Fig. 4.  

Fig. 5.

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FALLING FILM TYPE HEAT EXCHANGER

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Fig. 6.

Fig. 7.

Fig. 8.

COOLANT 166
VAPOR AND NON-CONDENSABLES 151

COOLANT 160

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ABSTRACT OF THE DISCLOSURE

A plate type heat exchanger of the falling film type, such heat exchanger having an improved liquid distribution device which insures the creation of substantially uniform falling films on the entire heating surfaces of the heat exchanger plates. Liquid to be heated and/or evaporated is introduced to the heat exchanger through openings or nozzles disposed above the upper edges of the heat exchanger plates. A baffle or spray intercepting means is interposed between the openings or nozzles, such baffle preventing any substantial amount of the liquid from directly impinging upon any of the heating surfaces of the plates.

This invention relates to heat exchangers of the same general type as those disclosed and claimed in application Ser. No. 303,824, filed Aug. 22, 1963, by the present applicant; Ser. No. 310,527, filed Sept. 23, 1963, by Axel E. Rosenblad; and Ser. No. 350,454, filed Mar. 9, 1964, by Elief M. Rosenblad, all of such prior applications having been abandoned. All of such prior applications disclose heat exchangers of the falling film type wherein in liquid is distributed to the heating surfaces of the plates by means including spray nozzles or the like disposed within liquid medium receiving channels adjacent the top thereof. In all of such prior devices, if the films formed upon the heating surfaces are to be substantially uniformly distributed. Therefore, the spray or jet producing means must be located close to the heating surfaces. This leads to difficulty in maintaining the spray or jet producing openings clean and working at their maximum efficiency, particularly when the liquid being heated and/or evaporated carries a substantial amount of solid matter in particle form. The requirement of a small distance between the jet-forming means or nozzle and the heating surfaces entails frequent maintenance and cleaning of the apparatus if the films on the plates are to remain substantially uniform and to cover the full extents of the heating surfaces.

In accordance with the present invention, liquid to be heated and/or evaporated is introduced into the heat exchanger through one or more openings or nozzles disposed above the upper edges of the heat exchanger plates. The openings or nozzles are preferably disposed so as to be substantially uniformly distributed over a given zone or area of the upper ends of the plates. Interposed between such openings or nozzles and the upper entrance ends of the medium receiving channels of the heat exchanger is a novel baffle or spray intercepting means of such construction as to prevent any substantial amount of the liquid falling from the openings or nozzles from directly impinging upon any of the heating surfaces of the plates, including the top portions thereof. Liquid intercepted by the upper portion of such baffle means falls downwardly therealong under the action of gravity and preferably falls upon a still further portion of the baffle means which leads it in the form of a falling film onto the upper edges of the heating surfaces of the plates over the entire lengths thereof.

The baffle means in accordance with the invention is so made that it presents no narrow apertures or passages therethrough in which solid particles entrained in the liquid being distributed may catch. Consequently, heat exchangers provided with liquid distributing means in accordance with the invention may be run for long periods without the necessity of being cleaned.

In the preferred embodiments of the invention disclosed herein, the baffle means includes elongated upwardly convex hood or baffle members, either solid or hollow, which are disposed along the upper edges of the heating channels of the heat exchanger. The baffle means includes at least one further set of generally similar upwardly convex hood or baffle members which are disposed above and between the first set of hood members so as to overlap the first hood or baffle members when viewed from the points of view of the respective liquid discharging openings or nozzles employed to supply liquid to a particular area of the heat exchanger plates. As above set forth, it is a prime requisite of the present invention that the baffle means functions to prevent direct impingement of any substantial amount of liquid from the liquid discharging openings or nozzles onto the heating surfaces of the heat exchanger.

It is accordingly among the objects of the present invention to provide a novel liquid distributing system for a falling film type heat exchanger.

A further object of the invention resides in the provision of a novel liquid distributing system of the type described which insures the formation of films of liquid of substantially uniform thickness which cover the entire heating areas of the plates of the heat exchanger. Yet another object of the invention lies in the provision of a liquid distributing device for heat exchangers of the falling film type wherein the liquid conveying passages of the distributing device are of substantial width and breadth whereby the device may pass liquid containing solid particles without becoming plugged thereby.

A still further object of the invention, in preferred embodiments thereof, lies in the provision of a liquid distributing device, incorporating one or more liquid discharging openings or nozzles spaced above the plates of the heat exchanger and in combination therewith a novel baffle device which prevents direct impingement of any substantial amount of the liquid from the openings or nozzles onto the heating surfaces of the heat exchanger while forming the intercepted liquid into films of substantially uniform thickness and forwarding them to the upper edges of the plates over substantially the entire lengths thereof.

