Dec. 30, 1952 J. C. ARNAUD 2,623,580

CENTRIFUGAL EVAPORATOR

Filed March 5, 1947 2 SHEETS—SHEET 1

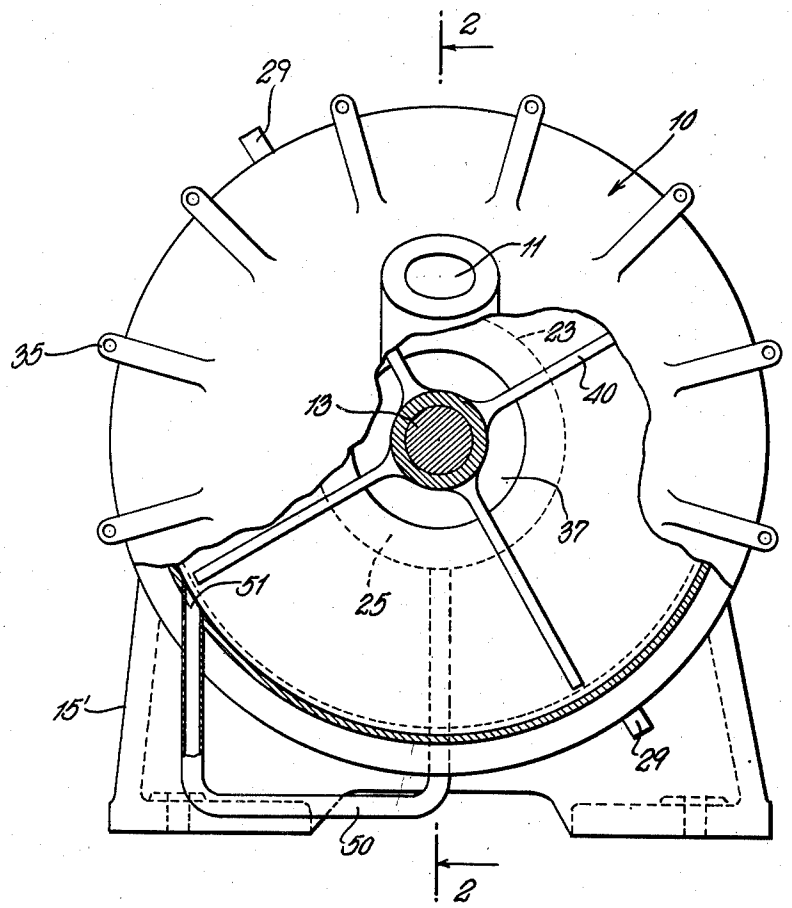


Fig. 1.

INVENTOR.
JEAN CLAUDE ARNAUD
BY

Dale A. Bauer
ATTORNEY

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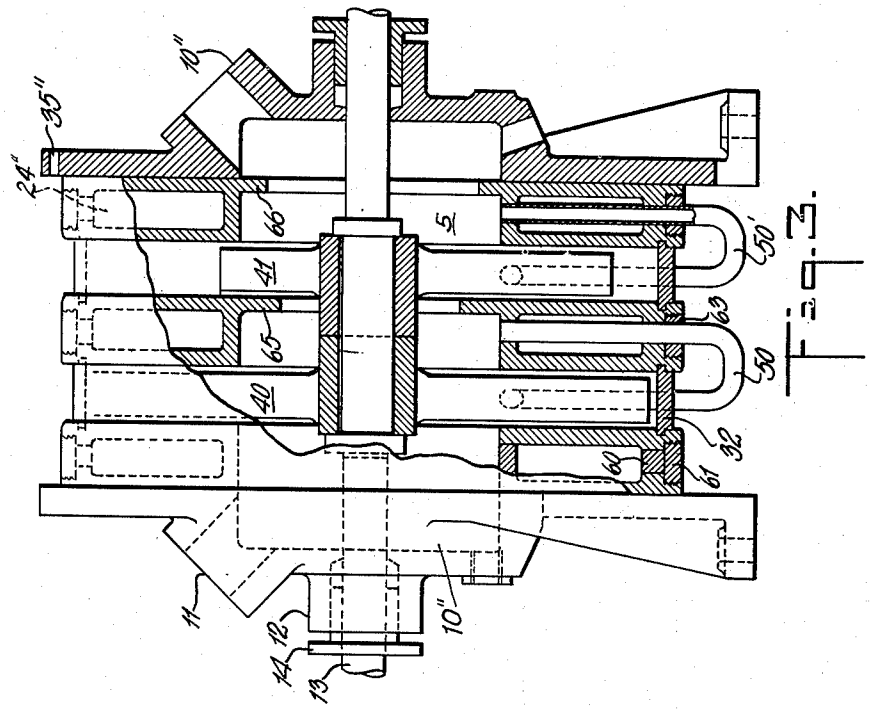


Fig. 2.

