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2,884,050

CENTRIFUGAL EVAPORATOR

Filed March 23, 1954

2 Sheets-Sheet 1

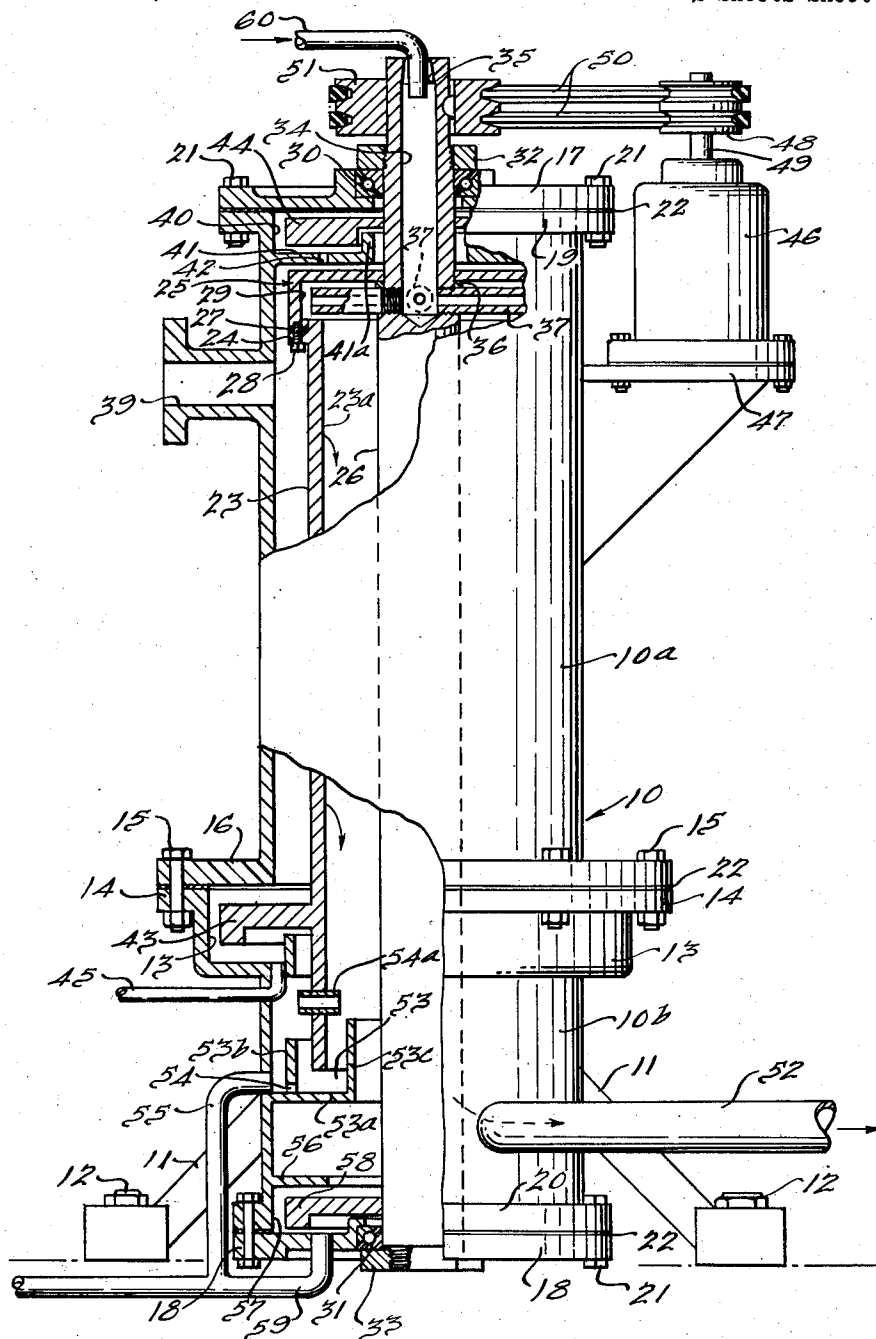


FIG. 1.