The above and further objects and novel features of the invention will more fully appear from the following description when read in connection with 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 view in vertical section through a first illustrative embodiment of plate type heat exchanger provided with a fluid distributing device in accordance with the invention, the section being taken transverse to the broad surfaces of the plates of the heat exchanger;

FIG. 2 is a view in vertical section through the heat exchanger of FIG. 1, the section being taken at right angles to the section of FIG. 1 and along the line 2—2 in FIG. 1 looking in the direction of the arrows;

FIG. 3 is a view in horizontal section through the heat exchanger shown in FIGS. 1 and 2, the section being taken along the line 3—3 of FIG. 1;

FIG. 4 is a fragmentary view in perspective of a portion of the liquid distributing device of the heat exchanger of FIGS. 1, 2, and 3;
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FIG. 5 is a fragmentary view in vertical section taken similarly to FIG. 1 of another embodiment of liquid distributing system in accordance with the invention, such liquid distributing system being readily removable from the plate section of the heat exchanger;

FIG. 6 is a fragmentary somewhat schematic view in vertical section through a still further embodiment of liquid distributing system for a falling film plate type heat exchanger, the section being taken transversely of the plates of the heat exchanger;

FIG. 7 is a fragmentary somewhat schematic view in vertical section through another embodiment of liquid distributing system for a falling film plate type heat exchanger which may be used, for example, as a condenser, the section being taken transversely of the broad extents of the plates of the heat exchanger; and

FIG. 8 is a fragmentary view in vertical section through the heat exchanger of FIG. 7, the section being at right angles to that of FIG. 7 and along line 8–8 of FIG. 7 in the direction of the arrows.

As is apparent from the above, there are shown herein four embodiments of heat exchangers in accordance with the invention: The embodiment of FIGS. 1–4, inclusive, which show a heat exchanger for a falling liquid distributing system permanently mounted therein; FIG. 5, which fragmentarily shows a heat exchanger similar to that of FIGS. 1–4, inclusive, but with a modified, readily demountable liquid distributing system therefor;

FIG. 6, which shows a heat exchanger of the falling film type incorporating a still further embodiment of liquid distributing system in accordance with the invention; and

FIGS. 7 and 8, which show a heat exchanger adapted for use, for example, as a condenser.

Turning now to the embodiment of heat exchanger shown in FIGS. 1–4, inclusive, such heat exchanger is generally designated by the reference character 10. The heat exchanger is generally in the form of a vertical column of rectangular horizontal section, the heat exchanger having an enclosure with a left-hand cover plate 11 (FIG. 1), and a right-hand cover plate 12, the vertical edges 14 and 15 of that cover extending outwardly to form flanges by means of which the cover plates, heat exchanger plates, and sealing and spacing bars between the edges of the plates are bolted together (FIG. 2). Vertically disposed within the enclosure in spaced parallel relationship therewith and parallel to the cover plates 11 and 12 are a plurality of heat exchanger plates 16. Alternate successive pairs of plates are closed at their ends, tops, and bottoms to form a plurality of channels 17 which receive the fluid heating medium for the exchanger. The other set of channels, designated 19, are interposed between successive heating channels 17. Channels 19 are closed at their ends but are open at their tops and bottoms to receive medium to be heated and/or evaporated by the heat exchanger. As shown, the parallel spacing of the plates 16 is substantially maintained despite pressure differentials in the channels 17 and 19 by means of conventional spacers or distance studs 18, which are secured to one of each pair of confronting plates 16.

Heating medium such as steam is supplied to the channels 17 by a pipe 20 connected to a manifold 21 which spans and is connected to each of the heating channels 17 at the top thereof, as shown. Condensate from such heating medium is exhausted from the channels 17 through a manifold 23 which spans and is connected to the channels 17 at the bottoms thereof. The manifold is connected to a discharge pipe 22 through which the condensate is led to a sump or the like. Disposed as an extension above the main portion of the enclosure about the plates 16 is a header 24 which forms a compartment above the heating plates into which the liquid medium to be heated and/or evaporated by the heat exchanger is introduced. Such liquid, after having traveled in the form of films along the heating surfaces of plates 16 and channels 19, falls into a vapor body or lower compartment 25 to form a pool of liquid 26 such as a concentrated liquor therein. If the liquor 26 carries a considerable amount of vapor by reason of evaporation effected by the heat exchanger, a baffle 27 is provided interiorly of the compartment 25 so as to separate vapors formed on the heating surfaces from the liquor and to discharge the vapors through a conduit 29 connected to the baffle.