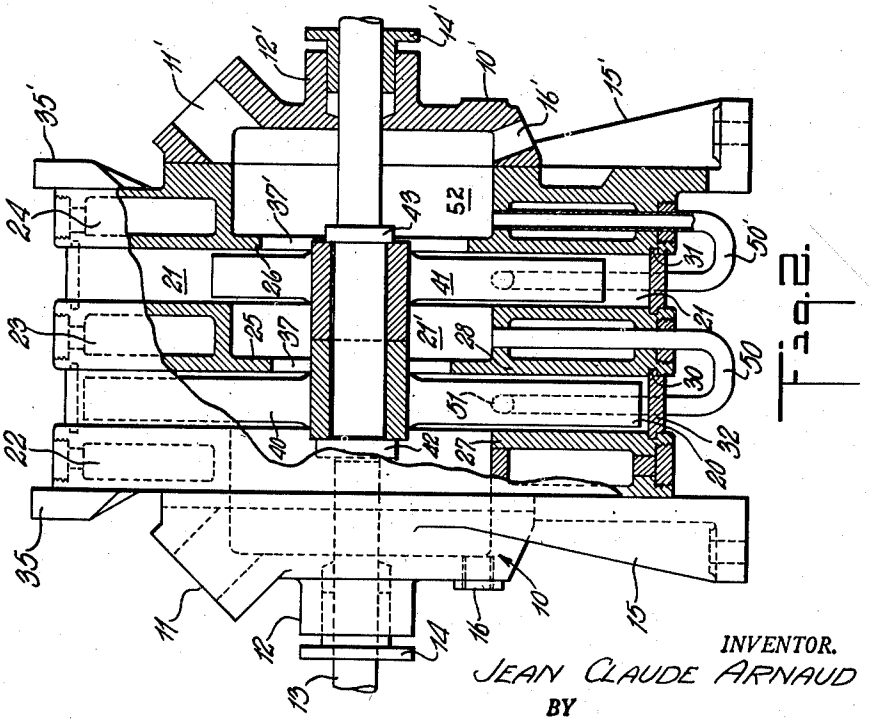


Fig. 3.

INVENTOR.
JEAN CLAUDE ARNAUD
BY

Dale A. Bauer
ATTORNEY

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CENTRIFUGAL EVAPORATOR

Jean Claude Arnaud, Facture, France, assignor to
La Cellulose du Pin, Paris, France

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16 Claims. (Cl. 159—6)

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This invention relates to an evaporator that will be called a "dynamic concentrator" because of the new principles involved, and to a new method of evaporating liquids.

Heretofore, evaporation has been carried out by putting heat under a boiler containing a liquid, heat transmission within the liquid being largely by convection. Invention has been concerned largely with variations on that old idea designed to attain some improvement in efficiency. Despite such efforts improvements have been slight and the phase change of liquid to gas still remains one of the least efficient of operations.

It is an object of this invention to apply to the evaporation of liquids new principles that improve the efficiency of heat transfer, hasten evaporation, conserve space, and economize fuel. The invention will be described with relation to a particular apparatus, and in connection with the evaporation of viscous liquids, such as sugary juices and the black liquor of the paper trade, which have been particularly difficult to concentrate. It is to be understood, however, that the particular description is not a limitation.

Fig. 1 is an end elevational view of a concentrator embodying principles of this invention, a part of the casing being broken away.

Fig. 2 is a side elevational view of the machine of Fig. 1 with the casing broken away and the exposed parts sectioned on line II—II of Fig. 1 and

Fig. 3 is a view similar to Fig. 2 showing a modified form of the machine.

Referring now to the numerals in Figs. 1 and 2, 10 is an end member of the "dynamic concentrator" having a gas outlet orifice 11, a bearing sleeve 12 to receive shaft 13, packing gland 14, and supports 15. An orifice 16 serves to admit to the machine the dilute liquid that is to be concentrated within it, and which will be delivered thereto by a valved pipe, not shown, so that the rate of delivery may be controlled.

At the other end of the apparatus is another end member having structure like that which has just been described except that its orifice 16' is aligned for the discharge of concentrated liquids. The orifice 11' serves in this end, like orifice 11 at the left end, for the escape of vapors liberated in the concentrator. The numbers given to the right end of the machine are primed to distinguish its parts from those of the left end.

