# United States Patent

Javet

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[45] Feb. 8, 1972


## [54] HEAT EXCHANGERS


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[73] Assignee: The Battelle Development Corporation, Columbus, Ohio



[22] Filed: May 4, 1970

[21] Appl. No.: 48,793

**Related U.S. Application Data**

[63] Continuation of Ser. No. 750,411, July 5, 1968, abandoned.

[30] **Foreign Application Priority Data**

July 4, 1967 Switzerland ..... 9474/67
May 17, 1968 Switzerland ..... 7407/68

[52] U.S. Cl. ..... 159/6, 202/236, 202/238, 233/11, 233/18

[51] Int. Cl. ..... B01d 1/22, B01d 3/08

[58] Field of Search ..... 159/6, 49; 233/11, 18; 202/236; 203/89



[56] **References Cited**

UNITED STATES PATENTS

2,884,050 4/1959 Brownell ..... 159/6



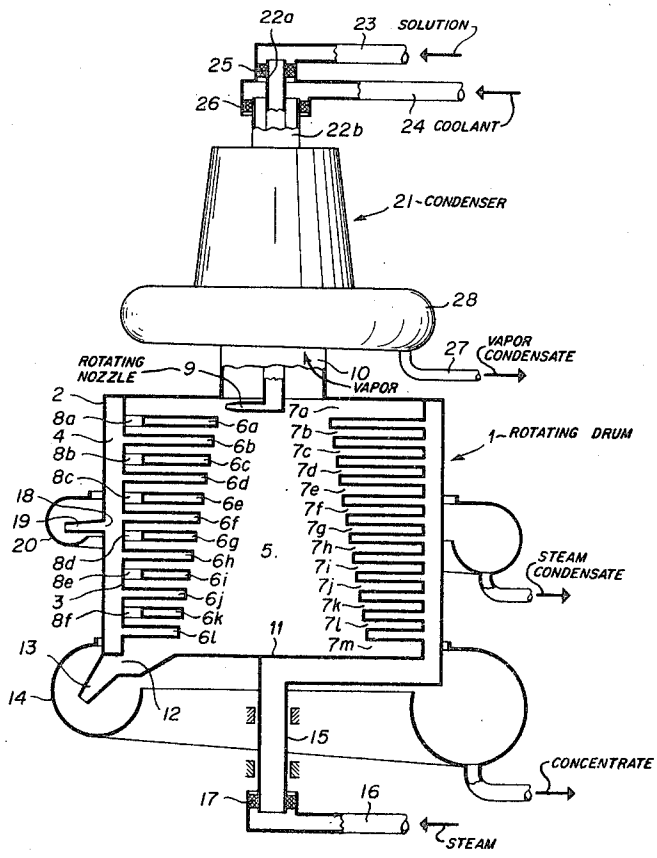
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*Assistant Examiner*—G. T. Sofer
*Attorney*—Gray, Mase and Dunson



[57] **ABSTRACT**

A hollow walled cylindrical revolving basket is provided with a heating medium in the hollow wall. To the inner wall are secured axially spaced flat, hollow rings whose successive inner diameters increase axially in liquid flow direction and into which rings the heating medium flows from the hollow wall. Alternate rings are provided with axial through passages at the inner wall connecting the channels between the rings. Liquid feed to be evaporated is injected into the channel between the ring with smallest inner diameter and the adjacent end wall of the basket. Concentrate is removed from the final channel and vapor is removed axially.