In the illustrative embodiment the heat exchanger 10 is shown employed to concentrate waste sulphite pulp-cooking liquor from a pulp-making operation. The concentrate 25 so as to separate vapors formed on the heating surfaces with falling films. This is accomplished by having the liquor pass downwardly through a discharge pipe 30 into a pump 31 which forwards it under pressure through a pipe 32 to a further manifold pipe 39. Pipe 39 supplies the spray nozzles 41 and 42 of the liquid distributing device of FIGS. 1–4, to be described. The liquor supplied to such nozzles is mixed with fresh dilute liquor fed through a pipe 34 which is connected to a valve 35 as shown in FIG. 2.

Valve 35 is under the control of a conventional means 37 responsive to the level of concentrated liquor 26 in the vapor body. Device 37 with valve 35 causes the system to deliver a continuous flow of liquor to the evaporator, the determining level 37 determining greater concentration, termed the "product." The rate of flow of the product liquor is usually manually controlled by a valve (not shown) in the product line 28.

In the embodiment of FIGS. 1–4, inclusive, liquid to be heated and/or evaporated in the heat exchanger is introduced into the chamber 24 at the top thereof through a plurality of nozzles which create wide downwardly directed sprays. Three such nozzles are shown, the central nozzle being designated 41, and the two outer side nozzles being designated 42. Nozzles 41, 42 are disposed within a central extension 40 rising above the chamber closure 24. The nozzles are of such character and are so disposed that the sprays therefrom substantially uniformly cover the areas of the heat exchange plates above which they are disposed while slightly overlapping at the upper portion of the baffle members 50 to insure complete coverage of all of baffle means. The sprays from the nozzles 41, 42 are intercepted by a baffle means 49, 50, to be described, such baffle means being such as to spread the sprayed liquid thereover and to lead it onto the upper edges of the heating plates 16. The baffle means also includes first baffle members 44 which in the embodiment shown are generally in the form of inverted V's which are symmetrically disposed above the upper edges of the heating channels 17. Members 44 may be formed of thin plate metal pieces 45 slightly curved as shown and secured together as by being welded at 47 to form a central peak. In the embodiment shown, the lower edges of the plates 45 are welded at 46 to the upper edges of the plates 16, the lower edges of the plates 45 lying in alignment with the upper edges of plates 16 so that films of liquid formed upon plates 45 flow smoothly down from the upper edges of the plates 16. In the embodiment shown, the baffle members 44 secured to the plates 16 of channels 17 form the upper end closure therefor. If desired, the baffle members 44 and plates 16 may be formed integrally of a single plate bent to the shape shown.

Disposed above the baffle members 44 and staggered in symmetrical relation thereto is a second row of baffle members 49 of generally the same shape as members 44. At the ends of the row of baffles 49 there are disposed half baffles 49' secured to the end walls 11, 12 of the heat exchanger as shown in FIG. 1. A third row of baffle members generally designated 50 is disposed above baffle members 49 in laterally stag-
gered symmetrical relation thereto, the baffles 50 being shown as disposed vertically above the respective baffles 44. Baffles 44, 49, and 50 are of such size and shape and so disposed that liquid from any of the nozzles 41, 42 can not impinge directly upon the heating surfaces of plates 16. Thus the lower edges of baffles members 49 somewhat overlap the confronting surfaces of baffle means 44 in a horizontal direction, and the lower edges of baffle means 50 somewhat overlap the inner confronting surfaces of baffle means 49. Thus spray from the nozzle forms into films on the successive baffle means 50, 49, the films flowing downwardly to drop upon plates 45 of baffle means 44. By the time the films have reached the upper edges of plates 16 they are of substantially uniform thickness and extend throughout the entire horizontal length of each of such plates.

In the embodiment of FIGS. 1-4, inclusive, the baffle means 49, 49, 50 are permanently secured together, and the baffle means itself is permanently secured to the plates 16 of the heat exchanger. For this purpose there are provided two or more horizontally aligned spaced rows of supporting bars 51 which support the baffle means 49 from baffle means 44. Bars 51 are generally in the shape of inverted 'T's, each having a lower horizontal portion 52, the ends of which are welded at 54 to the confronting surfaces of the respective plates 45. Each bar 51 has a central upstanding portion 55, the upper end of which extends into the respective baffle means 49 which in this instance is formed of sheet metal plates 57 which are welded together at their upper edges at 58. Portions 55 of the supporting bar is welded interiorly of plates 47 at zones 56, as shown.

