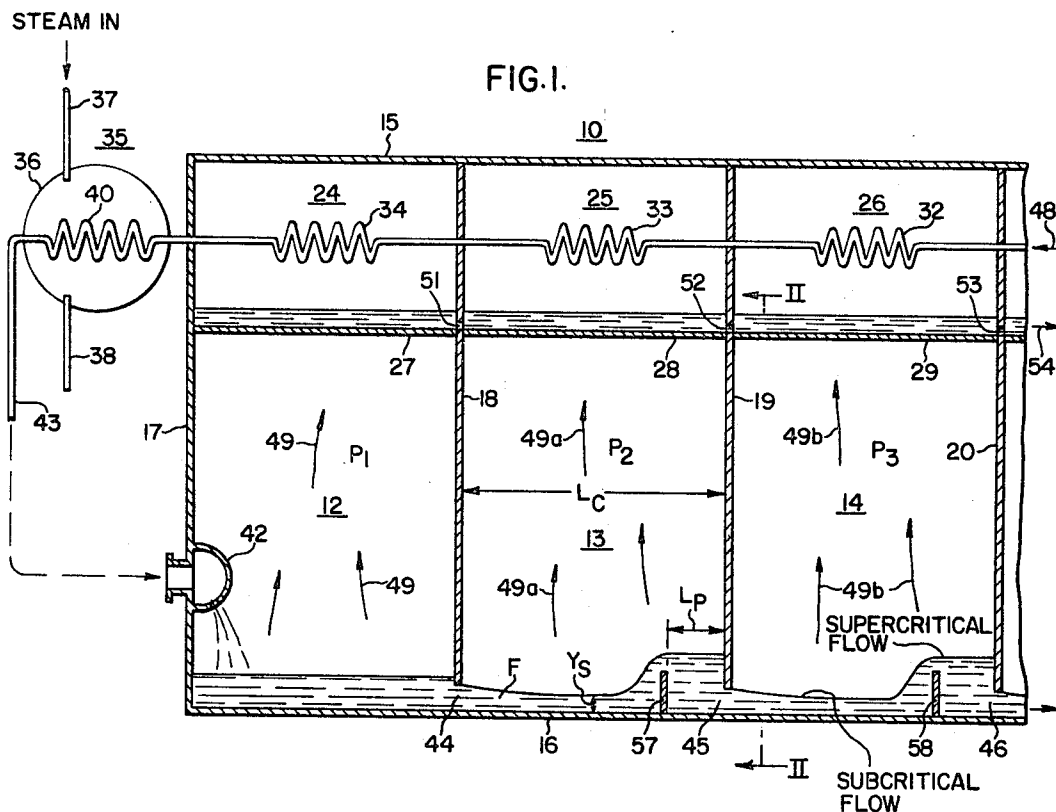
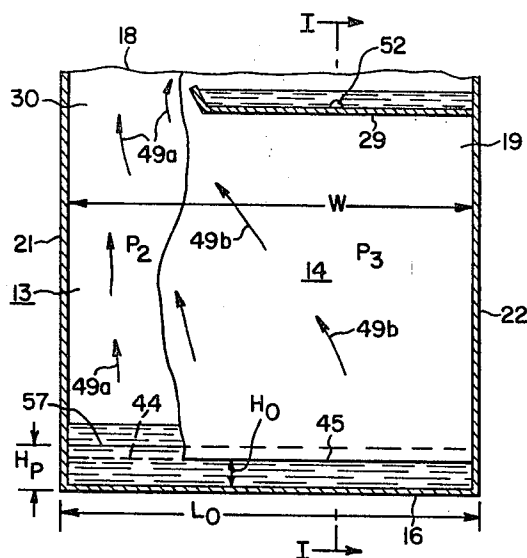


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MULTI-STAGE FLASH EVAPORATOR WITH MEANS
TO INDUCE HYDRAULIC JUMP
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WITNESSES

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MULTI-STAGE FLASH EVAPORATOR WITH MEANS TO INDUCE HYDRAULIC JUMP

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ABSTRACT OF THE DISCLOSURE

This invention relates to evaporators, more particularly to multi-stage flash evaporators, and has for an object to provide an improved arrangement permitting operation of the flash evaporation chambers with optional minimal depth of the distilland, yet substantial decrease in the possibility of vapor "blow-by" between adjacent chambers. The above is attained by providing means including orifice means and upstanding means positioned, and so arranged and proportional with respect to the length of the chamber that the phenomenon known as "hydraulic jump" is induced in the distilland stream, which phenomenon is effective to raise the height of the flowing stream in that portion of the chamber adjacent the orifice from below "critical depth" to above "critical depth." Critical depth as referred to in the specification and claims is a specific hydraulic term defining a depth at which the specific energy of a flowing liquid is at a minimum value.

