June 22, 1937. J. P. RATHBUN 2,084,743

HEAT EXCHANGER

Filed May 17, 1935 2 Sheets-Sheet 1

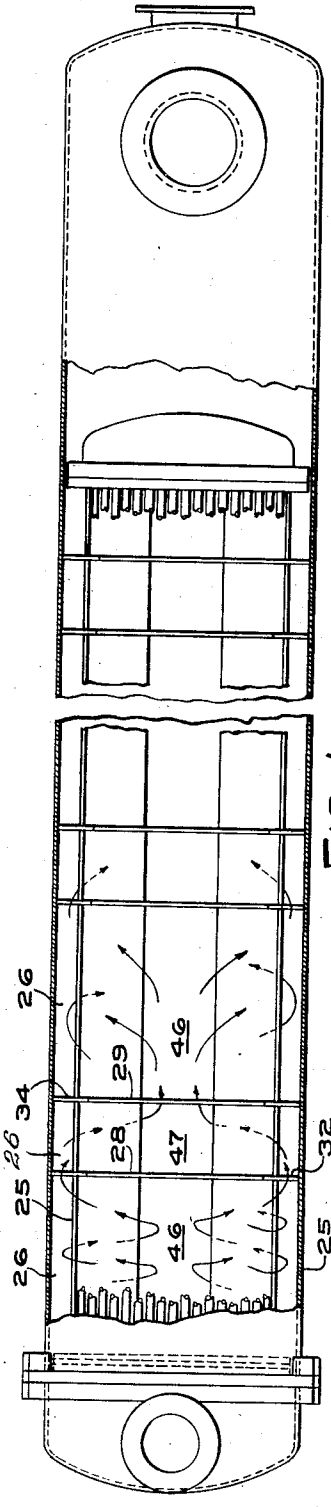


FIG. 1.

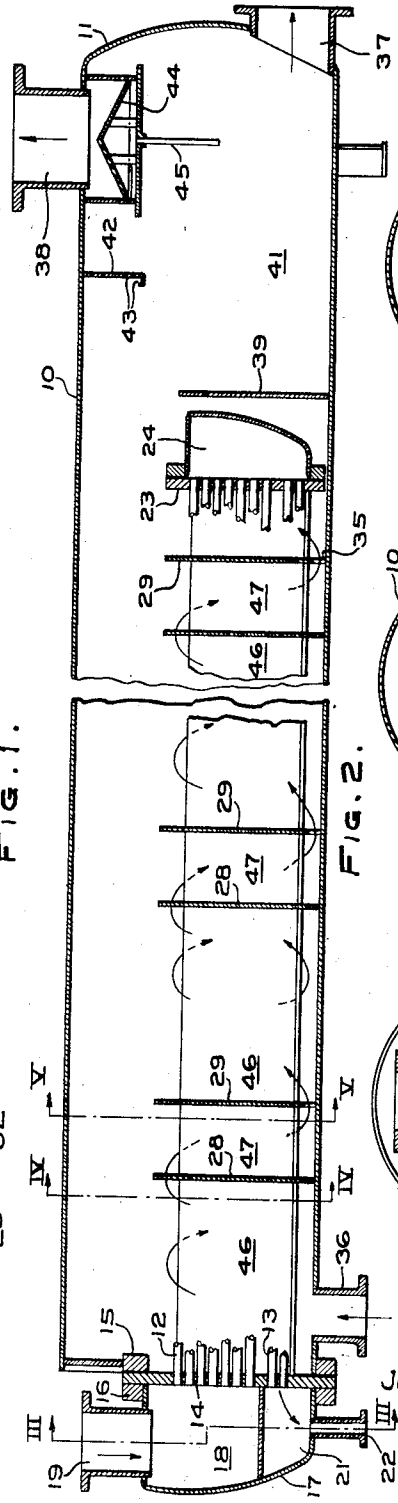


FIG. 2.

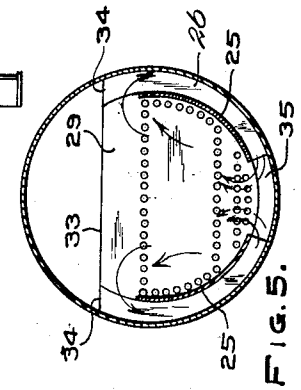


FIG. 5.