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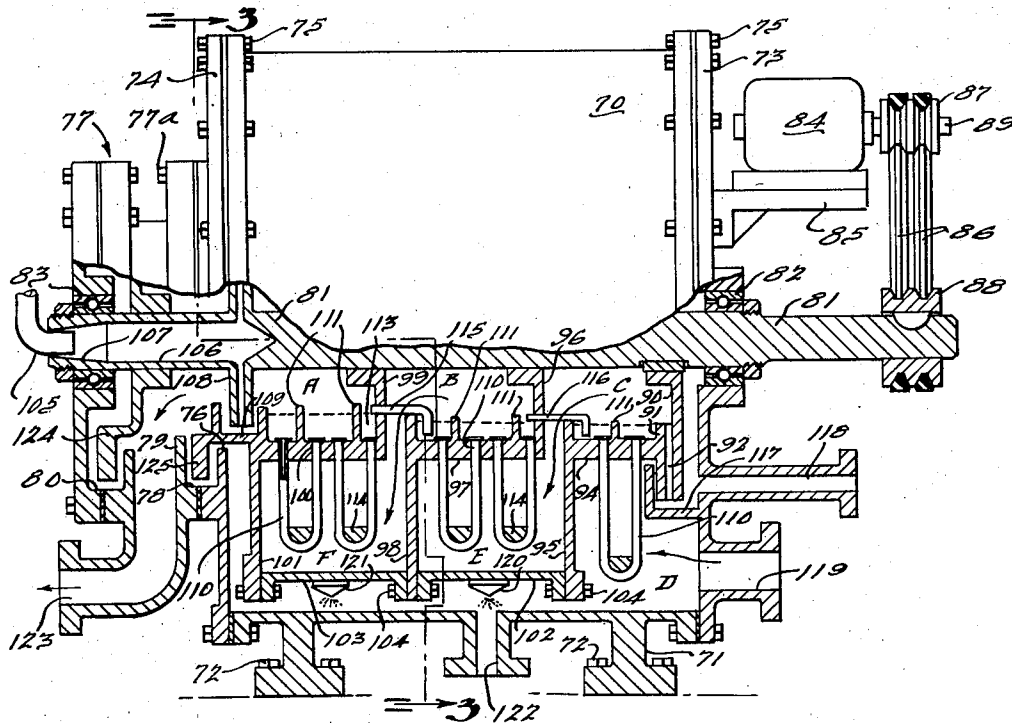


FIG. 2.

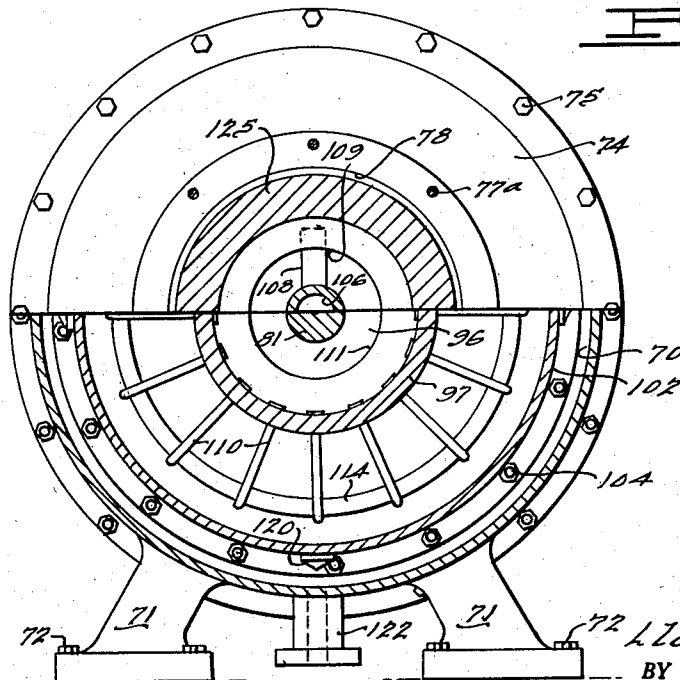


FIG. 3.

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CENTRIFUGAL EVAPORATOR

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7 Claims. (Cl. 159—6)

This invention relates to a centrifugal evaporator of the type particularly adapted for concentrating radioactive solutions or for evaporating sea water.

An object of the invention is to provide an improved and highly efficient method and apparatus for evaporating liquids, particularly aqueous solutions, in situations where an uncontaminated vapor is desired as the end product, as for example in concentrating radioactive solutions wherein entrainment of particles of the liquor with the vapor during the evaporation process must be positively avoided, or as for example in the evaporation of sea water to produce distilled water.

Another object is to provide a centrifugal evaporator which is particularly compact and simple in construction and substantially noiseless in operation, thereby being readily adaptable for use on board ships, particularly submarines during wartime, wherein compactness and quietness of operation are of great importance.

In the concentration of radioactive solutions, it is frequently difficult for maintenance personnel to approach the evaporator because of radiation. It is accordingly another object of the invention to provide an improved vertical type centrifugal evaporator which is self draining when not in use and which employs self draining liquid seals between the rotating and stationary parts, the seals requiring little or no maintenance and being particularly effective when the evaporator is in operation.

Other objects are to provide a method and apparatus of the foregoing character wherein the liquor to be evaporated is fed by centrifugal force to the inner surface of a rotating cylindrical heat exchanger, and wherein steam is applied directly to the outer surface of the heat exchanger to heat the same. The liquor is maintained in a thin film or layer on the inner heat exchanger surface and is rapidly moved axially therealong from the inlet or feed area by the centrifugal force.

