July 19, 1966 H. E. JACOBY 3,261,392

EVAPORATION SYSTEM AND METHOD

Filed Oct. 16, 1963 2 Sheets-Sheet 1

Fig. 1.

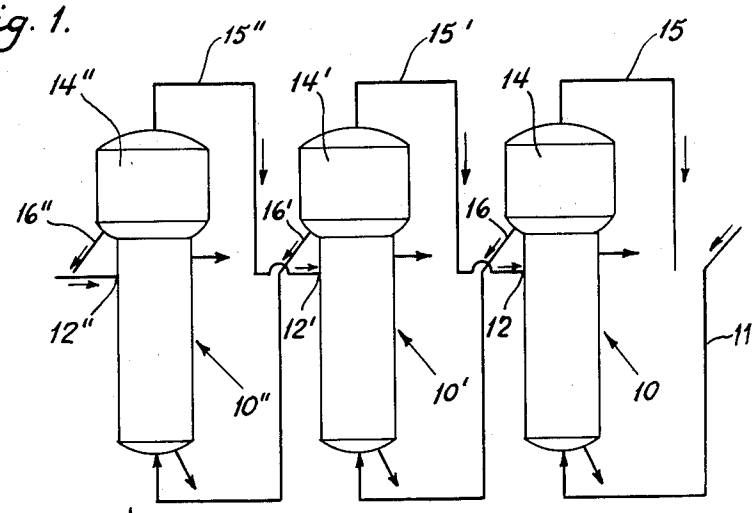


Fig. 2.

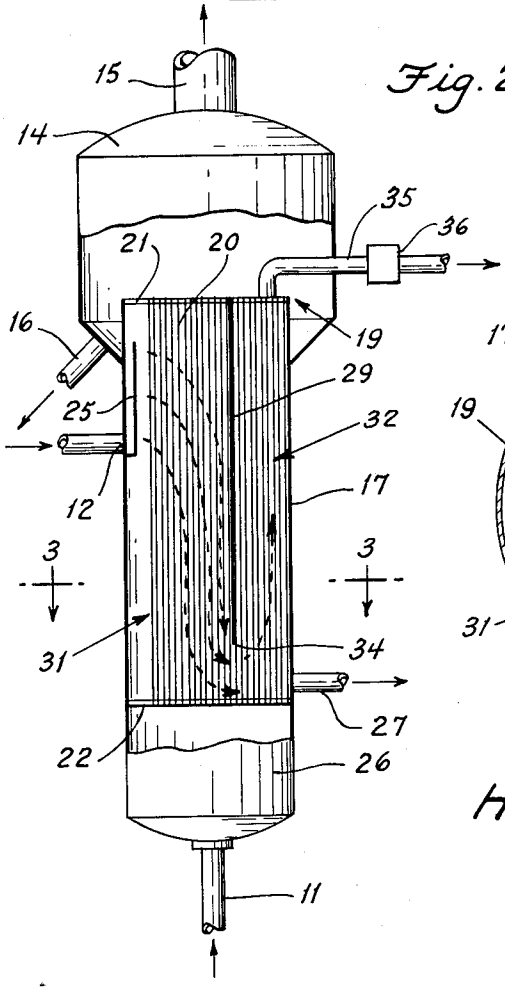
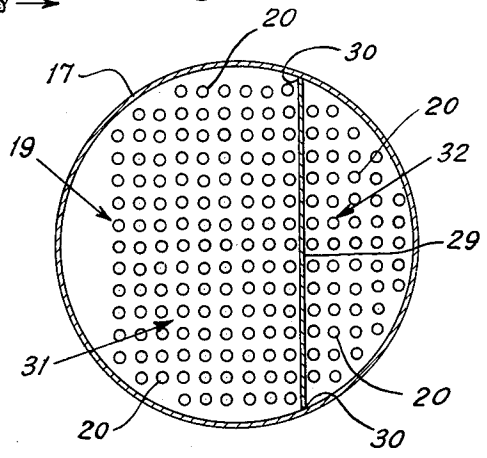


Fig. 3.