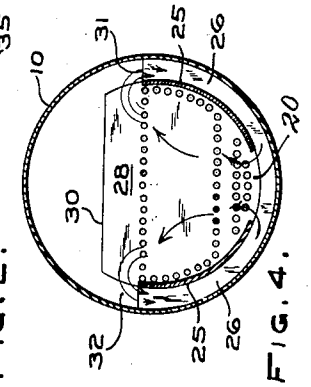


FIG. 4.

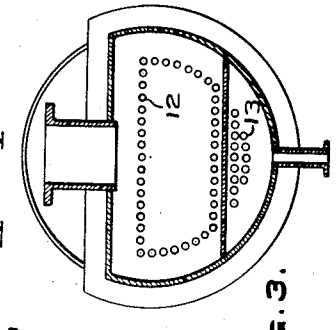


FIG. 3.

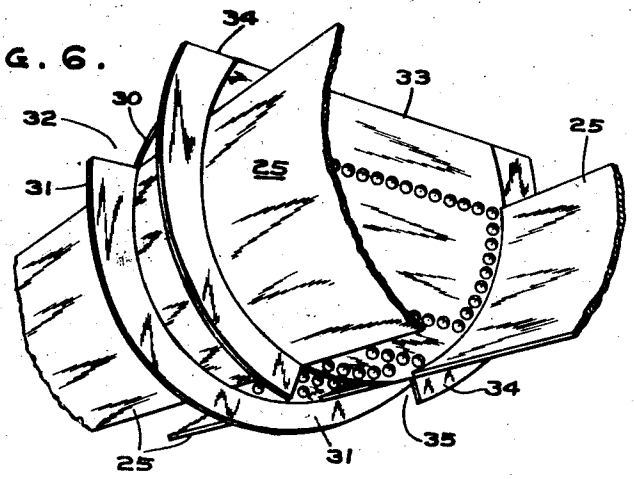
INVENTOR
JOHN P. RATHBUN
BY
A. B. Rines
ATTORNEY

June 22, 1937. J. P. RATHBUN 2,084,743

HEAT EXCHANGER

Filed May 17, 1935 2 Sheets-Sheet 2

FIG. 6.



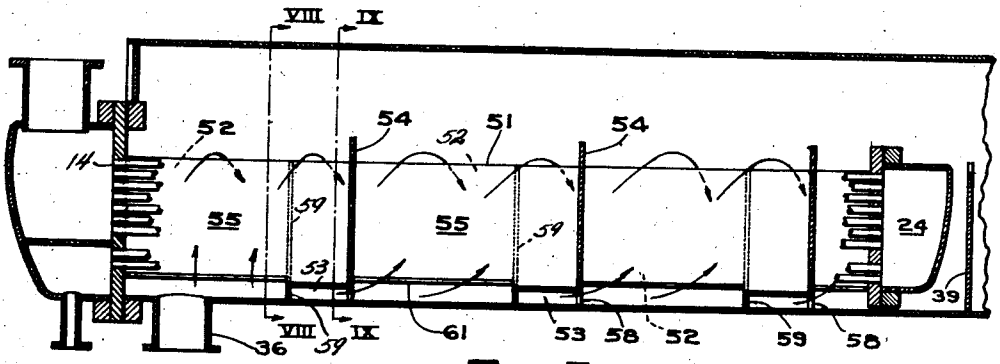


FIG. 7.

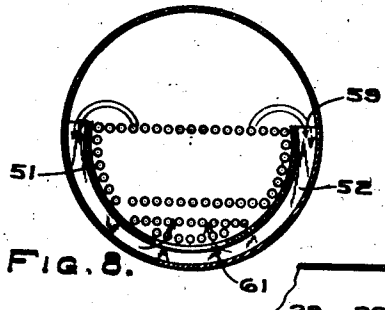


FIG. 8.

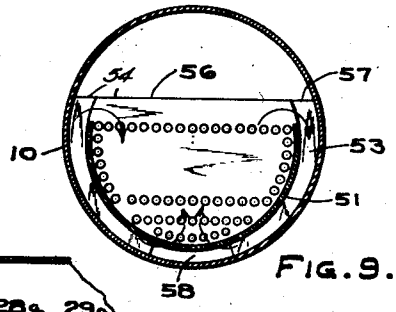


FIG. 9.