By virtue of the foregoing, the centrifugal force prevents the collection of condensate on the outer or steam side of the cylindrical heat exchanger, achieving a high coefficient of heat transfer thereto from the steam. The high velocity of axial movement obtained by the liquor film on the inner side of the heat exchanger results in a high coefficient of heat transfer from the heat exchanger and through the liquor. The latter coefficient is materially enhanced by the intimate contact achieved between the liquor and heat exchanger by reason of the centrifugal force acting on the liquor film, whereby a high rate of evaporation without the formation of bubbles either below or on the surface of the liquor is readily achieved. In addition entrainment of liquor particles with the vapor, which ordinarily results from the rupturing of bubbles at the surface of a boiling liquid, is positively avoided. If some cause such as splashing of the liquor as it is fed to the evaporating area results in droplets being thrown into the vapor space, these droplets are thrown back to the liquor film by the centrifugal force before the vapor leaves the evaporating area.

Another object is to provide an improved centrifugal

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evaporator wherein the centrifugal force is employed to force the liquor through a number of evaporating stages, readily permitting the economy of multiple stage evaporation without recourse to valves or auxiliary pumps.

Other objects of this invention will appear in the following description and appended claims, reference being had to the accompanying drawings forming a part of this specification wherein like reference characters designate corresponding parts in the several views.

Fig. 1 is a fragmentary elevational view of an evaporator embodying the present invention, portions being shown in vertical mid-section to illustrate details of construction.

Fig. 2 is a fragmentary elevational view of a modification of the present invention, portions being shown in vertical mid-section to illustrate details of construction.

Fig. 3 is a vertical section taken in the direction of the arrows substantially along the line 3—3 of Fig. 2.

It is to be understood that the invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being practiced or carried out in various ways. Also it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

Referring particularly to Fig. 1, a vertical type centrifugal evaporator is shown comprising an outer generally cylindrical shell or housing 10 having in the present instance upper and lower cylinder portions 10a and 10b respectively. The portion 10b is provided with a number of footings 11 adapted to be secured to a foundation by bolts 12, whereby the housing 10 is firmly supported, and is enlarged at its upper end to comprise the lower and outer walls of an annular radially inwardly opening liquid seal channel 13. The upper wall of the channel 13 comprises an annular flange 16 of the cylinder 10a secured to the edge 14 of the cylinder 10b by bolts 15. The lower wall of the channel 13 extends radially inwardly beyond the inner circumference of the flange 16 and cylinder 10a and terminates in an upturned annular flange 13a.

Upper and lower end closure plates 17 and 18 respectively close the ends of the housing 10 and are secured to annular flanges 19 and 20 at the upper and lower ends of the cylinders 10a and 10b respectively by bolts 21. Suitable gaskets 22 interposed between the paired flanges 14, 16 and 17, 19 and 18, 20 complete steam tight seals.

Rotatable coaxially within the chamber 10 is a tubular inner shell or heat exchanger 23 having a smooth vertical inner cylindrical surface 23a and an outer cylindrical surface spaced from the inner circumference of the flange 13a. A radial outer shoulder 24 below the upper end of the heat exchanger 23 provides an annular seat for the lower wall of an annular radially inwardly opening channel member 25, the upper wall of the latter extending radially inward and being keyed to a vertical drive shaft 26 coaxial with the cylindrical shells 10 and 23. The juxtaposed portions of the member 25 and flange 24 are provided with a sealing gasket 27 therebetween and are clamped tightly together by bolts 28, the upper edge of the heat exchanger 23 being flush with the upper surface of the lower channel wall of the member 25 and comprising an inward extension thereof to complete an annular liquid feed seal channel 29.

The shaft 26 is journaled at its upper and lower ends in bearings 30 and 31 seated within the plates 17 and 18 respectively and is maintained in axial position by retainer nuts 32 and 33 screwed snugly against said bearings. Opening coaxially into the upper end of the shaft 26 is a feed bore 34 having a conically restricted upper inlet 35. Above the base of the bore 34 and spaced below

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the upper wall of the member 25 by an annular spacer 36 are a plurality of radial feed distributing ducts 37. The latter comprise tubular conduits having radially inner ends in communication with the bore 34 and secured to the shaft 26 at locations spaced uniformly around its circumference, their outer ends opening into the annular channel 29 outwardly of the surface 23a.

Steam is supplied to the steam chamber or space between the shells 10 and 23 and directly to the exterior surface of the heat exchanger shell 23 via a steam inlet duct 39 which opens radially into housing 10. The upper and lower ends of the steam chamber are determined by upper and lower liquid seals formed by rotating condensate water at high speed within the annular channel 13 and an upper annular water seal channel 40. The latter opens radially inwardly and is formed between the top plate 17 and an annular flange 41 integral with the shell 10 and extending radially inwardly therefrom at a location spaced somewhat below the plate 17. The inner periphery of the flange 41 turns upwardly in an annular flange 41a spaced outwardly from the shaft 26 to permit upward passage of steam around the shaft 26. One or more small weep openings 42 in the flange 41 drain condensate from the channel 40 when the evaporator is not in operation.