**8 Claims, 2 Drawing Figures**



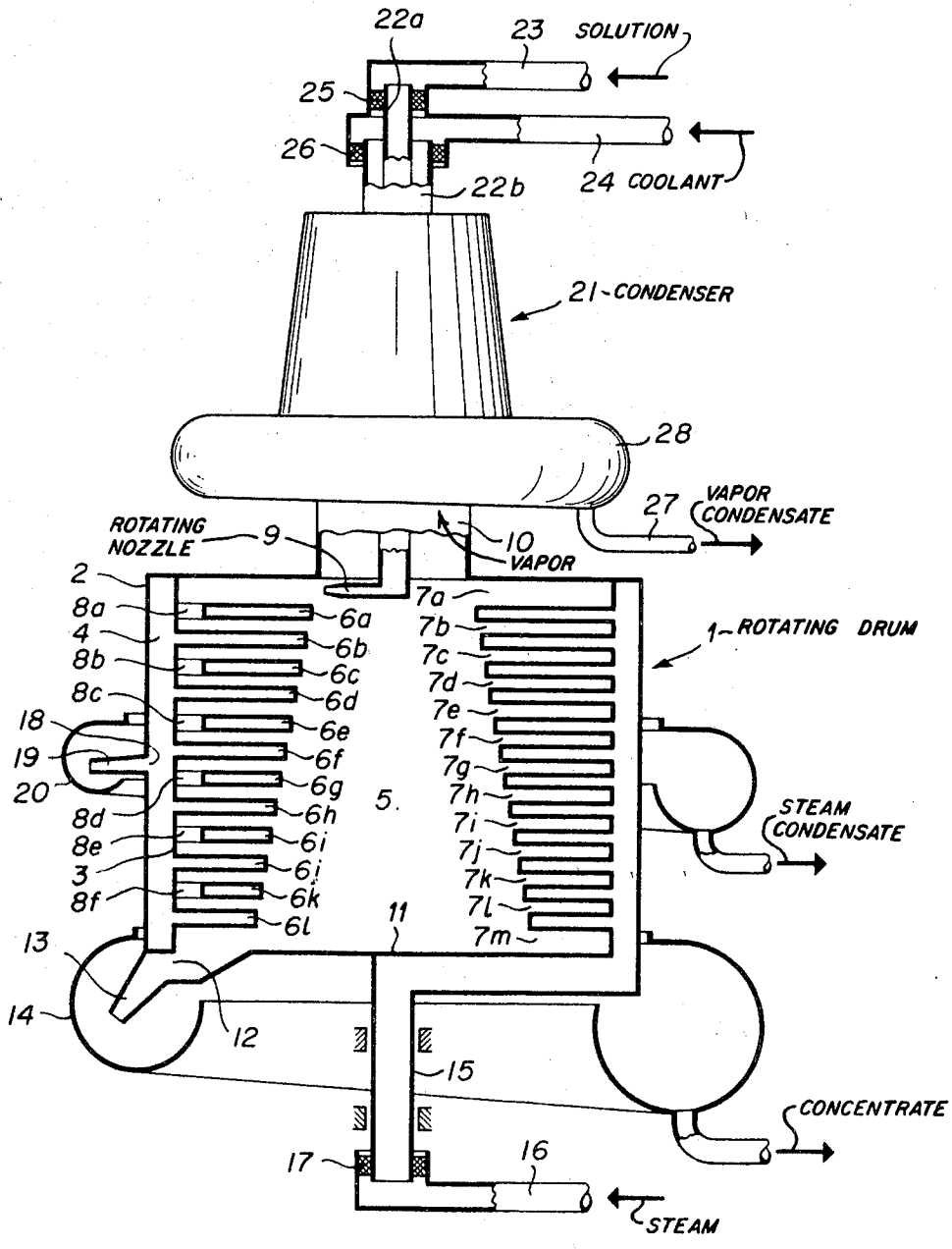

22a
23
SOLUTION
25
26
24 COOLANT
22b
21-CONDENSER
28
27
VAPOR CONDENSATE
ROTATING NOZZLE
9
10
VAPOR
2
8a
4
8b
8c
18
19
20
8d
8e
3
8f
6a
6b
6c
6d
6e
6f
6g
6h
6i
6j
6k
6l
7a
7b
7c
7d
7e
7f
7g
7h
7i
7j
7k
7l
7m
1-ROTATING DRUM
5
STEAM CONDENSATE
11
13
14
12
15
CONCENTRATE
17
16
STEAM