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Fig. 4.

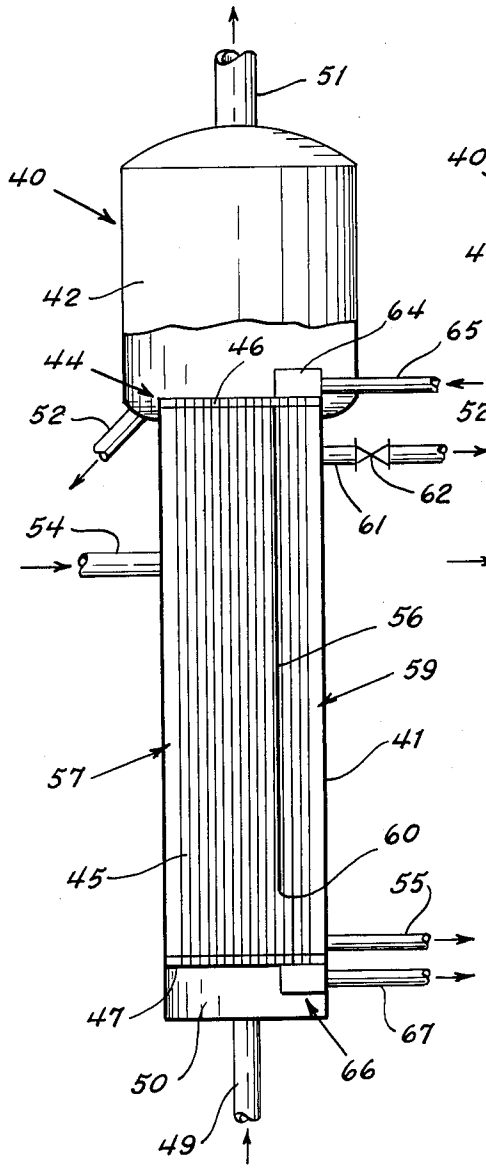
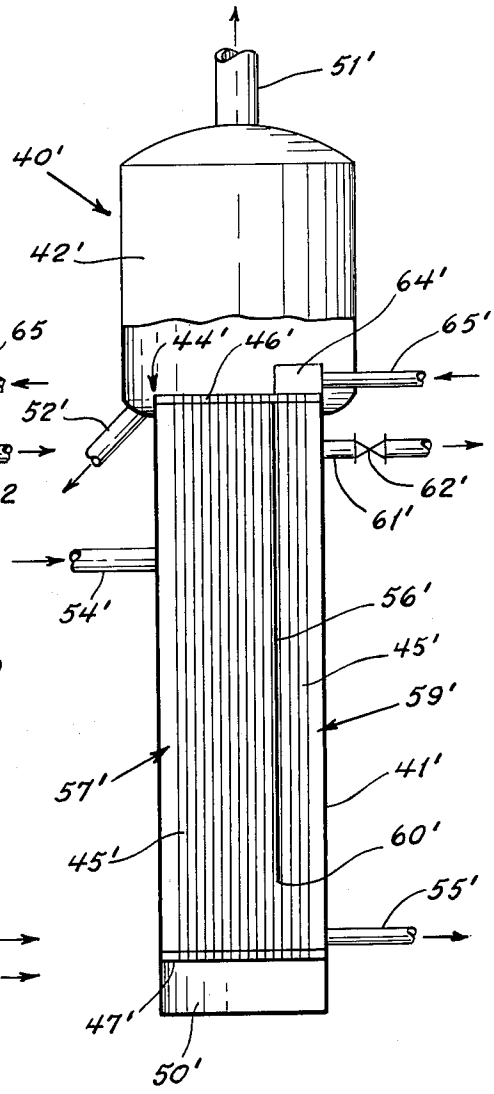


Fig. 5.



