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DRAWINGS ATTACHED

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(54) MULTIPLE EFFECT EVAPORATORS

(71) We, AEROJET-GENERAL CORPORATION, of 9100 East Flair Drive, El Monte, California, United States of America, a Corporation organized and existing under the Laws of the State of Ohio, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to distillation apparatus, and particularly to multiple effect distillation evaporators wherein the liquor concentrate evaporated in one effect is fed to a subsequent effect in series.

Multiple effect evaporators are characterized by the use of several evaporator effects serially arranged so that the feed liquor is operated on by each evaporator effect sequentially. Ordinarily, each evaporator effect utilizes a falling film evaporator wherein the liquor forms a thin film on a heat transfer wall and flows by means of gravity down one side thereof. Hot vapor is applied to the opposite side of the heat transfer wall so that condensation of the vapor occurs on the one side and evaporation of the liquor occurs on the other. The hot vapor condensed on one surface of the wall transfers heat to the thin film of liquor on the opposite side thereof to thereby vaporize some of the liquor. The enriched liquor (concentrate) is then fed to the next subsequent effect, where the vapor evolved from the liquor in the first evaporator effect heats the liquor.

Prior multiple effect evaporation systems have utilized individual evaporators in separate tanks interconnected by a complex array of external piping carrying the various liquids and vapors from chamber to chamber. Insulation, structural support, and piping requirements have rendered such multiple effect systems costly and relatively inefficient to operate.

It is an object of the present invention to provide a multiple effect evaporator which more effectively distills liquor than previous evaporators.

Another object of the present invention

is to provide a multiple effect evaporator that makes more effective use of space.

Another object of the present invention is to provide a tortuous flow path for the vapor which is segregated from the liquor thereby aiding in the removal of brine droplets from vapor.

Another object of the present invention is to provide evaporator apparatus which effectively removes non-condensable gas from the vapor to maximize the heat transfer capabilities of the heat transfer surfaces.

In accordance with the present invention there is proposed a multiple effect evaporator having a number of effects with each effect a bundle of vertical heat exchange tubes having a condensing side and an evaporating side to form a concentrate and a hot vapor, which vapor is condensed on the condensing side of the next lower pressure effect, thus providing a condensate, and having provision for transferring concentrate from a prior effect to the vertical tubes of the next adjacent effect with respect to liquor flow and having means for removing condensate from the condensing side of each effect and means for withdrawing uncondensed vapor from the condensing side of each effect. This evaporator is characterized in that it has a horizontally-disposed elongated shell closed at its opposite ends with a plurality of effects being contiguously juxtapositioned and transversely oriented in the elongated shell with a bundle of tubes vertically disposed in the condensing side of each effect, and a baffle arrangement for directing vapor flow across the several bundles substantially perpendicular to the longitudinal axis of the shell and in opposite directions in adjacent effects.

Preferably the flow path of the vapor across the respective tube bundles decreases in horizontal section in the direction of vapor flow across them, and the breadth of each of the several bundles converges in horizontal section in the direction of vapor flow across them, said convergence of successive bundles occurring in opposite directions in adjacent effects.

The multiple effect evaporator in accord-

ance with the present invention is particularly useful in connection with the evaporator system described in the copending Application 21480/71 (Serial No. 1,319,554).

The invention will be more fully understood from the following detailed description and from the accompanying drawings, in which:

Fig. 1 is a plan view, partly in horizontal section, of a multiple effect evaporator in accordance with the presently preferred embodiment of the present invention;

Fig. 2 is a vertical transverse cross-section view of the evaporator taken at line 2—2 in Fig. 1, and

Fig. 3 is a vertical transverse cross-section view of the evaporator taken at line 3—3 in Fig. 1.

The apparatus in accordance with the presently preferred embodiment of the present invention comprises a housing 10 having a substantially cylindrical portion 11 and an elongated rectangular portion 12 surmounting cylindrical portion 11. Housing 10 contains a plurality of evaporator effects 13, 14, 15, 16, 17, 18, 19, 20, each having a bundle of evaporator tubes illustrated at 21, 22, 23, 24 and 25 for evaporator effects 13 through 17, respectively. Each of the bundles comprises a plurality of evaporator tubes such as those described in British Patent Specification 1,290,050. Each tube bundle is preferably trapezoidal in cross-section, but it is to be understood that the tube bundles may be of any desirable shape. The tubes are disposed in a vertical position normal to the axis of the cylindrical housing.