Between the end plates of the machine are a series of circular chambers 20, 21 that are

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centrally interconnected with each other and with the orifices 11, 11', 16, 16'. The chambers are formed by hollow rings 22, 23, 24 having inwardly extending flanges 25, 26 that do not extend into contact with the shaft 13 or the paddle wheel axles carried by it, but leave an open space extending axially from end to end of the machine. The flanges are of different size, decreasing progressively in height toward an end of the machine. The hollow rings are filled with heating fluid, such as steam, through suitable orifices 29, so that their walls, such as 27, 28 are kept at a temperature sufficient to vaporize some part of the liquid admitted to the machine. The annular chambers 20, 21 serve as hot pockets during operation.

The walls 27, 28 are provided with circular grooves 30 that receive circular flanges 31 on spacing rings 32 that determine the width of the chambers and constitute, with the hot rings and the ends, the casing of the machine. Sealing compounds, compositions, or materials may be employed in these and in all joints subject in fluid contact.

By means of this structure the number of chambers in the apparatus may be varied at will, and the temperature applied at particular points may be varied. Thus, a hotter temperature can be maintained in ring 24 and chamber 21 by serving the ring with a current of superheated steam while ring 22 is served with wet steam. Radial arms 35, 35' having apertures through which pass long bolts serve to hold the parts of the machine in assembled relation and to permit the ready increase or decrease of the parts necessary to change the number of its chambers.

The chambers are each composed of a larger part such as 21, and a smaller part 21', which is adjacent the flange 25, and are interconnected through the openings 37—37' so that vaporized liquid finds its way readily to orifices 11 or 11'.

Mounted on the shaft 13 are paddle wheels 40, 41, having several blades each. The blades of wheel 40 extend to the periphery of the chamber 20 but without touching the wall of the chamber at any point. These wheels are keyed on the shaft 13 and have hubs of such length that the blades are properly spaced within the chambers once the first wheel has been placed against the abutment 42 on the shaft. The abutment 42 is a collar which may be fixed to the shaft by a set screw or in any other standard manner. In assembling the parts of the machine the shaft is mounted in the end 10, the collar

42 is set on the shaft, and spacers 32, rings 22, 23, 24, and paddle wheels are alternately assembled until the selected number of chambers has been made up. Then the collar 43 is set on the shaft, and end 10' is mounted.

Steam or other heating liquid is circulated through the rings 22, 23, 24, the shaft is driven by a motor or from a power shaft, and liquid is admitted through orifice 16, making its way into the bottom of chamber 20, where it is picked up by wheel 40 and carried around the hot chamber in contact with the heated walls. All or a part of it will be vaporized and the vapor will escape through orifices 11—11'. Any concentrated liquor is forced by centrifugal force through a pipe 50 that enters the chamber 20 at a point 51 in the periphery of spacer 32 and passes through the adjacent ring to the small part of chamber 21' where it pours into the large part of chamber 21 and is whipped into cylindrical form against the hot outer wall by the blades of wheel 41 and further vaporized and concentrated. A pipe 50' transfers the final liquid concentrate to the discharge chamber 52 where any final distillate is given off and the liquid residue is passed to the orifice 16'.

The height of flanges, dam or weirs 25, 26, decreases toward the discharge end, for the following reason: There are two methods of running the apparatus, in one of which only enough liquid is admitted to require all liquid to flow from chamber to chamber through the pipes 50—50', and in the second of which so much fluid is admitted that some of it passes over the circular flanges from chamber to chamber. However, in the latter case, as evaporation has taken place in the leading rings, no such flow would take place in the following chambers, if the flanges were of the same internal radius. In order to permit this flow to take place over the flanges, the flanges toward the discharge end are reduced in height to compensate for the loss of liquid. This method of operation is desirable and efficient.

By passing the pipes 50—50' through the hot fluid inside rings 23, 24, their content is kept at high temperature and the internal efficiency of the unit is kept at high level.

Fig. 3 shows a preferred form of the invention in which the flanges 65—66 are so placed that the delivery of fluid through the pipes is toward the center from the rim but to the same chamber. This gives improved distribution of the contents of the evaporator among the several chambers, and produces a more marked separation of products in the different stages of concentration. The flanges constitute weirs that control the flow of the liquid from chamber to chamber. The end pieces 10—10' in this form of the invention are so cast that the rings of the casing may be all alike if desired, whereas in the form of Fig. 2 the end ring 24 is of necessity differently constructed from ring 23. The arms 35'' are integral with the end 10'', which has a flat inner face abutting the ends of rings 24''. The apertures for the pipes 50 are shouldered, having a small inner and a large outer end, of which the inner is closed by a plug 60 held in place by screw threaded retainer 61, the apertures being provided with screw threads 63 for that purpose, when no pipe is necessary.