Baffle means 50 are similarly supported upon and secured to the intermediate baffle means 49. Thus there are employed a plurality of spaced rows of supporting bars 59 of generally inverted T-shape. Each of bars 59 has a lower horizontal portion 60 which is welded at its ends to plates 57 of baffle means 49. The upper ends of the central upright portion 62 of each bar 59 extends into the baffle means 50 and is secured to the plates 65 thereof at the zones 64.

The embodiment of heat exchanger schematically shown in FIG. 5 is generally similar to that of FIGS. 1-4, inclusive, with the exception that the baffle means is made readily removable from the plates of the heat exchanger and the lowermost baffle means do not also function as closures for the heating channels. Accordingly, parts shown in FIG. 5 which are similar to those in FIGS. 1-4, inclusive, are designated by the same reference characters with an added prime. The liquid distribution device in FIG. 5 is generally designated 67. The joint 69 between the lower edges of the plates 45' forming baffle means 44' is such that the means 67 is readily removable vertically from the assembly of plates 16'. Horizontal longitudinally extending bars 70 welded to the upper edges of the heat exchanger plates seal the heating channels 17', as above explained. Rising vertically from at least one bar 70 and preferably from a plurality of such bars are a plurality of pins 68 spaced longitudinally of the bar. Pins 68 are accurately received within holes in a horizontal plate 73 which is welded at its ends to the inner surfaces of plates 45'. With the construction of FIG. 5, the header of the heat exchanger corresponding to part 24 in FIGS. 1 and 2, may have an upper removable cover so that the distribution means 67 may be removed as a unit from the heat exchanger upon the opening of the upper end thereof. It is to be understood that distribution means 67 may, if desired, be built in sections to make its removal easier. It is also to be understood that the solid bars 70 may be replaced by V-shaped bars, if desired.

A still further embodiment of heat exchanger in accordance with the invention is schematically shown in FIG. 6, wherein the heat exchanger is generally designated by the reference character 130. As there shown, the plates 131 of the heat exchanger are vertically disposed in parallel relationship to form a first set of heating channels 132 and a second set of liquid medium receiving channels 134 alternating with the first channels. The outer surfaces of the plates 131 forming the channels 132 are spaced apart a distance D, channels 134 having a width d which may, if desired, be different from D. Channels 132 are closed in this embodiment by U-shaped bars 135 which are disposed between the upper edges of plates 131 and are welded thereto.

The baffle means employed in this embodiment is made up of a first lower set of baffle members 136 which are made in the form of vertically symmetrical hooded made, for example, of sheet metal having side plate 137 joined at an upper curved peak 139. Baffle members 136 may, if desired, be made of a single sheet of metal bent into the form shown and welded at its lower edges to the upper edges of plates 131. Located above baffle members 136 in symmetrically staggered relationship with respect thereto are elements forming a second set of baffle members 140. Members 140, which are in the form of inverted V's, have sides 141 joined at peaks 142. In the embodiment shown, the distance D between confronting lower edges of successive members 140 is somewhat less than the distance D, so that the members 140 overlap members 136 in a horizontal direction.

In the embodiment of FIG. 6, liquid to be heated and/or evaporated is distributed to the baffle system 136, 140 and thus to the heated surfaces of plates 131 through a multi-perforated plate 144. Plate 144 may be, for example, the bottom of a shallow distributing tank or it may be the lower wall of a conduit. Liquid conducted to the plate 144 by means not shown flows through the holes 145 therein to form falling streams 146 which impinge baffle members 149 and/or 156. The thus intercepted streams of liquid spread out over members 140 and 136 and then flow smoothly downwardly in the form of falling films of substantially uniform thickness onto the upper edges of the heating surfaces of plates 131.

In FIGS. 7 and 8 there is shown a further embodiment of heat exchanger employing a liquid distribution system in accordance with the invention. Such heat exchanger, which is generally designated by the reference character 150, is adapted for use, for example, for condensing vacuum-steam from steam turbines. Heat exchanger 150 has an enclosure 151 which is divided into an upper compartment, generally designated 152 and a lower compartment 154, the two compartments being separated and sealed from each other by a broadly folded or pleated plate 155 which may be generally flat surfaced although it is preferably horizontally corrugated, as shown.

The plate 153 is formed into a plurality of similar upright small angled V-shaped portions forming upwardly open liquid receiving channels 156 and a plurality of similar inverted V-shaped portions forming downwardly open steam receiving channels 157 alternating with channels 156. The walls of channels 156 and 157 extend at a relatively small angle with respect to the vertical, and thus may be said to be generally vertically disposed.