Steam is introduced into the system through conduit 26 so that steam enters chamber 27 of first evaporator effect 13. The steam passes over the upper edge of wall 28 (which defines the longer base of the trapezoidal configuration) to condense on the outside surface of the tubes in bundle 21 and heat the same. As readily seen in Fig. 2, the wall 28 extends to the bottom inside surface of the housing 10 and, thus, provides a liquid barrier between the adjacent effects. Liquor to be evaporated is introduced into the region or chest 29 above the tubes in the bundle by means of conduit 30. The brine or saline water is introduced through conduit 30 and is distributed into the tubes to flow in thin films down the interior wall surface of the tubes of bundle 21 to be heated by the steam condensing on the outside of the tubes of bundle 21 so that a portion of the liquid brine in the tubes is evaporated. Any hot vapor and non-condensable matter which are not condensed on the outer walls of the tubes of bundle 21 passes through suitable apertures in wall 31 (which forms the

shorter base of the trapezoidal configuration) and is discharged through conduit 32. As illustrated particularly in Figs. 2 and 3, suitable manifolds 33 may be provided for directing the remaining steam through conduit 32. Condensed steam (condensate) which condenses on the outer surface of the tubes of the tube bundles is collected and discharged through conduit 34.

As the thin film of brine or liquor flows down the interior surface of the tubes of the respective tube bundles, it is heated by the condensing steam and some of the liquor is evaporated. The vapors produced from the liquor flow out through the lower end of the tubes (which are sealed in apertures in barrier-tube sheet 35 of the housing) and into the lower region of chamber 36 of the next effect (chamber 40 in Fig. 2, chamber 41 in Fig. 3). Likewise, the concentrated brine (concentrate) is collected in the lower region of the chamber 36 and is removed through conduit 137. As more readily seen in Figs. 2 and 3, the lower region of each chamber 36, 37, 38, 39, 40, 41, and 42 is separated by a horizontally-disposed elongated liquid-vapor filter 50 from the upper region of the respective chamber. The vapors collected in the upper region of chamber 36 are directed over the top of wall 28 of the next effect 14. Thus, the heating fluid for condensing on the outside surfaces of the tubes of each successive evaporator effect comprises the vapor developed in the previous effect. The brine carried through conduit 37 of each effect may be pumped back through a suitable pump 38 into conduit 30 of the next effect for further evaporation in the next effect.

With reference to Figs. 2 and 3, the operation of the apparatus in accordance with the present invention is more fully explained. Figs. 2 and 3 are section views of two sequentially arranged effects 17 and 18 which share a common chamber 40 located between the outlet of tubes 25 of effect 17 and the inlet to the tube bundle 25a of effect 18. Brine from effect 16 (in chamber 39) is taken out through conduit 137¹ in chamber 39 and is pumped into inlet conduit 30 associated with effect 17 via pump 38. The brine flows through the tubes of bundle 25 of effect 17 and is heated by steam from chamber 39 of previous effect 16. Some of the heated brine evaporates, with the vapor passing into the lower region of chamber 40 (Fig. 2), and the concentrate also collects in the lower region of chamber 40 (Fig. 2). The brine collected in the lower region of chamber 40 is taken out via conduit 137 (Fig. 3) and pumped via pump 38a to conduit 30a of next effect 18. The vapor present in lower region of chamber 40 passes through entrainment separa-

tor or filter 50 (see both Figs. 2 and 3) into the upper region of chamber 40 and from there passes over wall 28a (Fig. 3) to heat the brine flowing through the tubes in bundle 25a of effect 18. Uncondensed vapor is discharged through conduit 32 from bundle 25 in effect 17 (Fig. 2), carrying with it non-condensable gas. Similarly, uncondensed vapor is removed from effect 18 via conduit 32a. The vapor may, for example, be utilized in the preheating of the feed liquor or brine as described in the aforementioned Application 21480/71 (Serial No. 1,319,554). Condensed vapor (condensate) of effect 17 of Fig. 2 is taken out via conduit 34 and may, for example, be utilized in preheaters as described in said Application 21480/71. As the steam passes through the tube bundle of effect 18, it condenses, the condensate is removed through conduit 34 in Fig. 3 and uncondensed vapor is carried out through conduit 32a, as heretofore described.

