects to the receiver 22, leads to a suitable condensing apparatus whereby a desired degree of vacuum can be maintained.

Operation of the apparatus described above, and the carrying out of the method involved, are as follows:—The liquid to be evaporated, after being heated to a predetermined temperature, is conveyed through pipe 13 to the head 12 of the first heater 1. In passing through this head and into tubes 3 the preheated liquid is converted by a primary evaporation, due to the maintenance in heater 1 of a pressure lower than the vapor pressure of the liquid, into a highly dispersed mixture of vapor and liquid. As the mixture of vapor and liquid passes down through the tubes 3, a further expansion of liquid into vapor occurs under the influence of heat supplied by the steam in jacket 6, whereby the liquid is maintained in the form of a fine mist from which progressive evaporation occurs throughout the length of the tubes. Maintenance of the liquid in the form of a

highly dispersed mist through the length of the tubes is effected by the primary flash evaporation and by the continued evaporation in the tubes by the transfer of heat therein to the primarily formed vapor-liquid mixture in which the volume of the vapor is sufficiently large compared to the volume of liquid to hold the liquid mist particles in dispersion. It will be evident that the discharge from the lower ends of tubes 3 will consist of vapor and entrained mist particles of liquid.

The partially evaporated liquid separated out in the receiver 14 is delivered by pump 33 to the heater 2a of the second effect. In flowing downwardly through the evaporating tubes 3a, evaporation occurs in substantially the same manner as described above in connection with the first heater 1. Liquid from the heater 2a, which has collected in the receiver 22, is delivered by pump 35 to the heater 2b. Here the liquid is further concentrated by passing downwardly through the tubes 3b, so that as finally delivered by the pump 37 it is of the concentration desired.

Due to the concentration occurring in the first effect, it is evident that the liquid supplied to the second effect is considerably smaller in volume as compared to the liquid fed through pipe 13, and in most instances it is of higher viscosity. If such partially concentrated liquid were passed through a single heater forming the second effect, having tubes affording the same cross-sectional flow area as in the heater of the first effect, it would not be possible to attain the degree of high concentration desired, without decreasing the volume of liquid supplied to such a low point, in comparison with the cross-sectional flow area afforded by the evaporating tubes, that incrustation of the tubes would result and the rate of heat transmission to the liquid would be lowered. However, with two heaters such as described, each having a considerably smaller number of tubes than the heater of the first effect, to afford less aggregate cross-sectional flow area, a greater quantity of liquid is caused to pass through each tube. It has been found that as the liquid material becomes more concentrated, more efficient evaporation is obtained without incrustation, when the quantity of liquid supplied to each tube is increased. This can be better explained by pointing out that in general as the liquid material becomes more concentrated, its surface tension and viscosity increases, and more energy is required to disrupt the liquid into fine mist particles. Such mist particles are desired in order to afford a high rate of heat transmission and to avoid incrustation. Such factors are taken in account in the present invention by avoiding a decrease in the amount of liquid in any one tube of the second effect, for a given instant, below a minimum value such as will be found to cause uneven distribution of particles of the liquid with the tubes and consequent incrustation and inefficient heat transfer. This minimum value, which is made possible by the reduced cross-sectional flow area afforded by the evaporating tubes of the second effect, can not precisely be specified, but can be readily determined by experiment for each particular liquid material and set of conditions presented. Because of the manner in which evaporation is conducted, and particularly because of the manner in which concentrated liquid material is handled in the second effect, a high degree of concentration is obtained in a minimum number of effects and with-

out returning any of the liquid material for a second passage through the heaters.

It may be further explained that evaporating conditions within the tubes 3, 3a, and 3b, can be likened to a flash evaporator in which the liquid, instead of flashing within an enlarged chamber, is flashed into an elongated restricted passage which is being continuously supplied with heat, whereby the conversion of more liquid into vapor occurs progressively throughout the evaporating tubes. Transit of vapor and liquid through the evaporating tubes occurs at a rapid and ever-increasing rate and produces a condition of turbulence which promotes efficient heat transfer and vapor evolution from the liquid mist, and which is also conducive to a minimum amount of incrustation on the inner tube walls. The relatively high rate of passage through the tubes precludes blanketing of the inner walls with streaming films of liquid, and consequently the vapors discharged from the lower ends of the tubes are superheated to a material degree.

Better control of the equipment can be secured if the pumps 33, 35 and 37 are of such a character as to have decidedly drooping head capacity curves. We have reference to pumps of the centrifugal type which are sensitive to a change in inflow head. Assuming that the pump 33 is of this type, it is evident that while the pump is operating at a constant speed the quantity of liquid material delivered to the second effect through pipe 34 will vary automatically, in accordance with the amount of liquid flowing through pipe 19 from the receiver 14. Thus, if all of the pumps 33, 35 and 37 are of this type, it is evident that the receivers 14 and 22 can be maintained entirely drained of liquid at all times, in spite of slight variations occurring in normal operation. Aside from facilitating control of the apparatus, maintenance of receivers 14 and 22 substantially entirely drained of liquid at all times is advantageous in that by such operation the amount of liquid being treated in the apparatus, at any one time, is at a minimum. The apparatus is particularly adapted for organic liquid materials, such as milk products or fruit juices, since the period of time for which the material is subjected to heat treatment, is reduced to a minimum.