FIG. 1

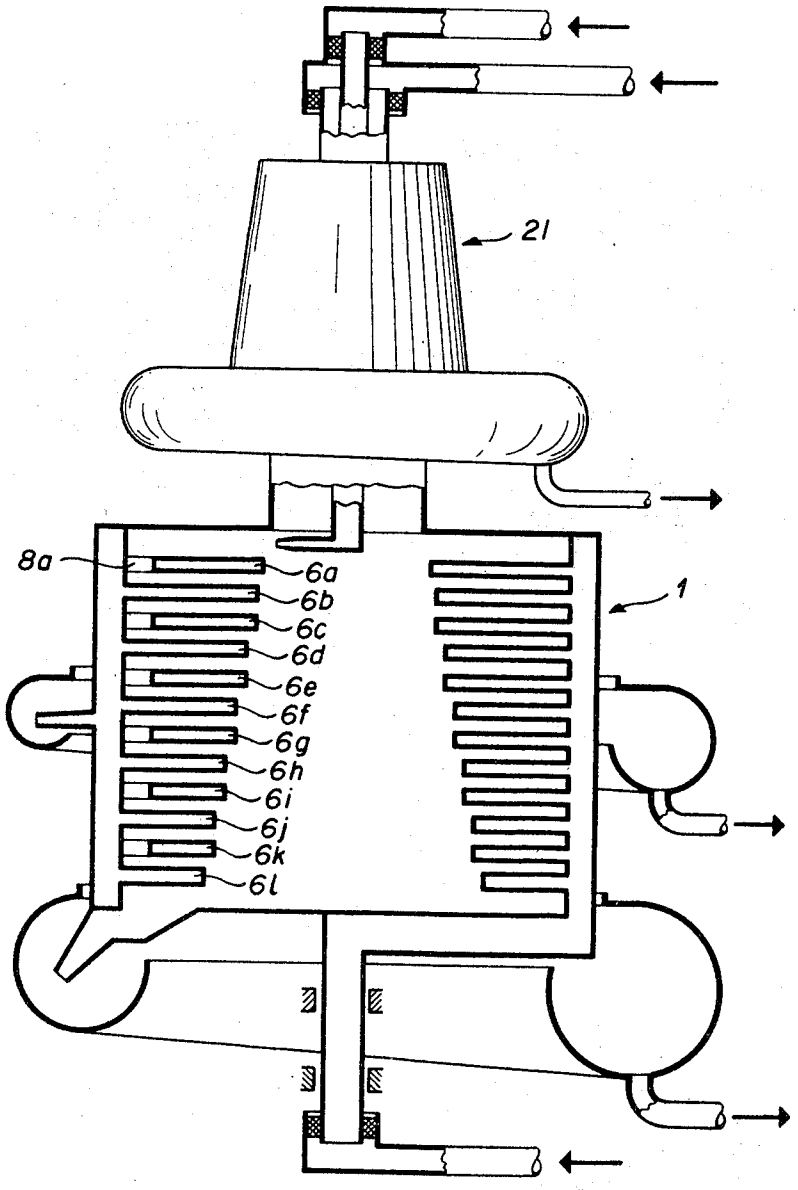



FIG. 2

# HEAT EXCHANGERS

This application is a continuation of application Ser. No. 750,411 filed July 5, 1968 and now abandoned.

The present invention relates to heat exchangers and provides in particular an improved evaporator, i.e., an apparatus for concentrating solutions of any kind.

In British Pat. No. 598,531 there is disclosed an evaporator comprising a casing of circular cross section having a vertical axis, in which is rotatably mounted a horizontal disc provided on its top face with a concentric series of annular blades each arranged to project into a relatively wide annular channel lying between two blades carried by the bottom face of a stationary disc arranged above the rotatable plate within said casing.