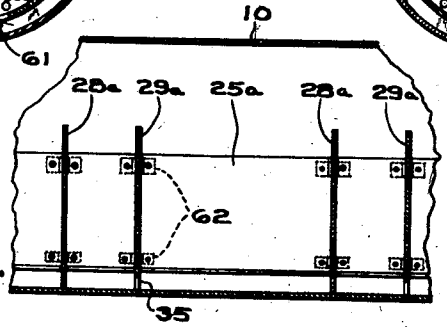


FIG. 10.

WITNESSES:
E. Lutz
J. K. Mossers

INVENTOR
JOHN P. RATHBUN
BY
A. B. Rivers
ATTORNEY

Patented June 22, 1937 2,084,743

UNITED STATES PATENT OFFICE

2,084,743

HEAT EXCHANGER

John P. Rathbun, Prospect Park, Pa., assignor to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

Application May 17, 1935, Serial No. 22,085

13 Claims. (Cl. 257—236)

My invention relates to heat exchange apparatus, more particularly to heat exchange apparatus in which one fluid is at least partially vaporized, and it has for an object to provide improved apparatus.

A further object is to improve the heat transfer rate of such apparatus.

In accordance with my invention, I provide a shell or other vessel in which there are disposed heating elements, such as tubes containing heating fluid. Baffles are arranged to provide a plurality of passages through which liquid flows upwardly in contact with the heating elements to be heated thereby. Other passages convey the fluid, out of contact with the heating elements, from the upper ends of heating passages to the lower ends of the heating passages. The vapor formed in each heating passage is removed through the upper portion of the shell. Thus, natural convection currents are utilized to provide maximum flow and heat transfer.

The above and other objects are effected by my 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:

Fig. 1 is a plan view, partly in section, of one embodiment of the apparatus;

Fig. 2 is a vertical longitudinal section thereof;

Figs. 3, 4, and 5 are transverse sectional views taken on the lines III—III, IV—IV, and V—V, respectively of Fig. 2;

Fig. 6 is an enlarged broken perspective view showing the baffles;

Fig. 7 is a vertical longitudinal section of a modified form of heat exchanger;

Figs. 8 and 9 are transverse sectional views taken on the lines VIII—VIII and IX—IX of Fig. 7; and

Fig. 10 is a fragmentary section of a modified baffle construction.

Referring to the drawings in detail, the heat exchange apparatus comprises a cylindrical shell 10 which may have an integral closure 11 at one end. The shell 10 contains tubes 12 and 13 for circulating heating fluid, the tubes being arranged in a nest or bundle in the lower portion of the shell, that is, somewhat below the top of the shell, as shown on the drawings. The tubes are secured at one end to a tube sheet 14, which is clamped between a flange 15 of the shell 10 and a flange 16 of a removable head 17. The latter comprises an inlet chamber 18 having an inlet connection 19 and an outlet chamber 21 having an outlet connection 22. At the opposite end, the tubes are secured to a floating tube sheet 23, to which a floating head 24 is secured. The floating head 24 provides a reversing chamber for directing the heating fluid from the tubes 12 to the tubes 13. It is to be understood that any suitable heating fluid may be used. For example, steam may be used as contemplated by the illustrated embodiment, in which case the tubes 12 may be greater in number than the tubes 13. The steam gives up its latent heat in the tubes 12 and the tubes 13 serve primarily for returning the condensate to the head 17. It is to be understood that any desired number of tube passes and any other desired arrangement of tube nest may be used.

As shown in Figs. 4 and 5, the tube nest is spaced from the cylindrical wall of the shell 11, and curved baffles 25 partially enclose the tube nest, extending about the sides and partly about the bottom of the tube nest and providing downwardly extending passages 26 between the tubes and the cylindrical wall of the shell. The upper edges of the baffles 25 extend approximately to the top of the tube nest, and the lower edges extend to the bottom of the tube nest but are in spaced relation to each other so as to provide communication between the lower ends of the passages 26 and the tube space which is partially enclosed by the baffles 25. The baffles 25 may be continuous, as in the illustrated embodiment, extending from the tube sheet 14 to the tube sheet 23.

The tube space is divided transversely of the tubes, by two groups of baffles, 28 and 29, arranged alternately, into a plurality of compartments 46 and a plurality of compartments 47, arranged alternately. As shown in Fig. 4, the baffle 28 comprises a member 30 which is disposed between the baffles 25 and which is slightly more than semi-circular in form. It further comprises an approximately semi-annular member 31 extending between the baffles 25 and the shell up to the height of the baffles 25. Thus, the baffle part 30 extends upwardly above the part 31, to form slots 32 as shown in Figs. 4 and 6 for flow of liquid, as hereinafter described. The baffle parts 30 and 31 are secured to each other and to the baffles 25 in any suitable manner, as by welding. They together form tube supports adapted to slide on the bottom of the shell.