In order to effect the water seals, a pair of impeller wheels 43 and 44 keyed coaxially on the shaft 26 extend radially into the channels 13 and 40 respectively. Each wheel is provided with a plurality of radially extending impeller blades at its periphery, whereby condensate on the wheels or within the channels 13 and 40 is thrown to the outer walls of these channels by centrifugal force when the shaft 26 is rotated. Draining of condensate from the steam chamber is accomplished via a drain conduit 45 which opens through the bottom wall of the channel 13 and extends outwardly through the cylinder 10 to a condensate sump.

The shaft 26 is powered by a motor 46 supported on a platform 47 mounted on the exterior of the cylinder 10. A drive pulley 48 keyed on the drive shaft 49 of motor 46 is coupled by means of pulley belts 50 with a driven pulley 51 keyed on shaft 26, whereby the latter is rotated at high speed upon operation of motor 46.

In order to discharge vapor from the heat exchanger shell 23, the latter extends somewhat below the impeller wheel 43 and opens at its lower end into the cylinder 10b which is in communication with a vapor discharge conduit 52. The lower end of the shell 23 extends into an annular liquid seal channel 53 which opens axially upwardly within the cylinder 10b. The channel 53 comprises an annular base flange 53a integral with the cylinder 10b and extending radially inwardly therefrom at a location spaced below the lower edge of the shell 23. Inner and outer annular flanges 53c and 53b spaced from the shell 23 and integral with the base flange 53a extend upwardly therefrom above the lower edge of the shell 23 at opposite sides thereof, the outer flange 53b being also spaced inwardly of the cylinder 10b and having a weep opening 54 near its bottom edge to permit draining of the channel 53 when the evaporator is not in use.

The opening 54 opens into the annular space between the flange 53b and cylinder 10b, which space in turn discharges via conduit 55 in communication with the interior of the cylinder 10b at a location immediately above the base flange 53a. Adjacent and above the seal channel 53 are two or more small pressure equalizer conduits 54a extending radially through the shell 23 at locations spaced uniformly around the latter's circumference, thereby to prevent surging of liquid in channel 53.

Spaced somewhat above the bottom plate 18 is an annular flange 56 integral with the cylinder 10 and extending radially inwardly therefrom to comprise in co-operation with the plate 18 and shell 10b a radially inwardly opening bottom liquid seal channel 57.

Keyed coaxially on the shaft 26 is a bottom impeller

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wheel 58 which extends radially into the channel 57 and is provided at its circumference with a plurality of blades for rotating condensate within the channel 57 to effect a vapor seal therein in the manner of the seals in channels 13 and 40. In order to drain excess condensate from the bottom of the cylinder 10b, a discharge conduit 59 opens into the channel 57 through the bottom plate 18 at a location radially inward of the impeller blades on the wheel 58. In the present instance the conduits 55 and 59 converge to a common duct from which the concentrate and condensate are recirculated through the evaporator if desired.

By virtue of the above described structure, when motor 46 is operated to rotate pulley 51, shaft 26 and the heat exchanger 23 are rotated as a unit, together with the impellers 43, 44 and 58, feed seal channel 29 and feed ducts 37. Dilute liquid to be concentrated, such as aqueous radioactive waste for example, is fed into the upper end of bore 34 via a feed conduit 60 while shaft 26 is rotated at sufficiently high speed to effect a centrifugal force at the surface 23a amounting to an order of magnitude approximating a thousand times the force of gravity. For concentrating sea water or dilute aqueous radioactive solutions, a centrifugal force in excess of 600g is preferred in order to obtain optimum evaporating and heat transfer conditions, including a high speed of axial flow of a thin aqueous film along the surface 23a and the avoidance of bubble formations. Greater centrifugal forces will be employed to prevent boiling of solutions more volatile than water and to assure a rapid axial flow of solutions more viscous than water.

Any tendency for the incoming liquor to splash out of bore 34 is prevented by the upper conical dam at the inlet 35. The liquor is forced radially out of tubes 37 by centrifugal force into channel 29 which serves to prevent splashing and to trap suspended solids which might otherwise collect on the heat transfer surface 23a. The tendency to splash is minimized by the fact that the channel 29 and liquor therein, together with tubes 37, all rotate at the same angular speed.

The channel 29 also serves to spread the incoming liquor uniformly around the inner circumference of the heat exchanger 23. As the liquor overflows the lower wall of the channel 29, it is spread by the centrifugal force in a thin film over the surface 23a, causing the liquor in advance thereof to flow rapidly downwardly toward channel 53.