In this kind of evaporator, the liquid to be concentrated is fed into the cylindrical space surrounded by the innermost rotary blade, and is successively made to come into contact with all of the rotary blades by first being made to creep up this innermost rotary blade under the action of centrifugal force, by then being projected onto the adjacent stationary blade of greater diameter along which it flows downwards to drop on to the rotatable disc where it again becomes subjected to the action of the centrifugal force which then forces the liquid to creep up the second rotary blade, and so on.

Other apparatuses, in particular those described in British Pat. No. 18,050 A. D. 1912 and German Pat. No. 683,994, comprise a series of bladed discs keyed on to a common vertical shaft mounted for rotational movement in a casing whose sidewall envelops each disc radially to a certain extent to define in conjunction with all of the discs an annular chamber having an axial cross section of zigzag configuration.

The sidewall of the casing also forms one of the walls of a chamber into which is permanently fed, during operation, a stream of steam, the liquid to be concentrated being made to flow in the annular chamber defined by the various discs and by the casing. This flow is brought about by centrifugal force and is required to bring the liquid into contact with the steam-heated wall of the casing to ensure partial evaporation thereof.

In Swiss Pat. No. 391,658 there is disclosed an evaporating device for liquids which comprises an evaporation column of tubular shape provided with a heating jacket and fitted internally over its entire length with a series of spaced annular ridges for guiding the liquid to be evaporated, which is fed into the top of the tubular column and which flows down the inner face thereof, towards a series of rotary discs which are placed each beneath a particular one of the ridges and which serve to project the liquid they receive from their associated ridge on to the portion of the column face which extends from beneath this particular ridge to the next ridge, the resulting condensate being collected at the bottom of the column.

German Pat. No. 628,890 discloses a heat exchanger consisting of a stack of flattened frustoconical plates, in which alternate plates are turned upside down to form a series of pairs of plates contacting one another along their outer edges and in which the spaces enclosed by these pairs of plates communicate with one another through annular spacer members placed between said pairs and around central openings in the plates to define an elongated heating steam chamber. This stack is rotated about a vertical axis while the solution which is to be concentrated is poured on to its top face. Between each pair of plates is arranged an annular deflector sloping downwardly and inwardly for conveying the liquid which is spun off a pair of plates under the action of centrifugal force, towards the annular spacer member placed immediately beneath this pair of plates, and so on. The liquid to be concentrated thus flows under the action of centrifugal force successively on the top surface of each pair of plates towards its outer edge, then drops on to the deflector which lies opposite its bottom surface and is conveyed towards the annular spacer member lying immediately therebeneath, the evaporation of the most volatile fractions of the solution to be condensed occurring mainly while the solution flows over the top surface of each pair of plates and while dropping on to the associated deflector, by virtue of the molecular agitation which is then produced.



French Pat. Nos. 1,236,706 and 1,349,760 are concerned with evaporators which are similar to one another as regards their general principle of operation. These evaporators include a centrifuging rotor comprising a stack of frustoconical plates which are fitted into one another and which define therebetween and in conjunction with sealing rings, arranged both along their bottom base and along their top base, a series or chambers. Through alternate ones of these chambers flows a heating fluid while through the others flows in parallel the liquid to be concentrated, which liquid is introduced into these other chambers at the level of their radially innermost portion, whereas the condensate is recovered at the radially outermost portion of the chambers. The vapor phase formed by the volatile products is drawn off by setting up a depression in the narrowest region of each chamber, in the one case, and in the vicinity of their outer edge, in the other case.

In general, all of these evaporators operate by bringing a thin film of liquid to be evaporated into contact with a heating surface, the flow of this film being induced either solely by the centrifugal force to which this film is subjected or by the combined action of this force and of gravity; the liquid to be processed is fed to these evaporators by external pumps. Pumps are also used for liquid flow inside these apparatuses.

The present invention provides a heat exchanger—in particular an evaporator—of relatively reduced size for a high throughput, which includes constructional features conducive to considerable ease of manufacture, assembly and servicing and wherein the supply of liquid to be treated and liquid flow are achieved automatically, without any pump.