Remembering that the lower region of each of the chambers 36, 37, 38, 39, 40, 41 and 42 occupies the area beneath the trapezoidal-shaped tube bundle as well as the area beneath the rectangular shaped demister filter 50, it will be appreciated that in horizontal section the lower region of each of the respective chambers has a rough L-shaped configuration. The liquid passage between the legs of the L-shaped lower region is directly beneath the shorter side of the trapezoidal-shaped tube bundle and in the gap between adjacent and aligned walls 28 of alternate effects. The upper region of the respective chambers is above the demister filter 50 and in horizontal section is rectangular in shape and in transverse cross-section view is seen to have an arcuate-shaped volume.

It is preferred that when the brine enters chamber 29, 29a of each subsequent effect, that the pressure in such chamber 29, 29a be lower than the pressure of the incoming brine from the lower portion of the previous effect. Thus, as the brine enters each chamber 29, it is flashed or spontaneously evaporated so that some of the brine is cooled to the saturation temperature associated with the pressure in the region 29. If desired, a restriction (not shown) may be disposed at the entrance of each tube in bundle 25 so that de-pressurization, flashing and cooling take place as the brine enters the tube. The cooled brine flows in a thin film down the interior wall surface of the tube and a temperature differential is established between the cooled brine within the tubes of the bundle and the vapor condensing on the outer surface of the tubes. Hence, the heat transfer effect is maintained and

The heated brine taken via conduit 137 and the heated condensate taken via conduit

34, and the steam taken via conduit 32 may be circulated through a preheater, such as described in the copending Application 20150/71 (Serial No. 1,319,552). The preheater described in the said Application 20150/71 (Serial No. 1,319,552) utilizes the flashing principle wherein the heated liquid is flashed or spontaneously evaporated at a lower pressure in subsequent chambers to obtain partial vaporization of the liquid. The vapors then transfer heat to feed liquor thereby raising the temperature of the feed liquor prior to introduction into the first effect of the multiple effect evaporator. Further discussion of the operation of the overall system may be found in the aforementioned copending Application 21480/71 (Serial No. 1,319,554).

The present invention provides effective use of the space within the ellipsoidal or cylindrical housing, which results in a lesser overall length requirement for the containment of tube bundles, entrainment separators, pressure retaining bulkheads, and vapor channelization than heretofore required in the prior art. The overall length of the shell or housing is effectively shortened (see Fig. 1) by bunching the several tube bundles of the respective effects in a line along a central longitudinal portion of the shell and thereby forming a substantially continuous bank of tubes which tube bundle bank is interrupted at spaced intervals by transversely located baffles, which baffles provide walls between the respective tube bundles of adjacent effects. Heretofore, the tube bundles have been serially arranged in the direction of the axis of the extended housing, thereby requiring that the vessel length be sufficient for vapor channelization and entrainment separation. Hence, the space on each side of the tube bundle in housings of the prior art was not effectively utilized, and containment was both massive and costly. By directing the vapor in the direction transverse or normal to the axis of the multiple effect housing, the present invention provides increased efficiency of containment.

The tube bundles are so disposed and arranged that the vapor flow area continuously decreases along the direction of vapor flow. Thus, as vapor condenses on the tubes of the tube bundle, the mass continuously decreases (due to condensation of the vapor), and the decreasing area of the vapor flow offsets the reduction of mass of the vapor so that the velocity of the vapor flow is high in all portions of the tube bundle. This feature is of particular value in that it assures a higher velocity of vapor than would be expected if the area did not decrease in the direction of flow. Hence, the flow velocity across the tube bundle is maintained substantially constant

even though the total flow decreases due to the condensation. The high flow velocity in the bundle assures flow turbulence at the heat transfer surface of the tube bundles so that non-condensable materials present in the vapor flow may be removed. The reduction of area of the vapor flow is preferably achieved through the use of trapezoidally shaped tube bundles as illustrated in the drawings, although other configurations may be used. The trapezoidal shape is preferred because it permits efficient use of tube sheet material as several trapezoids may be cut from a single rectangular strip of tube sheet material.

The vapor flow between evaporator effects is directed from the exit of the tubes (below barrier 35 of the housing) to the entrance of the next tube bundle above wall 28 of the subsequent effect through several turns in the path. Minute droplets of brine in the vapor tend to impinge and condense on wall 11 of housing 10 as well as in entrainment separator 50, thereby assuring removal of brine from the vapor. The curvilinear shape to wall 11 of housing 10, which aids in directing the flow, minimizes vapor flow resistance.

The vertical tube evaporator described herein operates as a multiple effect evaporator in that hot water is introduced into the first effect and a heat rejection apparatus (not shown) is associated with the vapor outlet of the last effect. The heat rejection device (not shown) aids in the continuous removal of noncondensable material and also establishes a temperature and pressure profile for maintaining the operation of all the effects and of the feed heating stages.