Simultaneously, steam entering inlet 39 will heat the outer surface of the heat exchanger 23, causing evaporation of the liquor without boiling from the film or layer covering surface 23a. The resulting vapor discharges through outlet 52 at a location remote from the trap 29. Bubble formation cannot take place either adjacent the hot surface 23a or at the inner surface of the liquor film because the centrifugal force presses the liquor against the heat transfer surface 23a. Inasmuch as the coefficient of heat transfer to the liquor film is proportional to a function of the velocity of the film over the heat transfer surface, the coefficient of heat transfer is increased by the rapid downward flow of the liquor film urged along surface 23a by the centrifugal force. The latter exceeds the gravity force by such a large factor that the influence of the latter force is negligible.

The concentrated liquor collects in channel 53 and overflows into duct 55 because the height of inner flange 53c is greater than the height of flange 53b. In order to prevent passage of the liquor through the pressure equalizer duct 54a, the latter projects radially inwardly far beyond the liquor film. The loss of a small amount of vapor through duct 54a is negligible. The liquor concentrate in channel 53 and condensate circulated in channel 57 by impeller 58 prevent losses of vapor.

Steam condensing against the outer surface of the heat exchanger 23 is immediately thrown therefrom by the centrifugal force. Thus the outer surface of shell 23 is

maintained substantially dry and in intimate contact with the live steam, achieving optimum heat transfer. Condensate rotated in the channels 13 and 40 by the impellers 43 and 44 effect seals in these channels which limit the axial steam flow

Fig. 1 illustrates a vertical single effect evaporator construction which is advantageous in concentrating radioactive solutions. In handling such solutions simplicity and compactness are more important than steam economy, so that only a single evaporating effect is illustrated. Also the vertical unit shown drains more readily than a horizontal unit when not in use and is accordingly more satisfactory for handling radioactive solutions. It is to be noted however that the primary operational forces are centrifugal, so that a horizontal or inclined unit would be satisfactory in other applications. In any case the present process comprises feeding the liquor by centrifugal force to the inner cylindrical surface of a rapidly rotating heat exchanger whereby centrifugal force rapidly moves the liquor in a thin film or layer axially from the feed area to a collection area. At the same time, the outer surface of the heat exchanger is heated by steam, whereby condensate is thrown by the centrifugal force from said outer surface to maintain a high heat transfer coefficient between the steam and heat exchanger. The heat is conducted to the inner surface of the heat exchanger and thence to the liquor film to cause evaporation, the centrifugal force preventing bubble formations thereby to avoid entrainment of liquid particles in the vapor and to effect in cooperation with the rapid axial movement of the liquor film a high coefficient of heat transfer to the liquor.

Referring to Figs. 2 and 3, a triple effect horizontal evaporator is illustrated which is particularly suitable for concentrating sea water, by way of example, although the unit is suitable for other industrial applications. The structure comprises an outer horizontal cylindrical shell or housing 70 mounted on footings 71 and secured to a firm support by bolts 72. End closures 73 and 74 are bolted to the ends of the shell 70 by bolts 75.

The end closure 74 is provided with a large central opening 76 and is suitably secured by bolts 77a to a fluid seal housing assembly indicated generally by the numeral 77, which completes a drum-like vapor chamber within the shell 70. The assembly 77 is formed to comprise in cooperation with the end closure 74 an annular radially inwardly opening liquid seal channel 78 having an outer annular sidewall 79 extending radially inwardly beyond the opening 76. Spaced axially endwise of the channel 78 is a similar annular liquid seal channel 80 formed in the assembly 77.

Extending coaxially through the housings 70 and 77 is a rotatable drive shaft 81 journaled adjacent opposite ends in bearings 82 and 83 mounted in the end closure 73 and housing 77 respectively. The shaft is rotated at high speed by means of a motor 84 supported on a platform 85 secured to the end closure 73. The motor 84 is operatively coupled with the shaft 81 by pulley belts 86 entrained around pulleys 87 and 88 keyed coaxially on the motor shaft 89 and drive shaft 81 respectively.

In the present instance, the space within housing 70 is partitioned axially into three separate evaporating effects A, B, and C by partitions rotatable as a unit with shaft 81. These partitions include a hub or annular plate 90 keyed to shaft 81 and spaced axially inwardly from end closure 73 to comprise the outer boundary of effect C. Extending radially through an axially inwardly thickened rim 91 of plate 90 are a plurality of liquor discharge bores or tubes 92 opening at their inner ends within the effect C and at their outer ends uniformly around the periphery of plate 90. Integral with the rim 91 and extending inwardly therefrom coaxially with shaft 81 at a location radially outward of the inner periphery of the rim 91 is a cylindrical tube sheet or plate 94 which comprises a horizontal boundary partition for effect C. The

inner end of plate 94 terminates in an annular plate 95 which extends radially outwardly from the plate 94.