The evaporator provided by the present invention comprises a rotatable casing for evaporating a liquid solution requiring concentration having a sidewall from the inner face of which project a plurality of annular evaporation blades or rings surrounding the rotational axis of the casing and defining therebetween and, at each end of said plurality, in conjunction with a portion of the end walls of the casing, a succession of annular channels, means for heating at least alternate blades, means for feeding the liquid solution tube to be concentrated into the casing, a first outlet for the concentrated solution and a second outlet for the vapors that are produced; wherein alternate blades are formed with continuous surfaces while the remaining blades are formed with passages to provide a series of pairs of communicating channels, wherein said feeding means are arranged to feed the solution to the first channel of said succession and said first outlet communicates with the last channel of said succession, wherein the distance between said rotational axis and the inner edge of each apertured blade increases from blade to blade in the direction of said first outlet, and wherein the distance between said rotational axis and the inner edge of each blade which has a continuous surface and which precedes an apertured blade is at most equal to the distance between said axis and this apertured blade, the arrangement being such that, upon rotation of the casing, there is formed in each of said pairs of channels two annular and antagonistic columns of liquid, said liquid flowing from one channel to the other in each pair through said passage, and from one pair to the next, in the direction of said first outlet, over the inner edge of the blade separating these pairs, under the action of the centrifugal force exerted on the overflow liquid which adds itself at each instant to the liquid forming said antagonistic columns of each group.

In the accompanying diagrammatic drawings:

FIG. 1 is an axial section of an evaporator in accordance with the invention; and

FIG. 2 is a similar view of a slightly modified constructional form of evaporator.

The evaporator shown in FIG. 1 comprises a cylindrical drum 1 adapted to be rotated about a vertical axis at a particular speed by means not shown. The outer wall 2 of the drum defines, in conjunction with a second annular wall 3, a chamber 4 into which steam is introduced for heating purposes as will be explained later.

From the inner surface of wall 3 project a series of annular and hollow blades 6*a* to 6*l* which communicate with chamber

4 and which extend radially into an evaporation chamber 5 surrounded by wall 3.

Blades 6a to 6l are equidistantly spaced from one another and define, in conjunction with wall 3 and the top of drum 1, a series of transverse and superposed annular channels 7a to 7m. Alternate blades, to wit blades 6a, 6c, 6e, 6g, 6i and 6k, are formed along their radially outer edge portion with passages 8a, 8b, 8c, 8e and 8f, respectively, thereby to connect channels 7a to 7l in pairs, to wit 7a and 7b, 7c and 7d, 7e and 7f, 7g and 7h, 7i and 7j, and 7k and 7l. As will be observed from FIG. 1, the radial length of each blade decreases from the top of drum 1 downwardly.

The solution requiring concentration is fed radially into the first, 7a, of the channels defined by blades 6a to 6l, by a distributor 9 which is rotationally rigid with drum 1 and it is the difference in radial length of the blades which enables the solution so to flow as to come successively into contact with both faces of each blade. In this connection, it will be observed that the solution, as soon as it enters channel 7a, is chased under the action of the centrifugal force set up by rotational motion of the drum, into channel 7b through passage 8a, with the radial depth of solution in channels 7a and 7b progressively increasing by an equal amount as the distributor 9 keeps ejecting solution into channel 7a.

When channel 7b is full, channel 7a is still not quite full since blade 6a which defines it in conjunction with the top wall of drum 1 is radially longer than blade 6b which forms channel 7b in conjunction with the portion of blade 6a lying opposite thereto.

Thus, any further flow of liquid solution into channel 7a will cause an increase in "depth" of the liquid contained in channel 7b such that this liquid will flow over the radially inner edge of blade 6b. This overflow will immediately be subjected to the action of the centrifugal force and will be urged to the bottom of channel 7c and hence into channel 7d through passage 8b. Channels 7c and 7d will fill up practically at the same rate until channel 7d, of lesser depth, is full. From then on, any liquid flowing over blade 6b into channel 7c will exert on the mass of liquid which partly fills channel 7c and which wholly fills channel 7d a thrust, due to centrifugal force, inducing liquid flow from channel 7c towards channel 7d.