The transverse baffles 29 comprise a central baffle part 33, similar in form to the baffle part 30, also extending upwardly above the tube nest. It further comprises arcuate parts 34 between the baffles 25 and the shell. The parts 34 ex-

tend upwardly to the upper edge of the part 33 and extend downwardly only to the lower edges of the baffles 25, thereby forming a port 35 in the bottom of the baffle 29, through which liquid may flow from one compartment 47 to the next compartment 46.

The entire tube bundle, including the baffles, may be removed as a unit through the left hand end of the shell upon disengaging the flanges 16 and 15.

The shell is provided with a liquid inlet 36 in the bottom thereof in the end adjacent the head structure 17 and with a liquid outlet 37 at the other end. It is formed with a vapor outlet 38 in the upper portion thereof adjacent the end wall 11. A weir 39 may be provided adjacent the floating head 24 to insure complete submergence of the tubes in the liquid, and the shell may be extended beyond the weir 39 to provide a storage chamber 41 for liquid leaving the shell. A baffle 42 may be provided at the top of the shell between the weir 39 and the vapor outlet 38 and provided with a trough 43 adapted to collect and drain to the cylindrical wall of the shell any liquid particles collected by the baffle 42. A liquid separator 44 may be provided at the vapor outlet 38 to separate out any liquid particles carried in suspension by the vapor leaving the shell. The liquid may be drained through a conduit 45 into the storage chamber 41.

The operation of the above-described apparatus is as follows: while the above-described apparatus is useful generally for vaporizing liquid, it is particularly adapted to be used as a reboiler in oil refinery apparatus, to separate a component or components of lower boiling point from a component or components of higher boiling point. Natural convection or thermosyphonic circulation of liquid in each compartment 46, 47 is effected by the heating action of the tubes 12, 13, the liquid flowing upwardly through the space between the baffles, over the upper edges of the baffles 25, downwardly through the passages 26 around the lower edges of the baffles 25 back into the space between the baffles 25. In each of the compartments 46, 47, a portion of the circulating liquid is continually passed on to the next compartment and added to the liquid circulating therein, as will now be described. The liquid containing a mixture of components of both higher and lower boiling points is admitted to the shell 10 through the inlet 36 into the first compartment 46. It joins the liquid coming down through the passage 26, and the mixture flows upwardly through the passage provided between the lower edges of the baffles 25 into the tube space enclosed by said baffles. As it flows upwardly it comes in contact with the heating tubes 12 and 13 and is heated thereby. As it reaches the top of the tube nest, the components of lowest boiling points, or lighter fractions, vaporize and flow off into the vapor space formed in the upper portion of the shell above the tube nest. One portion of the liquid rising to the top of the tube nest spills over the upper edges of the baffles 25 and flows downwardly through the passages 26. From the latter, it is again admitted through the passage between the lower edges of the baffles 25 to the tube space enclosed by said baffles and is recirculated as described. Another portion of the liquid rising to the top of the tube nest spills over the upper edges of the baffle parts 31, through the notches 32, into the next compartment 47 between the baffles 28 and 29.

In the compartment 47, the liquid flows downwardly through the passages 26 to the bottom of the shell. One portion of the liquid then flows upwardly through the tube space of the compartment 47, and another portion flows through the port 35 into the next compartment 46 between baffles 29 and 28. The portion of the liquid flowing upwardly through the tube space in the compartment 47 spills over the upper edges of the baffles 25, giving off to the vapor space the vapor formed as it is passed over the tubes, and again passes downwardly through the passages 26. The portion of the liquid passing through the port 35 joins the liquid in the next compartment 46 which is flowing upwardly through the tube space.

The liquid then flows successively through the remaining compartments 46 and 47 in the same manner as just described, the components of successively higher boiling points being gradually vaporized. From the last port 35, the liquid flows upwardly over the ends of the tubes 12 and 13 and the floating head 24, and spills over the upper edge of the weir 39 into the storage chamber 41, from which it is withdrawn through the outlet 37.