Circulation is established in conduits 50 and 50' by the difference in pressure existing because of the centrifugal force and the speed of the liquid between the orifices of entry and discharge. The concentrated liquor driven to the periphery of the chambers is thus returned to the center of the apparatus.

The surface formed by the liquid in rotation being a cylinder with a horizontal axis parallel to and upwardly offset from the axis of rotation of the paddles, by an amount being a function of the speed of rotation, the discharge of the first chamber to the second, and of the latter to the outside, always takes place at the bottom of space 5, precisely in the neighborhood of the points where the tubes 50 and 50' discharge, so that it is the most concentrated liquid that leaves every tube to travel downstream.

Black liquor from the cooking of wood chips in paper manufacture by the soda process has been concentrated by this apparatus. This liquor contains principally combined soda, lignin, resins and glucides, and other things in lesser amount. In one case the wood digested was *Pinus maritimus* and the liquor discharged titrated 36° Bé. at 15° C., corresponding to a density of 1.332. The paddle wheels turned 200 R. P. M. The rings were heated by steam at a pressure of 2.5 kilograms per sq. cm. which was released to the air at the discharge. The apparatus received the liquor at 60° C. and discharged 100 liters/hr. of concentrated liquor titrating 45° Bé. at 15° C., density 1.453 and containing 73% solids. This corresponded to the manufacture of 1.4 metric tons of cellulose in 24 hours.

This invention is more efficient than prior art evaporation apparatus and processes despite the expenditure of power. The apparatus requires less room in the factory than any other apparatus having the same capacity. The apparatus is extremely flexible in operation and may be employed to evaporate different liquids under the conditions most favorable to each. For instance, with a liquid of low boiling point, one or two rings may be sufficient to produce an adequate concentration. In other cases it may be advisable to employ a dozen or more rings, each of which is heated to a progressively higher temperature so that the cold liquid will be progressively elevated in temperature without danger of local overheating of its contents.

A very great advantage of the invention arises in the evaporation of suspensions of solids in liquids wherein the solid is not dissolved and tends to settle out. Such mixtures are kept in a state of uniform suspension by the vigorous action of the paddles so that the deposition of cakes, which was a major difficulty in prior art apparatus, is avoided.

As many apparently widely different embodiments of the present invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited to specific embodiments except as defined in the appended claims.

What is claimed is:

1. An evaporator including a horizontal cylinder having inlet and outlet ports at its ends, a plurality of circular baffles extending inwardly from said cylinder and forming circumferential chambers about an axial open space communicating with said ports, heating means for the baffles, power means to circulate liquids admitted through said inlet port about the circumferences of the chambers, and conduit means opening into the circumference of a chamber and having a discharge outlet nearer the axis of the cylinder.

2. An evaporator including a horizontal cy-

lindrical casing separated into annular chambers by hollow heating rings having centrally positioned annular flanges, a rotatable shaft passing axially through the chambers and the casing, paddles carried by the shaft and rotated in the chambers, an orifice in one end of the casing to admit liquid, an orifice in the other end to discharge liquid, an orifice connected with the interior of the chambers for the discharge of vapors, and a conduit connected at one end to the rim of one chamber and at the other end to the central part of another chamber adapted to transfer liquid from the rim of said one chamber toward the center of said other under centrifugal force.

3. An evaporator including a horizontal cylindrical casing separated into annular chambers by hollow heating rings having centrally positioned annular flanges, an orifice to admit liquid, an orifice to discharge concentrated liquid, and an orifice for the discharge of vapor, a conduit opening at one end at the outer part of a chamber and opening at the other end closer to the central axis of the evaporator acting to transfer liquid from the outer part of the chamber closer to the center under centrifugal force, a rotatable shaft passing through the chambers and the casing axially, and paddles carried by the shaft and rotatable in the chambers.

4. An evaporator including a horizontal cylindrical casing separated into annular chambers by hollow heating rings, orifices to admit and discharge fluids, a conduit connected to the ring of one chamber and opening at the other end closer to the center of the casing, being thus adapted to transfer liquid from the rim of said one chamber toward the center of the casing under centrifugal force, and power driven paddles rotatable in the chambers.