The same action takes place in all of the channels that are defined by blades 6a to 6l.

It is thus the centrifugal force that is acting on the liquid flowing over blades 6b, 6d, 6f, 6g, 6h, 6j and 6l which constitutes the driving force for the liquid flow that occurs in the various channels, which channels are thus in series relationship.

While flowing in contact with the various blades of the evaporator, the solution is caused to boil and the vapor which is given off leaves the solution where the latter flows over blades 6b, 6d, 6f, 6h, 6j and 6l in the form of bubbles.

The vapor which is thus given off is discharged from chamber 5 through an axial duct 10 rigid with drum 1.

The concentrated solution which flows over the lowermost blade 6l is driven radially out of chamber 5 through an annular channel 7m, defined by blade 6l and the bottom 11 of evaporation chamber 5, towards a passage 12 provided at the foot of wall 3. The concentrated solution is then discharged out of drum 1 through a nozzle 13 which projects into an annular opening of a collector trough 14 having a spirally sloping bottom and surrounding the lower portion of drum 1. This nozzle is simply provided with an orifice so gauged that vapor cannot escape.

Nozzle 13 and its orifice can of course be replaced by any other suitable device capable of fulfilling the same function, e.g., of the kind disclosed in the specification of our copending Pat. application Ser. No. 752,110 filed on even date under the designation "Fluid flow control means," now abandoned.

The steam for heating the drum is fed into steam chamber 4 via a duct 15 which is rigid with drum 1 and which is connected to a supply conduit 16 through the intermediary of a rotary seal coupling 17.

The steam which has condensed inside blades 6a to 6l is driven by the centrifugal force towards the outer wall 2 of drum 1 whence it is discharged through an opening 18, acting as a condensate outlet, into a second collecting trough 20 having a spirally sloping bottom, opening 18 being fitted with a nozzle 19 projecting into the opening of trough 20. Here again, nozzle 19 can be fitted with a valve, not shown, adapted to prevent any inflow of fluid, e.g., steam or air, into drum 1 when the latter is stationary or contains no steam.

As in the case mentioned earlier, nozzle 19 and its valve could with advantage be replaced by fluid flow control means of the kind disclosed in the specification of our aforementioned copending Pat. application Ser. No. 752,110.

In the illustrated embodiment, the vapors produced in chamber 5 rise through duct 10 into a centrifugal condenser which is mounted directly above the evaporator and whose rotary part is kinematically solid with drum 1.

Whereas the supply of solution to be concentrated to nozzle 9 takes place through a first rotary duct 22a extending axially through and rotationally rigid with condenser 21, the supply of cooling water for the condenser takes place through a second rotary duct 22b which surrounds the first and which is rigid therewith. These ducts are connected to appropriate sources of liquid by conduits 23 and 24 and through intermediate rotary seal couplings 25 and 26.

The condensed substances are recovered through a conduit 27 associated with a stationary collecting trough 28 surrounding condenser 21.

This condenser can either be of the kind disclosed in the specification of our copending application Ser. No. 742,589 filed on even date now U.S. Pat. No. 3,567,589, under the designation "Condensing apparatus," or be of a different construction, for instance not be rotationally solid with the evaporator and be connected thereto by a plain duct.

It should however be pointed out that with the illustrated arrangement of placing the condenser on top of the evaporator and in communication therewith it is possible to set up in the latter quite a substantial depression thereby correspondingly facilitating evaporation in chamber 5.

The modified constructional form shown in FIG. 2 differs from the FIG. 1 evaporator only as regards the radial length of the annular blades. In this modified constructional form, although all of the blades 6 which are formed with a passage 8a have a radial length which decreases from the top towards the bottom as before, the blades having continuous surfaces each have here a radial length corresponding to that of the apertured blade immediately beneath it. Thus, blades 6b and 6c, 6d and 6e, 6f and 6g, and 6h and 6i, and 6j and 6k are of equal length in each pair.