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EVAPORATION SYSTEM AND METHOD

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8 Claims. (Cl. 159—27)

This invention relates to an evaporation system and a method of evaporation, and more particularly relates to a system and method which are particularly effective in the removal of non-condensable gases from the system and which make more effective use of the heat available in such non-condensable gases.

In the evaporation of many solutions, particularly by evaporation systems of the multiple effect or vapor recompression types, after the vapors have been condensed on the evaporator heating surface there is a residue of non-condensable gases which must be removed from the system.

Many devices have been employed for the removal of such non-condensable gases. Relief vents for this purpose may be located on the shell enclosing the heating surface or as an internal tube or other device. In any case, the location of this vent point assumes that the gases will collect in the general area of this vent.

If such gases were not removed from the heating surface, they would eventually so cover the heating surface as to "blanket" the surface to a point where heat transfer could no longer occur. As a consequence, in normal practice non-condensable gas vents are opened continuously to insure that all gases are removed. In so doing, it is obvious that the gases will carry a normal saturation component of condensable vapors and an excess thereof because it is virtually impossible to obtain a 100% separation of non-condensable gases from condensable vapors. As a result of such venting, considerable heat is lost due to the discharge of condensable vapors from the system through the gas vent prior to their having been condensed on the heating surface.

The invention has among its objects the provision of an evaporation system incorporating novel means for collecting gases and related vapors in the system.

Another object of the invention is the provision of an evaporation system incorporating a gas collecting means which utilizes the available heat in the collected gas and related vapors in a novel manner.

Yet another object of the invention is the provision of novel methods of evaporation including the collection of gases and related vapors and the utilization of the heat and the related gases and vapors for processing purposes.

The above and further objects and novel features of the invention will more fully appear from the following description when the same is read in connection with the accompanying drawings. It is to be expressly understood, however, that the drawings are for the purpose of illustration only, and are not intended as a definition of the limits of the invention.

In the drawings, wherein like reference characters refer to like parts throughout the several views,

FIG. 1 is a somewhat schematic view of a portion of a multiple effect evaporating system, such system incorporating a plurality of effects or evaporating vessels made in accordance with a first embodiment of the invention;

FIG. 2 is a view partially in vertical section and partially in side elevation of such first illustrative embodiment of evaporating vessel or effect made in accordance with the invention;

FIG. 3 is a view in horizontal section on an enlarged scale through the apparatus of FIG. 2, the section being taken along the line 3—3 in the direction of the arrows of FIG. 2;

FIG. 4 is a view partially in vertical section and partially in side elevation of a second illustrative embodiment of evaporating vessel or effect in accordance with the invention; and

FIG. 5 is a view similar to that of FIG. 4 of a third illustrative embodiment of evaporating vessel or effect in accordance with the invention.

The evaporation system and method of invention may be employed to advantage in a number of different applications requiring the evaporation or concentration of solutions and a heat exchange between two or more fluids employed in a process. One use of such evaporation system is in the concentration of waste sulphite liquor or "black liquor" employed in the paper making industry. For this purpose there is ordinarily employed a multiple stage or "multiple effect" evaporation system, the first stage or stages of which are heated by a heating fluid such as steam, the heating in the latter stages being effected by vapors boiled from liquor evaporated in previous effects. For purposes of simplification, the apparatus and method of the present invention will be particularly described in connection with their use for concentrating a solution such as the above discussed black liquor. It is to be understood, however, that the apparatus and method of the present invention are not limited to such use. It is also to be understood that the novel evaporator of the invention may be employed as a single stage or effect or connected to form a multiple effect evaporator, or recompression evaporator.