Spaced axially inwardly from plate 95 to provide a vapor passage from effect C into a second condensing chamber E is a hub or plate 96 keyed to shaft 81 and comprising a vertical partition between effects B and C. Also similar to plate 94 is a cylindrical tube plate 97 integral with plate 96 and extending leftward from the outer periphery thereof coaxially with shaft 81 to comprise a horizontal partition between effect B and chamber E. The plate 97 terminates at its left edge in an annular plate 98 similar to plate 95 and extending radially outwardly from plate 97 to comprise a vertical left boundary for chamber E. The plate 95 comprises a vertical partition between chambers D and E.

Spaced axially outwardly from plate 98 to provide a vapor passage from effect B into a third condensing chamber F is an annular hub or plate 99 keyed to shaft 81 and comprising a vertical partition between effects A and B. A cylindrical tube plate 100 integral with plate 99 extends outward therefrom coaxially with shaft 81 to comprise a horizontal partition between effect A and chamber F and terminates in an annular plate 101 comprising a vertical outer boundary for chamber F. Cylindrical closure plates 102 and 103 coaxial with shaft 81 are secured by bolts 104 to the outer ends of plates 95, 98 and 101 to comprise the circumferential boundaries for chambers E and F respectively.

In operation of the structure described thus far, the motor 84 is operated to rotate shaft 81 at high speed, thereby to rotate the hubs 90, 96 and 99, together with the connected partition structure, the outer housings 70 and 77 remaining stationary. Liquor to be concentrated is fed from a stationary supply conduit 105 into a feed bore 106 extending axially into the left end of shaft 81. This liquid is accelerated to the angular velocity of the shaft, and, until it leaves the evaporator, is only contacted by rotating parts of the latter. A conical dam 107 machined on the inner surface of the bore 106 adjacent the latter's outer end prevents back flow of the liquor from the shaft. Centrifugal force causes the liquor to flow out of two or more radial feed nozzles 108 into an annular radially inwardly opening liquid seal channel 109 integral with plate 100. The nozzles 108 are spaced uniformly around shaft 81 and are secured thereto at their inner ends in communication with bore 106. The outer ends of the nozzles 108 extend into channel 109 which latter thus comprises a splash trap. The annular outer sidewall of channel 109 extends radially inwardly more than does the annular inner sidewall of channel 109, so that fluid entering the latter channel from nozzles 108 will overflow onto plate 100.

In order to increase the heat transfer area as described below, the liquid in each effect is forced to travel through hairpin or U-shaped tubes 110 having radially inner ends rolled into the cylindrical tube plates or sheets 94, 97 and 100. The loops of the tubes 110 extend radially outwardly into the condensing chambers D, E and F. As indicated in Fig. 3, the tubes 110 are spaced uniformly around the circumference of the tube sheets, but the spacing between adjacent tubes is exaggerated in the drawings for the sake of simplicity. By way of illustration, two annular sets of tubes 110 are shown opening into each of effects A and B, whereas one annular set of tubes 110 open into effect C. The open ends of each tube 110 are spaced axially, separated by annular baffles 111 extending radially inwardly from the tube plates, so that the liquid is forced to flow in series through the tubes 110 of the successive annular sets as it progresses axially from left to right. Fig. 2 illustrates the condition wherein a portion of the liquid in each effect A and B travels through two tubes in series to pass from its point of entry to its point of discharge. The remainder of the liquid feed may be baffled to pass in either a series or a parallel

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manner through the other tubes similarly located about the circumference of the cylindrical tube sheets. The velocity of the liquid in the tubes 110 is controlled by the rate of feed into bore 106 and by the baffle arrangement. The maximum velocity is obtained by baffling between each tube so as to force the liquid to travel in series through all the tubes 110 in a circumferential as well as in axial progression. Semi-circular inserts 114 machined to fit the inner side of the hairpin loops prevents distortion of the tubes 110 during rotation.

As the liquid flows through the hairpin tubes 110, it is heated by vapor condensing on the outside of the tubes, as described below. However, the high pressure on the liquid exerted by centrifugal force prevents boiling in the tubes. Evaporation occurs on the surface of the liquid where the pressure is the least. After rising in portion 113 of effect A, the partially concentrated liquid leaves the first effect via overflow tube 115 which passes through plate 99 into the next effect B. Since the overflow tube 116 for effect B is spaced radially outward from the axis of shaft 81 a greater distance than overflow tube 115, the surface of the liquid in effect B is subjected to a greater centrifugal force than the surface of the liquid in the previous effect A and the vapor pressure in effect B will be correspondingly greater than in effect A. The liquid again passes through the hairpin tubes 110 in effect B as in the previous effect and discharges through plate 96 via the overflow tube 116 into the last effect C. The liquid from the last effect C overflows through bores 92 into a stationary radially inwardly opening annular channel 117 having the outer periphery of rim 91 projecting thereinto. The latter is provided with impeller blades for rotating the concentrate in channel 117 to provide a liquid seal thereat in the manner of the seals in channels 13, 29, and 57. The channel 117 is integral with the end closure 73 and has an annular inner sidewall extending radially inwardly almost to the outer surface of plate 94. A concentrate outlet 118 opens into channel 117 through the end closure 73 at a location intermediate the base of channel 117 and the inner periphery of the inner sidewall of channel 117, whereby the concentrated liquor overflows into outlet 118 rather than into chamber D.