This leads to improved operation of the evaporator: earlier, it was stated that the liquid mass contained in channels 7a to 7l flows in these channels, from the top towards the bottom of the evaporator, only under the action of the centrifugal force exerted on the overflowing liquid which passes at each instant over blades 6b, 6d, 6f, 6h and 6j. The maximum thickness or "head" of this amount of overflowing liquid, which thus provides the driving force for moving the liquid between the blades, is equal, in the FIG. 1 embodiment, to the difference between the radial length of each blade having a passage 8a and the radial length of each adjacent continuously surfaced blade located immediately beneath the apertured blade being considered. Now, in the case of the FIG. 2 constructional form, the maximum "head" of overflowing liquid able to cause liquid flow in the channels of the evaporator is equal to the difference in radial length of each pair of blades formed with a passage 8a: it will therefore be clear, with apertured blades having radial lengths that vary by a common amount as in the FIGS. 1 and 2 constructional forms, that there will be room for a greater "driving head" of overflowing liquid in the upstream channel of any linked pair in the FIG. 2 evaporator than in the FIG. 1 evaporator.

The evaporators illustrated in FIGS. 1 and 2 can also be modified in other respects: for instance, in order to facilitate

dismantling for cleaning purposes, the evaporation chamber could be made up of a stack of dismantlable annular heating plates: in the FIG. 2 construction, there would thus be a plurality of pairs of plates having the same size. Moreover, the heating blades or plates could have a frustoconical inner edge which broadens out in the general direction of flow of the solution.

Clearly the blades could be heated differently, e.g., electrically, Further, in some instances, it might suffice to heat only one blade in two. Thus, in the illustrated constructional forms, blades *6a*, *6c*, *6e*, *6g*, *6i* and *6k*, which are formed with the axial passages, could be made solid instead of hollow and would thus merely act as intermediate baffles.

Since, in an evaporator according to the invention, liquid flow is achieved by centrifugal force, the operation of the apparatus is independent of gravity so that the axis of rotation of the apparatus could have any position other than the vertical position which has been illustrated by way of example in the drawings. Moreover, since any change in the flow rate of the liquid issuing from nozzle 9 leads to an inverse change in the length of time the liquid resides in the evaporator, it is possible, by acting on this flow rate, to regulate the concentration of the resulting liquid.

It should be pointed out that the speed at which the liquid circulates in the illustrated evaporators is not dependent on the formation of vapor bubbles.

Further, the evaporator according to the invention can be made in the form of a multiple-acting or multistage evaporator. In this event, several evaporation chambers can be arranged along a common axis of rotation, with the solution flowing under the action of centrifugal force as explained earlier and passing from one chamber to another in series, whereas the solvent that is evaporated in each chamber except the last is used to heat the next chamber, the solvent that is evaporated in the last chamber being condensable in a suitable condenser.

In relation to the known forms of apparatus, referred to earlier, the evaporator according to the invention has, in brief, the following advantages:

- the evaporator can operate without a pump for feeding the solution requiring concentration thereinto since this solution is ejected continuously by the rotating distributor 9 under the action of the centrifugal force which is communicated to the solution by the rotating motion of the distributor;
- the solution to be concentrated can flow between the blades of the evaporator without need of a pump, the flow being due solely to the "cascade" arrangement of the various channels defined by the blades;
- the heating capacity provided by both faces of the blades can be used in full since the flowing liquid fills the entire space lying between the blades and does not merely form a film on only one of their faces;
- in the evaporation zone, along the edges of the channels defined by the blades, the liquid particles which the vapor would be liable to draw along therewith are in fact separated from this vapor under the action of the centrifugal force to which they are subjected and which holds them back while the vapor is given off;
- it even becomes possible to concentrate to a high degree solutions which normally would foam;
- inside the evaporator, there is no relative motion of mechanical components.