As is apparent from the above, three embodiments of the evaporating system of the invention are illustrated herein. The first of such embodiments is shown in FIGS. 1, 2, and 3, the apparatus illustrated in FIG. 1 being an intermediate portion of a multiple effect evaporator for the concentration of liquor such as black liquor in the paper making industry. The second illustrative embodiment, shown in FIG. 4, is of a modified construction which permits the solution in process or a further solution, separated from the main solution being evaporated by the apparatus, to be heated by the non-condensable gas and related vapors in the gas collecting zone of the apparatus. The third illustrative embodiment, shown in FIG. 5, is of a still further modified construction which permits the liquor being concentrated to be evaporated in the main portion of the apparatus in the usual manner after such liquor has been treated separately by being passed in heat exchanging relationship with the non-condensable gas and related vapors in the gas collecting zone of the apparatus.

Turning now to FIGS. 1, 2, and 3, there are shown in FIG. 1 three successive stages or effects of the evaporator, the liquor being evaporated and concentrated traveling in the system in a direction generally to the left from one effect to the next. Thus, in the portion of the system shown, black liquor enters the stage or effect **10** through a pipe **11** connected to the bottom of such effect. The black liquor rises in the heating surface in effect **10** and is boiled therein by indirect heat transfer from heating fluid entering through a port **12** connected to the vapor delivery pipe **15'** of the previous effect **10'**. Vapor which has boiled from the liquor in effect **10** is collected in a vapor dome **14** at the top thereof and is discharged through a pipe **15** which leads to a further stage or effect (not shown) where it is employed as a heating fluid for such further effect. Concentrated liquor collected in the bottom of the vapor dome **14** is discharged through a pipe **16** which leads to the bottom of

the next effect 10'. The concentrated liquor from effect 10' is discharged therefrom and fed into a still further effect 10", as shown. Parts of effects 10' and 10" which are the same as those of effect 10 are designated by the same reference characters but with an added prime and an added double prime, respectively.

Each of effects 10, 10', and 10" is provided with a novel means for collecting non-condensable gases and related vapors which is more particularly shown in FIGS. 2 and 3 which illustrate the effect 10 shown in FIG. 1. As there shown, the effect 10 has a vertical circular cylindrical casing 17 within which is disposed an evaporating and heating means 19 which is composed of a plurality of vertical parallel tubes 20 connected and sealed at the top and bottom by tube sheets 21 and 22, respectively. At the bottom of the casing 17 the liquor feed pipe 11 is connected to a chamber 26 whereby liquor entering through pipe 11 flows upwardly into the tubes 20. Chamber 26 is isolated from the space surrounding the tubes and within the casing 17 by means of tube sheet 22. The upper tube sheet 21, the upper portion of casing 17 and the vapor dome 14 not only close the upper end of the heating fluid receiving space within the effect 10, but form a vapor and concentrated liquor receiving space which is in direct communication with the upper ends of tubes 20. The heating fluid for effect 10 enters casing 17 through the port 12 as above described, and is initially deflected upwardly and sidewardly by a short upwardly extending baffle plate 25. The heating fluid then flows downwardly around the upper end of plate 25 into the heating space within the casing 17 so as to heat the exterior of each of the tubes 20. Condensate from such heating fluid is collected at the bottom of the effect above tube sheet 22 and is discharged therefrom through a pipe 27.