It is to be noted that the radial distances of the inner ends of the outlet bores 92 from the axis or shaft 81 are greater than the corresponding radial distance to the outlet 116, which in turn is greater than the corresponding radial distance to outlet 115, and the latter distance is greater than the corresponding radial distance to the inner circumference of the annular inner sidewall of channel 109. Thus the liquor level indicated by the dotted horizontal lines in Fig. 2 will be at a location subject to a maximum centrifugal force in effect C, an intermediate centrifugal force in effect B, and a minimum centrifugal force in effect A. The baffles 111 in each effect extend radially inwardly beyond the liquor level in the associated effect. Likewise the plates 95 and 98 also project radially inwardly beyond the liquor level in the effects C and B respectively.

Referring now to the vapor side of the evaporator, steam at the desired operating pressure enters condensation chamber D through nozzle 119 and condenses on the tubes 110 in the latter chamber. The centrifugal force throws the condensate from the tubes 110, maintaining a high condensing film coefficient of heat transfer. Heat transferred to the liquid causes evaporation in effect C, but at a lower temperature and pressure than the steam in condensing chamber D. The vapor from effect C enters condensing chamber E and condenses on the cooler tubes 110 therein. The condensate is thrown to the rotating wall 102 where it accumulates until sufficient pressure permits its escape through a spring loaded valve 120. The foregoing process is repeated in the first effect A. Heat from vapor condensing in chamber E releases vapor at lower temperature and pressure in effect B. Vapor from effect B condenses on the cooler tubes in chamber

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F and is thrown to wall 103, from which the condensate is released through a spring loaded valve 121. The condensate from all three condensing sections is discharged through nozzle 122 at the bottom of housing 70.

The vapor from the first effect A passes axially between the rotating feed tubes 108 and is discharged through vapor outlet 123 opening radially into housing 77 at a location intermediate the liquid seal channels 78 and 80. This vapor is condensed in a condenser separate from the evaporator and added to the condensate from nozzle 122. The latter nozzle is in communication with steam entering from nozzle 119, but steam loss is blocked by a suitable steam trap in the discharge conduit from nozzle 122.

An impeller wheel 124 keyed on shaft 81 and having peripheral impeller blades rotating in channel 80 rotates condensate therein to effect a liquid seal and prevent loss of vapor from effect A. Similarly an impeller wheel 125 having blades rotating in channel 78 rotates condensate therein to effect a liquid seal and prevent loss of steam entering via inlet nozzle 119. At the other end of the housing 70, passage of steam from chamber D is blocked by the liquid seal in channel 117. Although the preferred liquid seals are disclosed herein, conventional packing seals will be employed in accordance with the requirements of other applications.

By virtue of the structure described, the direction of vapor flow is contrary to the direction of liquor flow and is baffled or interrupted so as to avoid a continuous rapid vapor flow and the possibility of entrainment of liquor that would otherwise result in a rapid vapor flow. Thus steam in chamber D is isolated from chambers E and F and from the evaporating effects A, B, and C. Vapor in effect C can pass to chamber E, but is isolated from effect B in chamber F. Vapor in effect B can pass to chamber F, but is isolated from effect A, which exhausts via outlet 123. The centrifugal force on the liquor surface in effects A, B, and C achieves evaporation without boiling, thereby positively avoiding an additional cause of entrainment.

I claim:

1. In a centrifugal evaporator for concentrating liquids and preventing entrainment of non-vapor particles in the evaporate, rotatable heat exchanger means comprising a multiple effect evaporator, the evaporating effects being in axially spaced succession along a common axis of rotation and sealingly partitioned from each other against vapor flow, each effect comprising a radially inwardly opening trough adapted to hold liquid therein when said heat exchanger means is rotated about said axis, means for feeding liquid into the trough of the first effect of said succession, means for feeding liquid from each effect into the next successive effect comprising an outlet for each trough connected with the trough of the next successive effect, the radial distance from said axis to the outlet of the trough in each effect being shorter than the corresponding radial distance in the next successive effect, liquor discharge means in communication with the outlet of the last effect in said succession, a vapor passage from each effect, except the first, to a condensing chamber in heat exchange relationship with the next preceding effect, with regard to liquid flow and heating means for heating said heat exchanger means to evaporate liquid therein.