The plate 155 at the bottom folds thereof rests upon horizontal supporting bars 158, as shown. The bottoms 159 of channels 156 are connected at their ends to the bottom of compartment 152 to allow cooling liquid to be discharged from channels 156 to the bottom of compartment 152. Compartment 152, which is connected at 164 to each such channel, condenses the steam flowing downwardly from channels 157 into the header 161 and is discharged therefrom through a pipe 165.

Cooling liquid is introduced into compartment 152...
through one or more pipes 166 have a plurality of downwardly directed spray nozzles 167 connected thereto. A substantial distance below nozzles 167 there is disposed a baffle means generally designated 169 which may be constructed similarly to the baffle means 49, 50 of FIG. 4 or baffle means 49, 59 of FIG. 5. For simplicity of illustration the means supporting the lower baffle members 171 and the upper baffle members 170 are omitted in FIGS. 11 and 12. The sprays 168 from nozzles 167 overlap somewhat to cover the entire horizontal area of the baffle means 169. The members 171 are located centrally of channels 156; the members 170 are located above and horizontally centrally between successive members 171. The baffle members 170 and 171 are of such size both relative to each other and to the spacing between the tops of successive channels 156 that spray of liquid from nozzles 167 is substantially prevented from direct impingement upon the surface of plate 155 within channels 156. The heat exchanger of FIGS. 7 and 8 possesses the same advantages as those of the other embodiments so far as the liquid distribution system thereof is concerned. Such heat exchanger is also highly efficient, when used as a condenser, because of the excellent counter current flow between the steam and the cooling liquid.

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, as will now be apparent to those skilled in the art.

What is claimed is:

1. In a falling film heat exchanger and vaporizer having a plurality of generally vertical, parallel, aligned and substantially equi-spaced plates forming in part two sets of alternating interdigitated channels, the upper edges of the plates lying substantially in a horizontal plane, the first set of channels being open at the top to receive liquid to be heated and vaporized on its interior surfaces while the second set of channels receives a heating medium interiorly, the improved means for distributing liquid to be heated over the heating surfaces of the heat exchanger plates in the first channels, which comprises an upwardly convex hood disposed above and closing each of the second channels and extending along the upper edges of the heat exchanger plates, the lower edges of the hoods being substantially coextensive and coplanar with the upper edges of the heat exchanger plates at the heating surfaces thereof, a liquid conducting means having at least one discharge opening therethrough disposed centrally above the plates at the top thereof, and liquid distributing means interposed between the liquid discharging opening and the hoods for intercepting substantially all of the liquid directly discharged from the opening and distributing it to fall substantially uniformly onto the hoods, whereby the thus intercepted liquid flows down the sides of the hoods to form substantially uniform films flowing down the entire area of the heating surfaces of the heat exchanger plates, the fluid distributing means comprising at least one set of baffle members offset laterally with respect to the hoods and disposed in a generally horizontal row located above the hoods, each of the baffle members horizontally overlapping two successive hoods.

2. A heat exchanger as claimed in claim 1, wherein the fluid distributing means comprises at least one set of further baffle members, the set of further baffle members being offset laterally with respect to the first recited baffle members and disposed in a generally horizontal row located above the first recited baffle members, each of the further baffle members horizontally overlapping two successive first recited baffle members.

3. A heat exchanger as claimed in claim 1, wherein the hoods and the baffle members are substantially of the same shape and size.

4. A heat exchanger as claimed in claim 3, wherein the hoods and the baffle members are generally of laterally symmetrical inverted V-shape in vertical transverse section.

5. A heat exchanger as claimed in claim 3, comprising means supporting the baffle members upon the hoods.

6. A heat exchanger as claimed in claim 5, wherein said supporting means for the baffle members comprises at least two generally parallel rows of cross bars spaced longitudinally of the hoods, said cross bars having base portions spanning between and being supported upon confronting sides of successive hoods, said bars having upstanding portions connected to the baffle members.

7. A heat exchanger as claimed in claim 6, wherein the bars are of inverted T-shape, the lower cross portion of each bar spanning the space between the sides of successive hoods, the baffle members being disposed symmetrically with respect to the upright portions of the bars.

8. A heat exchanger as claimed in claim 6, wherein the hoods and bars are permanently secured together.

9. A heat exchanger as claimed in claim 6, wherein the hoods and the baffle members are permanently secured to the supporting bars, and the hoods are removable secured to the upper edges of the plates of the heat exchanger.

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