Although in the preceding description reference has only been made to an evaporator, the previously set forth inventive concepts can clearly be applied in a more general manner to the construction of any heat exchanger.

I claim:

1. An evaporator which comprises a rotatable casing for evaporating a liquid solution requiring concentration, said casing having a hollow cylindrical sidewall from the inner face of which project a plurality of flat annular evaporation rings surrounding the rotational axis of the casing and defining therebetween and, at each end of said plurality, in conjunction with a portion of the end walls of the casing, a succession of annular evaporation channels, means for heating at least alternate rings, means for feeding the liquid solution to be concentrated into the first channel lying between the ring of smallest inner diameter and the adjacent end wall of the casing, a concentrate outlet for the concentrated solution from the last channel lying between the ring of largest inner diameter and the adjacent casing end wall and an axial outlet for the vapors that are produced; wherein alternate rings are formed with continuous surfaces while the remaining interposed rings are formed with longitudinal flow passages at the intersections of said remaining rings with the inner face of said hollow sidewall to provide a series of pairs of communicating channels, wherein the distance between said rotational axis and the inner edge of each ring having continuous surfaces increases from each such ring to the next such ring in the direction of said concentrate outlet, and wherein the distance between said rotational axis and the inner edge of each apertured ring is less than the distance between said axis and the inner edge of the adjacent ring having continuous surfaces lying to the side of the apertured nearer said concentrate outlet, the arrangement being such that, upon rotation of the casing, there is formed in each of said pairs of channels two annular and antagonistic columns of liquid, said liquid flowing from the remote to the other in each pair through said axial passage, and from one pair to the next, in the direction of said concentrate outlet, over the inner edge of the ring separating these pairs, under the action of the centrifugal force exerted on the overflow liquid which adds itself at each instant to the liquid forming said antagonistic columns of the next pair.

2. An evaporator as claimed in claim 1, wherein the distance between said rotational axis and the inner edge of each apertured ring is equal to the distance between said axis and the inner edge of the adjacent ring having continuous surfaces lying to the side thereof away from said concentrate outlet.

3. An evaporator as claimed in claim 1 wherein at least the heated rings are hollow to enable a heating fluid to circulate therein, and wherein a jacket surrounds the sidewall of said casing and defines therewith an annular chamber which communicates with the interiors of the hollow rings via passages formed in said sidewall, said chamber forming a collector for the ring heating fluid and being connectable to a source of said fluid.

4. An evaporator as claimed in claim 2 wherein at least the heated rings are hollow to enable a heating fluid to circulate therein, and wherein a jacket surrounds the sidewall of said casing and defines therewith an annular chamber which communicates with the interiors of the hollow rings via passages formed in said sidewall, said chamber forming a collector for the ring heating fluid and being connectable to a source of said fluid.

5. An evaporator as claimed in claim 3, wherein said casing is rigidly connected to a hollow rotary axial shaft communicating with said chamber via an intermediate duct and providing means for connecting said chamber to said source of fluid.

6. An evaporator as claimed in claim 4, wherein said casing is rigidly connected to a hollow rotary axial shaft communicating with said chamber via an intermediate duct and providing means for connecting said chamber to said source of fluid.

7. An evaporator as claimed in claim 1, wherein the means for feeding the liquid solution to be concentrated into the casing comprises a nozzle located in said casing and having a discharge axis lying substantially at right angles to the rotational axis of said casing and in the plane of said first channel.

8. An evaporator as claimed in claim 2, wherein the means for feeding the liquid solution to be concentrated into the casing comprises a nozzle located in said casing and having a discharge axis lying substantially at right angles to the rotational axis of said casing and in the plane of said first channel.

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# UNITED STATES PATENT OFFICE

# CERTIFICATE OF CORRECTION

Patent No. 3,640,330 Dated February 8, 1972

Inventor(s) Alain Javet

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 6, line 23, after "apertured" insert -- ring --.

Signed and sealed this 18th day of July 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
* U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334