5. A dynamic concentrator having orifices of admittance and discharge and including a plurality of interconnected, axially horizontal ring shaped hot chambers having parts of different radius, centrifugal means to circulate a liquid within the parts of greater radius, and conduits connecting the parts of greater radius with the parts of the same chambers of lesser radius.

6. A dynamic concentrator having orifices of admittance and discharge, and including a plurality of interconnected, axially horizontal ring shaped hot chambers having parts of greater and lesser radius, power means to circulate a liquid centrifugally about a said part of greater radius, and a conduit connecting said part of greater radius with a said part of lesser radius adapted to transfer circulating liquid from the said part of greater radius closer to the center of the concentrator.

7. A dynamic concentrator having orifices of admittance and discharge, and including an annular hot chamber having cylindrical rings of different internal radius, power means to drive a liquid about a ring of greater internal radius, and a conduit connecting said rings adapted to transfer the outer and most concentrated part of the driven liquid from the ring of greater internal radius to the ring of lesser internal radius.

8. An evaporator having a vented horizontal cylindrical casing, a horizontal shaft therein supporting a plurality of paddle wheels that extend into a plurality of encircling cylindrical chambers which are interconnected by central free space extending from end to end of the evaporator, said chambers being formed between radially extending hollow rings encircling the said shaft, said rings having inwardly extending flanges, a pipe connected to the rim of a said chamber in a direction forming an acute angle with a tangent to the point of connection, said pipe extending away from the rim in a direction in reverse to the circumferential direction taken by the fluids impelled through the chamber by said wheels, and thereafter passing through a said hollow ring to a place of discharge nearer the center of the casing than the said point of connection, means to pass heating fluid through said hollow rings, the said hollow rings being assembled by means of circular, interfitting flanges and grooves.

9. An evaporator having a vented horizontal cylindrical casing, a horizontal shaft therein supporting a plurality of paddle wheels that extend into a plurality of encircling cylindrical chambers which are interconnected by central free space, said chambers being formed between radially extending hollow rings encircling the said shaft, said rings having inwardly extending flanges, a pipe opening into the rim of a said chamber, extending through a said hollow ring and discharging nearer the center of the evaporator than its point of connection to said chamber, and means to supply the hollow rings with heating fluid.

10. An evaporator having a vented horizontal cylindrical casing, a horizontal shaft therein supporting a plurality of paddle wheels that extend into a plurality of encircling cylindrical chambers which are interconnected by central free space, said chambers being formed between axially extending heated rings encircling the said shaft, said rings having inwardly extending annular flanges, a pipe extending from one part of a said chamber through a heated ring to a chamber portion of lesser radius, the rim of a said chamber consisting of a ring having a flange seated in grooves in the sides of adjacent heated rings.

11. An evaporator having a vented, horizontal cylindrical casing with a plurality of internal circular chambers which are connected to the vent for the discharge of vapor, said chambers being formed between ring shaped barriers, said ring shaped barriers having inwardly extending annular flanges, impeller means to circulate fluid about said chambers, means to heat a said barrier, and conduit means extending from one part of a said chamber through a heated ring shaped barrier to a discharge port at a lesser distance from the center of the casing than the said one part of said chamber.

12. An evaporator having a vented horizontal cylindrical casing, the cylindrical wall of which has internal circumferential grooves, means to heat the sides of the said grooves, impellers constructed and arranged to circulate fluids in said grooves, and conduit means extending from a said groove, thru said heating means and discharging in a more central part of the casing.

13. An apparatus for the concentration of liquids by the contact of liquids with heated surfaces comprising a cylindrical enclosure divided into annular compartments by heated radial walls, a rotor coaxial with the cylinder carrying paddles rotating inside the compartments, successive compartments having communication by means of a conduit opening at the periphery of an upstream compartment and discharging at the central part of a downstream compartment.

14. An apparatus for the concentration of liquids by the contact of liquids with flat surfaces comprising a cylindrical enclosure divided into annular circumferential compartments by heat-

ing walls of materially less height than the radius of the cylinder and which are substantially perpendicular to the axis of the cylinder, a rotor coaxial with the cylinder having paddles turning inside said compartments, successive compartments being connected by a conduit opening at the periphery of the upstream compartment and discharging at the central part of the downstream compartment.

15. An apparatus constructed in accordance with claim 13 in which the heated walls surround an open central space having a diameter greater than that of the rotor.

16. The apparatus according to claim 13 in which the heated walls are prolonged by annular diaphragms.

JEAN CLAUDE ARNAUD.

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