Multi-stage flash evaporators are usually provided with a plurality of flash chambers disposed in liquid communication with each other by interconnecting orifices provided in the bottom portions of the partitions dividing the chambers. The liquid to be evaporated (distilland) is heated under pressure and then progressively directed from chamber to chamber through the orifices for partial evaporation in each chamber. To effect the staged evaporation, the chambers are maintained at progressively lower pressures (considered in the direction of liquid flow) and the vapor generated therein is condensed and withdrawn from the apparatus.

In flash evaporators of the above type, the orifices are preferably in the form of horizontally elongated slots and so proportioned that the distilland flow path closely approximates horizontal open-channel flow under a sluice gate. In the design of such evaporators, several factors must be considered, first limitation of the height of the apparatus to reasonable dimensions, and second attainment of good thermal equilibrium in the apparatus. Both of these factors lead directly to a flow path for the distilland through the chambers that approaches the minimum depth. However, when minimum depth of flow is designed for the possibility of vapor "blow-by" through the orifice from a higher pressure stage to its adjacent lower pressure stage is increased, since the distilland flow level may fluctuate sufficiently to uncover a portion of the orifice. As well known, the vapor "blow-by" phenomenon leads to a degradation of available energy in the distilland with a resulting reduction in thermal efficiency of operation.

A primary object of this invention is to provide a multi-stage flash evaporator having improved thermal efficiency and equilibrium characteristics yet more economical to manufacture.

A further object of this invention is to provide a multi-stage flash evaporator arranged to provide a distilland flow path through the flash chambers that is maintained at substantially optimal minimum depth with substantial decrease in the possibility of vapor "blow-by" between adjacent chambers.

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A still more specific object of the invention is to provide a flash evaporator of the above type in which the distilland flow stream in the evaporation chambers is initially at a depth less than critical depth and means is provided to induce a subsequent hydraulic jump in the flow stream.

Briefly, in accordance with the invention there is provided a multi-stage flash evaporator having a plurality of flash chambers formed by top and bottom wall structure and horizontally spaced upwardly extending partitions and outer wall structure. The partitions are provided with horizontally elongated orifices or slots arranged to transfer the distilland from chamber to chamber at a level or depth below the critical depth. Critical depth, as well known in fluid mechanics, is the depth at which the specific energy of a flowing liquid is at the minimum value.

An upstanding member disposed on the bottom wall structure and extending transversely of the direction of liquid flow is disposed intermediate the upstream and downstream orifices of the chambers. The vertical extent of this member (which may be a plate) is that required to increase the depth of the liquid flow from below critical to above critical and is effective to induce the phenomenon known as "hydraulic jump." During this transition, the liquid flow is converted from low depth and high velocity (rapid flow) to greater depth and lower velocity (tranquil flow). Hence, the downstream orifice is maintained in a submerged condition and the possibility of vapor "blow-by" is substantially eliminated or at least considerably reduced.

The above and the objects are effected by the invention as will be apparent from the following description and claims taken in connection with the accompanying drawings, forming a part of this application, in which:

FIGURE 1 is a diagrammatic vertical sectional view taken on line I—I of FIG. 2 and illustrating a portion of a multi-stage flash evaporator having the invention incorporated therein; and

FIG. 2 is a transverse sectional view taken on line II—II of FIG. 1.

Referring to the drawing in detail, FIG. 1 shows a portion of a multi-stage flash evaporator 10 having a plurality of flash evaporation chambers 12, 13 and 14 disposed in side-by-side relation with each other and defined by wall structure including top and bottom walls 15, 16, side wall 17, internal partitions 18, 19 and 20, and front and rear walls 21, 22 (see FIG. 2). A greater number of flash chambers may be employed, if desired, as well known in the art.

In the upper portion of the wall structure, a plurality of vapor condensing chambers 24, 25 and 26 are provided by horizontally extending tray-like shelf structures 27, 28 and 29 terminating short of the front wall 21 and jointly therewith forming flow passages, such as flow passage 30, for directing vapor generated in the flash chambers upwardly into the associated condensing chambers.

Each of the condensing chambers 26, 25 and 24 is provided with respective heat exchange tube structures 32, 33 and 34 serially connected to each other and a suitable external heater 35, known as a top heater, is connected to the tube structure 34. The top heater, as illustrated, comprises a shell structure 36 having a heating fluid inlet 37 through which a hot fluid such as steam, may be directed, and a spent fluid outlet 38. The heater 35 is further provided with a heat exchange tube structure 40 connected at one end to the tube structure 34 and at its other end to a spray inlet 42 in the wall 17, by a conduit 43.