In accordance with the invention there is provided within the heating device 19 a partial partition or baffle which effectively divides the upper portion of the heating space within device 19 into two portions. Such baffle, shown at 29 in FIGS. 2 and 3, is connected to and depends from the upper tube sheet 21 and is connected and sealed to the casing 17 along the edges of the baffle as shown at 30 in FIG. 3. In the embodiment shown, the baffle 29 is positioned somewhat to the right of a vertical central plane normal to the plane of the paper in FIG. 2, and through the effect 10 so that the portion 31 of the heating space to the left of the baffle 29 is in immediate communication with the port 12 and has a markedly greater volume than the portion 32 of the heating space to the right of the baffle. It is to be understood that the lateral positioning of the baffle 29, and thus the ratio of the volumes of heating spaces 31 and 32, may be varied appropriately depending on the volume of uncondensable gas relative to the volume of condensable vapor. The baffle 29 is terminated at its lower edge 34 so as to lie a substantial distance above the lower tube sheet 22. Heating fluid (vapor and gases) entering the casing 17 through the port 12 travels through portion 31 of the heating space in directions generally indicated by the dotted lines in FIG. 2, leaving space 31 by passing through the passage formed by the lower edge 34 of the baffle and the lower tube sheet 22 and into the bottom of the space 32 into which it then rises. Space 32, as we have seen, is shielded from the direct travel of the heating vapor and gases thereinto by the baffle 29. Because of such length of travel of the heating fluid, during which vapors progressively lose heat to the pipes 20 which they encounter, the fluid rising within space 32 becomes markedly higher in gas content than that in space 31. Thus the non-condensable gases are collected as they rise within space 32 and are cooled appreciably, a substantial part of the remaining condensable vapors being condensed and falling into the space 26 at the lower end of the casing so as to be removed as condensate. The non-condensable gases are removed from the effect through a pipe 35 connected to the casing 17 so as to communicate with the space 32 therein at its upper end as shown. The pipe 35 may conveniently be provided with a selectively operable vent valve 36, as indicated in FIG. 2.

The embodiment of evaporator, shown in FIG. 4, which is a modification of that above described in connection with FIGS. 1, 2, and 3, employs the partially shielded portion of the heating space of the evaporator, between the baffle 56 and the gas exhaust vent, for gas cooling in heat exchange with process liquor. In most multiple effect evaporator systems liquor transferred from an effect of low pressure to one of high pressure requires that the liquor be preheated to the boiling point of the effect at higher pressure. The gases and vapors collected in the shielded portion of the heating space provide heat which may be conveniently and economically employed in heating such process liquor. Additionally, such process liquor, being relatively cold, in flowing through the tubes in the shielded portion of the heating space function efficiently to condense vapors and to cool non-condensable gases collected in such shielded portion of the heating space.

The apparatus shown in FIG. 4 is somewhat similar in some details as that of FIGS. 1, 2, and 3. Because some of the elements differ therefrom, however, the elements in FIG. 4 are designated by different reference characters from those employed in connection with the first embodiment. The evaporator or effect shown in FIG. 4 is generally designated by the reference character 40. Effect 40 has a casing 41, provided with a vapor dome 42. The heating and evaporating device within the casing 41 is generally designated by the reference character 44; device 44 is composed of a plurality of spaced vertical parallel tubes 45 which are connected and sealed to upper and lower tube sheets 46 and 47, respectively, both of which are sealed to the casing 41. Liquor to be evaporated and concentrated is introduced through a pipe 49 into a lower header 50, which is connected and sealed to the lower end of casing 41. Vapors boiled from the liquor after the latter has passed upwardly through the tubes 45 is discharged from the vapor dome 42 through a conduit 51. Concentrated liquor is exhausted from the lower end of dome 42 through a discharge pipe 52.

Heating fluid for the effect 40, which may be steam, if the effect is one of the first effects of a multiple effect system, or the vapor and gases from a previous effect in a multiple effect system, is introduced into the casing 41 through a pipe 54 near the upper end of casing on one side thereof. The condensate from the heating fluid is discharged from the casing through a pipe 55 which is connected thereto above the lower tube sheet 47 at a location remote from the inlet pipe 54. A vertical baffle 56 extends from the upper end of the casing and from side to side thereof downwardly to its lower end 60 which is spaced somewhat above the lower tube sheet 47, the baffle forming a first portion 57 of the heating space to the left of the baffle and a second shielded portion 59 of the heating space to the right of the baffle, in the embodiment shown, portion 57 markedly exceeding portion 59 in volume. Connected to the wall of the casing 41 opposite the wall to which the pipe 54 is connected is a gas exhaust conduit 61 in which there is interposed a selectively operable valve 62. Heating fluid entering the heating space through pipe 54 spreads throughout the larger portion 57 thereof and surrounds tubes 55 and then flows downwardly through the passage formed between the lower tube sheet 47 and the lower edge 60 of the baffle 56. From such passage the fluid rises within the smaller, shielded portion 59 of the heating space where residual vapors are condensed, and gases are collected and cooled and are finally passed out of the casing through pipe 61 and open valve 62.