2. In a centrifugal evaporator for concentrating liquids and preventing entrainment of non-vapor particles in the evaporate, a rotatable shaft, a succession of evaporating effects spaced axially along the axis of said shaft, means partitioning each effect from the others, each effect comprising a trough opening radially inwardly with respect to said axis and connected to said shaft to rotate therewith, thereby to contain liquid therein by centrifugal force upon rotation of said shaft, means for feeding liquid by centrifugal force into the trough of the first effect of said succession comprising axially extending liq-

uor conduit means within said shaft to rotate therewith and arranged symmetrically with respect to said axis, said conduit means having an inlet opening axially at one end and also having an outlet located radially outwardly from said inlet and in communication with the last named trough, means for feeding liquid from each effect except the last into the next successive effect comprising an outlet for each trough connected with the trough of the next successive effect, the radial distance from said axis to the outlet of the trough in each effect being shorter than the corresponding radial distance in the next successive effect, liquor discharge means in communication with the last effect in said succession, and heating means for heating said heat exchanger means to evaporate liquid therein.

3. The combination in a centrifugal evaporator as set forth in claim 2 wherein said liquor conduit means includes a trough opening radially inwardly with respect to said axis adjacent the trough of said first effect, the latter two troughs having a common partition terminating radially inwardly at locations spaced radially outwardly from said inlet.

4. In a centrifugal evaporator for concentrating liquids and preventing entrainment of non-vapor particles in the evaporate, a rotatable shaft, a succession of evaporating effects spaced axially along the axis of said shaft, each effect comprising an annular trough coaxial with said shaft and opening radially inwardly with respect thereto, one sidewall of each trough extending radially inwardly to said shaft and being connected thereto and comprising a partition wall for the associated evaporating effect, a radially inwardly opening annular feed seal trough coaxial with said shaft, the axially inner sidewall of the feed seal trough comprising the axially outer sidewall of the trough of the first effect relative to liquid flow and extending radially inwardly a lesser distance than the axially outer sidewall of said feed seal trough, a radial tubular feed duct extending radially from said shaft and connected thereto to rotate therewith, the outer end of said feed duct extending into said feed seal trough to discharge liquor thereinto, a feed supply duct extending axially into said shaft and being in communication with said radial feed duct, means for feeding liquid from each effect into the next successive effect relative to liquid flow comprising an outlet for each trough connected with the trough of the next successive effect, the radial distance from said axis to the outlet of the trough in each effect being shorter than the corresponding radial distance in the next successive effect, liquor discharge means in communication with the outlet of the last effect in said succession, a succession of condensing chambers contiguously associated with said evaporating effects respectively, a first condensing chamber with respect to vapor flow being associated with the last evaporating effect relative to liquid flow and vice versa, means partitioning each chamber from the other chambers, a portion of the trough of each effect comprising a heat exchange surface partitioning that effect from the associated condensing chamber, vapor conduit means connecting each condensing chamber except the first with the evaporating effect associated with the next preceding condensing chamber relative to vapor flow, vapor inlet conduit means opening into the chamber at one end of said succession of chambers, and vapor outlet conduit means opening from the evaporating effect associated with the chamber at the other end of said succession of chambers.

5. The combination in a centrifugal evaporator as set forth in claim 4 wherein said one sidewall of the trough of each effect being the sidewall of that trough axially remote from said feed seal trough, the other sidewall of the trough of each effect being spaced from said one sidewall of the trough of the next preceding effect in the direction axially away from said feed seal trough and the spacing between juxtaposed troughs of the successive effects comprising said vapor conduit means, the trough of each effect also having a portion extending radially outwardly from adjacent said other sidewall thereof and comprising a radial sidewall of said means partitioning each chamber from the other chamber, the latter means also comprising a cylindrical partition spacing and connected to the radially outer edges of adjacent pairs of the radial sidewalls, and said vapor inlet conduit means opens into the chamber associated with the last evaporating effect relative to liquid flow in said succession of effects.

6. The combination in a centrifugal evaporator as set forth in claim 1 wherein said heating means comprises a succession of condensing chambers contiguously associated with said evaporating effects respectively, the first condensing chamber with respect to vapor flow being associated with the last evaporating effect with respect to liquid flow and vice-versa, a portion of the trough of each effect comprising a heat exchange surface partitioning that evaporating effect from its contiguously associated condensing chamber; vapor conduit means connecting each condensing chamber except the first with the evaporating effect associated with the next preceding condensing chamber relative to vapor flow; and vapor inlet conduit means opening into the first condensing chamber; and a vapor outlet opening in the first evaporating effect.

7. The combination in a centrifugal evaporator as set forth in claim 3 wherein said heating means comprises a succession of condensing chambers contiguously associated with said evaporating effects respectively, the first condensing chamber with respect to vapor flow being associated with the last evaporating effect with respect to liquid flow and vice versa, a portion of the trough of each effect comprising a heat exchange surface partitioning that evaporating effect from its contiguously associated condensing chamber; vapor conduit means connecting each condensing chamber except the first with the evaporating effect associated with the next preceding condensing chamber relative to vapor flow; and vapor inlet conduit means opening into the first condensing chamber; and a vapor outlet opening in the first evaporating effect.

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