The vertically extending partitions 18, 19 and 20 are provided with orifices 44, 45 and 46, respectively, dis-

posed adjacent the bottom wall 16 and providing serial fluid flow communication between the flash chambers 12, 13 and 14, respectively.

As thus far described, the structure is substantially conventional and operates in the following manner. The distilland or pressurized incoming liquid to be evaporated, such as sea water for example, is directed, as indicated by the arrow 48, successively through the heat exchange tube structures 32, 33 and 34 to the top heater 35, where it is heated to its maximum or top temperature and then introduced into the first flash chamber 12, through the inlet 42. The flash chamber 12 is maintained at an ambient pressure value P_1 that is lower than that of the incoming sea water. Hence partial vaporization of the sea water occurs as it flows through the chamber 12 and the vapors thus generated flow upwardly, as indicated by the arrows 49, into the condensing chamber 24, wherein, in the resulting heat exchange with the relatively cool heat exchange tube structure 34, the vapor is condensed and falls onto the shelf 27 and the sea water flowing through the tube structure 34 is heated.

The unvaporized sea water flows through the orifice 44 into the adjacent flash chamber 13, where it is exposed to an ambient pressure P_2 that is lower than the pressure P_1 with resulting additional flash evaporation. In a similar manner, the remaining unvaporized sea water flows through the orifice 45 into the third and still lower pressure (P_3) flash chamber 14 where it undergoes additional partial evaporation and is then directed through the orifice 46 for subsequent flash evaporation in additional and still lower pressure flash chambers (not shown).

The vapors 49a and 49b generated in the chambers 13 and 14, in a manner similar to the vapors 49 in the first flash chamber 12, are condensed with concomitant heating of the incoming sea water in the heat exchange tube structures 33 and 34 and the condensate is collected in the shelves 28 and 29, respectively. For expediency, the condensate collected in the shelves 27, 28 and 29 is directed through suitable apertures 51, 52 and 53 and withdrawn from the evaporator, as indicated by the arrow 54, as pure water for useful purposes.

In accordance with the invention the slotted orifices 44, 45 and 46 are so proportioned that the distilland flow stream is initially admitted into the associated evaporation chambers 12, 13 and 14 at a depth less than the critical depth of the stream and at a greater than critical velocity. Also, since the properties of saturated steam and water are such that the pressure drop between the flash chambers is less than the prevailing chamber pressures P_1 , P_2 , and P_3 , the cross-sectional area of the orifices 44, 45 and 46 vary in size although they are all substantially the same length and extend from the wall 21 to the wall 22. For example, the relation of the orifices is such that the orifice 44 has an area and hence a height smaller than that of the orifice 45 and the orifice 45 has an area and hence a height that is smaller than that of the orifice 46. Under such conditions, the flow stream immediately upstream of the associated orifice, for example, the orifices 45 and 46, is barely sufficient to cover the orifice, so that an unstable condition exists wherein the orifices may or may not perform as sluice gates or submerged orifices. When they are not submerged, vapor from the upstream chamber, for example the chamber 13, is free to "blow-by" or leak past the orifice into the immediately downstream chamber 14 because of the lower chamber pressure P_2 prevailing therein. This effect is highly undesirable, since the available energy in the distilland is degraded and the thermal efficiency of the evaporator is reduced. However, this effect is not significant in the first stage 12, since the distilland admitted thereto by the spray inlet 42 is at the highest pressure level existing in the evaporator and is maintained at a safe level 56 adequate to maintain the orifice 44 in properly submerged condition.

To overcome the above instability and thermal ineffi-

ciency due to "blow-by," the chambers 13 and 14 are provided with plate members 57 and 58 extending upwardly from the bottom wall 16 and extending across the entire width of the chambers, i.e. from the front wall 21 to the rear wall 22. The plates are vertically disposed in FIG. 1, however, they may be inclined in either upstream or downstream direction. The vertical height of the plate members 57 and 58 is selected to induce the phenomenon known as "hydraulic jump," i.e. to convert the subcritical to above critical flow, thereby to increase the depth of flow downstream of the plate members to a height above the critical depth and converting the high velocity subcritical flow to low velocity or tranquil flow.

Preferably, the height of the plate members is substantially equal to the critical depth of the distilland stream and the plate members are positioned upstream of their associated orifices a distance less than the length of the so induced hydraulic jump, thereby insuring submerged operation of the orifices and substantially eliminating the possibility of "blow-by" of vapor.