In order to condense residual vapor and to cool gases rising within portion **59** of the heating space as above described, the apparatus of FIG. 4 is provided with the following additional elements. A sub-header **64** is positioned within the vapor dome **42** and is sealed to the upper sheet **46**. Sub-header **64** is of such shape and horizontal area as to cover the upper ends of all of the tubes **45** within the portion **59** of the heating space. A conduit **65** extends inwardly through a wall of the vapor dome **42** to communicate with the sub-header **64**. At the bottom of the heating device **44** there is provided a similar but inverted sub-header **66** which is located within the lower header **50** and which is sealed to the lower tube sheet **47** so as to be connected with the lower ends of the tubes **45** within portion **59** of the heating space. A conduit **67** extends inwardly through the wall of the header **50** to communicate with the sub-header **66**.

Cold process liquor, separate from the liquor introduced into header **50** through conduit **49**, may be introduced into the upper sub-header **64** through the conduit **65**. Such liquor then travels progressively downwardly through tubes **45** within shielded portion **59** of the heating space, being progressively heated by the rising hot vapors and non-condensable gases flowing toward the exhaust pipe **61**. At the same time, as above explained, such action extracts heat from the vapors and gases causing the vapors to be progressively condensed and the gases to be cooled. Heated process liquor is collected in the lower sub-header **66** and is discharged therefrom through the pipe **67**. If desired, sub-headers or compartments **64** and **66** may be subdivided for well known reasons related to improved heat transfer by multi-pass flow.

The apparatus of FIG. 5 is the same as that of FIG. 4 except for the omission of the pipe **49**, and the omission of the sub-header **66** and the conduit **67** communicating therewith. Consequently, the elements of FIG. 5 are designated by the same reference characters as those employed in FIG. 4 but with an added prime. In the operation of the apparatus of FIG. 5 all of the tubes **45'** in space **59** are fed via conduit **65'** and compartment **64'** with the liquor to be evaporated in the tubes **45'** in space **57'**. The liquor which is fed through the tubes **45'** in portion **59'** of the heating space is appreciably colder than that collected in the main portion of the vapor dome **42'** and discharged therefrom through the conduit **52'**. The liquor entering sub-header **64''** is in heat exchanging relationship with the vapors and non-condensable gases rising within shielded portion **59'** of the heating space. Thus in the apparatus of FIG. 5 the vapors and non-condensable gases flowing toward the exhaust vent **61'** are effectively cooled, thereby increasing the efficiency of condensation and removal of vapors from the non-condensable gases being discharged from the apparatus.

Although only a limited number of embodiments of the invention have been illustrated in the accompanying drawings and described in the foregoing specification, it is to be especially understood that various changes, such as in the relative dimensions of the parts, materials used, and the like, as well as the suggested manner of use of the apparatus of the invention, may be made therein without departing from the spirit and scope of the invention will now be apparent to those skilled in the art.

What is claimed is:

1. In an evaporator having an elongated casing having a heating space therewithin, a plurality of spaced parallel tubes disposed longitudinally in the casing, first and second headers connected to the opposite ends of the tubes adjacent the respective first and second ends of the casing, means including an inlet port in the casing to introduce a heating fluid into said casing adjacent a first end thereof, means to introduce liquor to be evaporated into one of said headers, and means to exhaust concentrated liquor and vapor from the other of said headers, the improvement which comprises a gas exhaust vent in a part of the casing remote from the heating fluid inlet port therein, on a side thereof opposite said inlet port, and substantially spaced from the second end of the casing, a baffle extending from one side of the casing to the other and from the first end of the casing to terminate at a free end substantially beyond the gas exhaust vent and spaced from the other, second end of the casing, the baffle substantially dividing the heating space in the casing into a first heating space portion in direct communication with the inlet port and a second heating space portion in direct communication with the gas vent, each of said two portions of the heating space containing some of said tubes, said two spaces being connected only at the ends thereof adjacent the second end of the casing by a passage between the free end of the baffle and the second end of the casing, whereby heating fluid upon entering the inlet port travels through the casing between and around the tubes in the first portion of the heating space, then through the passage beyond the free end of the baffle, and then into the second portion of the heating space to the gas exhaust vent, a sub-header connected only to the first ends of the tubes within the second portion of the heating space, and a separate conduit connected to said sub-header for introducing a liquid to be heated into the tubes within the second portion of the heating space.