This invention is not to be limited by the embodiment shown in the drawings and described in the description, which is given by way of example and not of limitation.

WHAT WE CLAIM IS:—

1. A multiple effect evaporator having a number of effects with each effect comprising a bundle of vertical heat exchange tubes having a condensing side and an evaporating side to form a concentrate and a hot vapor which vapor is condensed on the condensing side of the next lower pressure effect, thus providing a condensate, and having provision for transferring concentrate from a prior effect to the vertical tubes of next adjacent effect with respect to liquor flow and having means for removing condensate from the condensing side of each effect and means for withdrawing uncondensed vapor from the condensing side of

each effect, characterised by a horizontally-disposed elongated shell closed at its opposite ends with a plurality of effects being contiguously juxtapositioned and transversely oriented in the elongated shell with a bundle of tubes vertically disposed in the condensing side of each effect, and a baffle arrangement for directing vapor flow across the several bundles substantially perpendicular to the longitudinal axis of the shell and in opposite directions in adjacent effects.

2. A multiple effect evaporator in accordance with claim 1 wherein the flow path of the vapor across the respective tube bundles decreases in horizontal section in the direction of vapor flow across them.

3. A multiple effect evaporator in accordance with claim 2 wherein the breadth of each of the several bundles converges in horizontal section in the direction of vapor flow across them, said convergence of successive bundles occurring in opposite directions in adjacent effects.

4. A multiple effect evaporator in accordance with claim 3 wherein the several tube bundles are each trapezoidal in horizontal cross section with the smaller bases of the trapezoids of adjacent effects facing in opposite directions.

5. A multiple effect evaporator in accordance with claim 1 wherein the elongated shell is cylindrical.

6. A multiple effect evaporator in accordance with claim 5 wherein the flow path of the vapor across the respective tube bundles decreases in horizontal section in the direction of vapor flow across them.

7. A multiple effect evaporator in accordance with claim 6 wherein the breadth of each of the several bundles converges in horizontal section in the direction of vapor flow across them, said convergence of successive bundles occurring in opposite directions in adjacent effects.

8. A multiple effect evaporator in accordance with claim 1 wherein the bundles of vertically-disposed tubes of the several effects are aligned along a central longitudinal portion of the shell and together form a substantially continuous bank of tubes.

9. A multiple effect evaporator substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

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The vertical tube evaporator described herein operates as a multiple effect evaporator in that hot water is introduced into the first effect and a heat rejection apparatus (not shown) is associated with the vapor outlet of the last effect. The heat rejection device (not shown) aids in the continuous removal of noncondensable material and also establishes a temperature and pressure profile for maintaining the operation of all the effects and of the feed heating stages.

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1. A multiple effect evaporator having a number of effects with each effect comprising a bundle of vertical heat exchange tubes having a condensing side and an evaporating side to form a concentrate and a hot vapor which vapor is condensed on the condensing side of the next lower pressure effect, thus providing a condensate, and having provision for transferring concentrate from a prior effect to the vertical tubes of next adjacent effect with respect to liquor flow and having means for removing condensate from the condensing side of each effect and means for withdrawing undensated vapor from the condensing side of

each effect, characterised by a horizontally-disposed elongated shell closed at its opposite ends with a plurality of effects being contiguously juxtapositioned and transversely oriented in the elongated shell with a bundle of tubes vertically disposed in the condensing side of each effect, and a baffle arrangement for directing vapor flow across the several bundles substantially perpendicular to the longitudinal axis of the shell and in opposite directions in adjacent effects.

2. A multiple effect evaporator in accordance with claim 1 wherein the flow path of the vapor across the respective tube bundles decreases in horizontal section in the direction of vapor flow across them.

3. A multiple effect evaporator in accordance with claim 2 wherein the breadth of each of the several bundles converges in horizontal section in the direction of vapor flow across them, said convergence of successive bundles occurring in opposite directions in adjacent effects.

4. A multiple effect evaporator in accordance with claim 3 wherein the several tube bundles are each trapezoidal in horizontal cross section with the smaller bases of the trapezoids of adjacent effects facing in opposite directions.

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8. A multiple effect evaporator in accordance with claim 1 wherein the bundles of vertically-disposed tubes of the several effects are aligned along a central longitudinal portion of the shell and together form a substantially continuous bank of tubes.

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