The following specific example employs figures and data attained with the invention under typical operating conditions, considering chamber 13:

$P_1 = .96$ p.s.i.a. at a saturation temperature $T_1 = 100.3^\circ$ F.
 $P_2 = .70$ p.s.i.a. at a saturation temperature $T_2 = 90.0^\circ$ F.
 $L_c = 15$ ft. (length of the chamber 13)
 $w = 3.25$ ft. (width of the chamber 13)
 $F = 3.25$ ft. (length of the orifices 44 and 45)

By employing suitable known hydraulic equations, the following data is obtained:

Critical flow depth Y_c in the chamber 13 = 4.8 in.
 The height H_0 of the orifice 44 = 3.27 in.
 The subcritical flow depth $Y_s = 1.97$ in.
 The theoretical length of the hydraulic jump = 4 1/4 ft.

Since the height H_0 of the plate 57 is determined by Y_s and Y_c , in this example, H_0 is greater than Y_s and no greater than Y_c and may range from about 2 1/8 to 4.8 ins.

Also, since the length of the hydraulic jump is equal to 4 1/4 ft. it will now be seen that the plate member 57 may be placed a distance L_p equal to but preferably less than 4 1/4 ft. from the partition 19, but never at a greater distance, in this example.

Data corresponding to the above may also be obtained for the flash evaporation chamber 14 and subsequent downstream chambers (not shown) to insure the occurrence of the required hydraulic jump in these chambers.

Although only one embodiment of the invention has been shown, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various other changes and modifications without departing from the spirit thereof.

We claim as our invention:

1. A multi-stage flash evaporator for evaporating a distilland flow stream therein having
 - a bottom wall structure and spaced upwardly extending first and second partitions at least partly defining first, second and third flash evaporation chambers,
 - means defining a first horizontally elongated orifice adjacent the bottom of said first partition,
 - means defining a second horizontally elongated orifice adjacent the bottom of said second partition,
 - said first orifice being effective to permit flow of unevaporated liquid distilland from said first chamber to said second chamber for partial evaporation and to attain a depth less than hydraulic critical depth in said second chamber,
 - said second orifice being effective to permit unevaporated liquid to flow from said second chamber to said third chamber for further evaporation, and
 - a member extending upwardly from the bottom wall structure of said second chamber and disposed intermediate said first and second orifices,

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said member extending substantially transversely to said distilland flow and having a vertical height that is substantially equal to the hydraulic critical depth of the liquid flow in said second chamber and effective to induce a hydraulic jump in said flow that is of a height greater than said hydraulic critical depth, said first orifice being so proportioned that the distilland flow stream is initially admitted into the second evaporator chamber at a depth not greater than the critical depth of the stream with a velocity not less than the critical velocity.

2. The structure recited in claim 1 wherein the member is a plate extending transversely to the direction of flow of the liquid and effective to modify all of the flow,

the second orifice is of greater area than the first orifice, and

the plate induced hydraulic jump attains a height greater than the height of the orifice and is effective to prevent blow-by of vapor from the second chamber to the third chamber through the second orifice.

3. The structure recited in claim 1 wherein the second orifice is of considerably less height than the depth of the hydraulic jump, and

the hydraulic jump inducing member is spaced upstream from the second orifice a distance less than the length of the hydraulic jump, thereby insuring that the second orifice is maintained in a submerged state during operation.

4. A multi-stage flash evaporator for evaporating a distilland flow stream therein having

a bottom wall structure, front and rear walls and spaced upwardly extending first and second partitions extending from said front to said rear wall and at least partly defining first, second and third evaporation chambers,

means defining a first orifice of substantially rectangular shape extending the full width of said first partition,

means defining a second orifice of substantially rectangular shape extending the full width of said second partition,

said first orifice being effective to permit flow of unevaporated liquid distilland from said first chamber to said second chamber for partial evaporation at a hydraulic subcritical depth in said second chamber, said second orifice being effective to permit unevaporated liquid to flow from said second chamber to said third chamber for further evaporation at a depth less than hydraulic critical depth in said third chamber, and

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a plate member extending upwardly from the bottom wall structure intermediate said first and second orifices and extending to said front and rear walls,

said plate member having a vertical height that is at least greater than said hydraulic subcritical depth and at most equal to the hydraulic critical depth of the liquid flow in said second chamber and effective to induce a hydraulic jump in said hydraulic subcritical flow that is of a height greater than said hydraulic critical depth, said first and second orifices being so proportioned that the distilland flow stream is initially admitted into the associated evaporator chambers at a depth less than the critical depth of the stream with a velocity greater than the critical velocity.

5. The structure recited in claim 4 wherein the second orifice is of less height than the hydraulic critical depth of the flow in the second chamber, and the plate induced hydraulic jump attains a height greater than the height of the second orifice and is effective to prevent blow-by of vapor from the second chamber to the third chamber through the second orifice.

6. The structure recited in claim 4 wherein the plate induced hydraulic jump is of greater depth than the height of the second orifice, and the plate is spaced upstream from the second orifice a distance less than the length of the hydraulic jump, thereby insuring that the second orifice is maintained in a submerged state during operation.

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