2. An evaporator as claimed in claim **1**, comprising a second sub-header connected only to the second ends of the tubes within the second portion of the heating space, and a second separate conduit connected to said second sub-header, whereby a separate body of fluid may be circulated through the tubes in the second portion of the heating space in heat-exchanging relation with the vapors and gases passing through said second portion of the heating space.

3. An evaporator as claimed in claim **2**, wherein the first and second sub-headers are subdivided to provide for multi-pass flow of the separate body of fluid through the tubes in the second portion of the heating space.

4. An evaporator as claimed in claim **1** wherein the elongated casing and the tubes therein are disposed vertically with the first end of the casing and the sub-header disposed at the upper end thereof, and with the second end of the casing disposed at the bottom thereof, and wherein the baffle is disposed substantially closer to the gas vent than to the inlet port, whereby the first portion of the heating space markedly exceeds the second portion thereof in volume.

5. In a method of handling fluids in an evaporator having a casing providing a heating space adapted to receive a first, heating fluid, said evaporator having a plurality of spaced parallel tubes disposed longitudinally in the heating space, a baffle extending parallel to said tubes from one side of the heating space to the other and from a first end of the heating space to terminate at a free end adjacent but spaced from the other, second end of the heating space, the baffle substantially dividing the heating space into a first heating space portion containing some of the tubes and a second heating space portion containing the remainder of the tubes, the steps which comprise introducing the first fluid into the first portion of the heating space adjacent the first end of the heating space, removing vapors and non-condensable gases from the first fluid from the second portion of the heating space adjacent the first end of the heating space, whereby the baffle effectively shields the tubes in the second portion of the heating space from direct impingement by the first fluid entering the heating space, the baffle diverting the heating fluid to flow generally longitudinally of the baffle toward the free end thereof, and around such free end of the baffle before flowing into the second portion of the heating space, introducing a second fluid into one end of the tubes in the first portion of the heating space and passing it through such tubes to heat and evaporate the second fluid by the first fluid, and introducing a separate liquid isolated from the other fluids into those ends of

the tubes within the second portion of the heating space which lie at the first end of the heating space, whereby said separate fluid flows in countercurrent to vapors and non-condensable gases and is heated thereby in its travel through the tubes in said second portion of the heating space.

6. A method as claimed in claim 5, comprising collecting in isolated condition the separate liquid as it is discharged from those ends of the tubes within the second portion of the heating space which lie at the second end of the heating space.

7. A method as claimed in claim 5, wherein the heating space is elongated and is disposed vertically and the tubes are disposed vertically with the first end of the heating space and the first ends of the tubes within the second portion of the heating space disposed at the upper end thereof, and with the second end of the heating space disposed at the bottom thereof, and wherein the baffle is disposed substantially closer to the zone of removal of the vapor and non-condensable gases than to the zone of introduction of the heating fluid into the heating space, whereby the first portion of the heating space markedly exceeds the second portion thereof in volume.

8. A method as claimed in claim 7, wherein the separate liquid is introduced in relatively cool condition into the upper ends of the tubes within the second portion of

the heating space, whereby such separate liquid flows downwardly countercurrent to the residual vapors and gases from the first fluid rising in the second portion of the heating space while being heated thereby, and comprising collecting in isolated condition the separate liquid as it is discharged from the lower ends of the tubes within the second portion of the heating space.

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