In some instances it may be found desirable to somewhat restrict communication between the upper ends of tubes 3a and 3b, and the chambers afforded by heads 12a and 12b. This can be accomplished by suitable means such as orifice plates overlying the upper ends of the tubes, and which have openings registering with the tube passages.

We claim:

1. In a liquid evaporating apparatus, a first stage heater including a plurality of evaporating tubes, means for introducing liquid to be evaporated into said tubes, a receiver connected to the discharge ends of said tubes and serving to collect liquid separated from discharged vapor, at least two second stage heaters each provided with evaporating tubes, means for delivering liquid from said receiver to the tubes of one of the second stage heaters, a receiver connected to the discharge ends of the tubes of both the second stage heaters and serving to collect liquid separated from discharged vapor, means serving to apply vapor discharged from the first stage heater for parallel heating of the second stage heaters, and means for introducing collected liq-

uid discharged from said one second stage heater to the tubes of the other second stage heater.

2. In a liquid evaporating apparatus, a first stage heater including a plurality of evaporating tubes, means for introducing liquid to be evaporated into said tubes, a receiver connected to the discharge ends of said tubes and serving to collect liquid separated from discharged vapor, at least two second stage heaters each provided with evaporating tubes, means for delivering liquid from said receiver to the tubes of one of the second stage heaters, a receiver connected to the discharge ends of the tubes of both the second stage heaters and serving to collect liquid separated from discharged vapor, means serving to apply vapor discharged from the first stage heater for parallel heating of the second stage heaters, and means for introducing collected liquid discharged from said one second stage heater to the tubes of the other second stage heater, the tubes for each of the second stage heaters affording substantially less cross-sectional flow area, than the tubes for the first stage.

3. In a liquid evaporating apparatus, at least two heaters each provided with evaporating tubes, means for delivering liquid to be evaporated to the tubes of one heater, a receiver connected to the discharge ends of the tubes of both said heaters and serving to collect liquid separated from discharged vapor, and means for introducing collected liquid discharged from said one heater to the tubes of the other heater, and means for separately removing liquid discharged from the tubes of said other heater.

4. In a process for the concentration of liquids, the steps comprising introducing the liquid to be concentrated into a heating zone in which evaporation of the liquid is effected, passing the mixture of liquid and vapor thereby produced into a low pressure zone, separating the liquid from the vapor in said low pressure zone, passing the separated liquid through a second heating zone in which further evaporation of the liquid is effected, returning the mixture of liquid and vapor thereby produced to said low pressure zone, separating the liquid from the vapor in said low pressure zone, removing said liquid separately from the first separated liquid and from the vapor and removing the vapor separated after both said heating stages at a rate effective to maintain a predetermined low pressure in said low pressure zone.

5. In a process for the concentration of liquids, the steps comprising introducing the liquid to be concentrated into a heating zone in which evaporation of the liquid is effected, passing the mixture of liquid and vapor thereby produced into a low pressure zone, separating the liquid from the vapor in said low pressure zone, passing the separated liquid through a second heating zone in which further evaporation of the liquid is effected, passing the mixture of liquid and vapor thereby produced into a second low pressure zone of lower pressure than the first zone, separating the liquid from the vapor in said second low pressure zone, passing the separated liquid through a third heating zone in which further evaporation of the liquid takes place, returning the mixture of liquid and vapor thereby produced to said second low pressure zone, separating the liquid from the vapor in said second low pressure zone, removing said liquid separately from the first separated liquid and from the vapor and removing the vapor from said

second low pressure zone at a rate effective to maintain the pressure therein lower than in said first low pressure zone.

5 6. In a process for the concentration of liquids, the steps comprising introducing the liquid to be concentrated into a zone of lower pressure than the vapor pressure of the liquid whereby the liquid is converted into a gas-liquid mixture, passing said mixture through a heating zone
10 in which further evaporation of the liquid takes place, thereafter passing the mixture into a second low pressure zone of lower pressure than the first zone, separating the liquid from the vapor in said second low pressure zone, passing

the separated liquid through a second heating zone in which further evaporation of the liquid takes place, returning the mixture of liquid and vapor thereby produced to said second low pressure zone, separating the liquid from the vapor
5 in said second low pressure zone, removing said liquid separately from the first separated liquid and from the vapor and removing the vapor from said second low pressure zone at a rate effective to maintain the pressure therein lower
10 than in said first low pressure zone.

DAVID D. PEEBLES.
PAUL D. V. MANNING.