In the above arrangement, the liquid flows upwardly in contact with the heating tubes and downwardly out of contact with the tubes, thereby setting up natural convection currents within each compartment, resulting in increased rate of flow and increased rate of heat transfer. The flow from one compartment to the next is effected by gravity, the liquid being admitted under pressure and rising to a sufficiently high level in the first compartment to effect such flow, the liquid levels in the successive compartments being successively lower.

In Figs. 7, 8, and 9, I show a modified baffle arrangement, the remainder of the structure being the same as in Figs. 1 to 5. A curved baffle member 51 extends about the sides and bottom of the tube nest in spaced relation to the wall of the shell, providing passages 52 and 53, shown in Figs. 8 and 9, respectively. The baffle member 51 may be continuous between the tube sheets. The tube space is divided by transverse baffles 54 into compartments 55. The baffle 54, as shown in Fig. 9, comprises an intermediate member 56 having openings through which the tubes extend and arcuate members 57 between the circular member 51 and the shell 10. The lower edges of the latter are in spaced relation to form a port 58, while the upper edges of the parts 56 and 57 are spaced a short distance above the top of the baffle member 51 and the tube nest. As shown in Fig. 8, an arcuate baffle member 59 between the curved baffle member 51 and the shell provides a division wall between the passages 52 and 53, and extends continuously from one side to the other to a height even with the top edge of the baffle member 51. The curved baffle member 51 is formed with a slot 61 in the bottom thereof in the part of each compartment 55 adjacent the passage 52, that is, from the tube sheet 14 or the baffle 54 to the baffle 59, while it is continuous adjacent the passage 53, that is, from the baffle 59 to the baffle 54.

In the operation of this embodiment, the liquid to be partially vaporized is admitted under pressure through the inlet 36, as in the first embodiment, and rises through the slot 61 and the tube space to the top of the group of tubes. From there, it spills over the upper edges of the baffle member 51 into the passages 52 and 53. The portion entering the passage 52 flows down-

wardly, joins the liquid entering through the inlet **36**, and reenters the tube space through the slot **61**. The flow of this portion is effected by the natural convection or thermo-syphonic circulation induced by the heating action of the tubes. The portion of the liquid entering the passage **53** flows downwardly to the bottom thereof and then through the port **58** in the baffle **54** into the next compartment. In the latter, it flows upwardly through the slot **61** into the tube space. The cycle of operation just described is then repeated in each compartment. From the last port **58**, the liquid flows upwardly over the ends of the tubes and the floating head **24** and spills over the weir **39**.

In this embodiment, the liquid flows upwardly in contact with heating tubes and downwardly out of contact therewith as in the first embodiment. The passages **52** provide recirculation of liquid within the several compartments, while the passages **53** provide for flow from one compartment to the next. In this case, the convection currents through the passages **53** assist the gravity flow of the liquid from the inlet to the outlet end of the tube space, since the head of the heavier unheated liquid in the passages **53** exceeds the head of the lighter boiling liquid flowing upwardly into the tubes in the next compartment.

As shown in Fig. 10, the curved baffles **25***a* may be made in sections so as to be removable. Each of the transverse baffles **28***a* and **29***a* is integral, instead of comprising separate parts as in Figs. 4 and 5. Each baffle section **25***a* extends between adjacent transverse baffles and is detachably secured thereto by angle members and bolts shown at **62**. Upon removing the curved baffle sections **25***a*, access to the tubes is provided for periodically cleaning the same. In all other respects, the baffle structure of Fig. 10 may be the same as that shown in Figs. 1 to 6.

A further advantage of the present invention is that all of the liquid is caused to rise repeatedly to the surface, at least once in each compartment, where the vapor separates from the liquid to a much greater extent because of the low hydrostatic head.

While I have shown my invention in several forms, 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 and I desire, therefore, that only such limitations shall be placed thereon as are imposed in the prior art or as are set forth in the appended claims.

What I claim is:

1. In heat exchange apparatus, the combination of baffle means providing a plurality of circuits each comprising a downwardly extending passage and an upwardly-extending passage, means for heating the liquid in the upwardly extending passage to vaporize a portion of the liquid and thereby to effect thermo-siphonic circulation of the liquid in the circuit, a dome or vapor space communicating with the upper portions of the several upwardly-extending passages for receiving the vaporized fluid, and means for conveying at least a portion of the liquid from one circuit to the next.

2. In heat exchange apparatus, the combination of a shell, heating elements within the shell, baffle means within the shell providing a plurality of upward passes for liquid to be heated in contact with said heating elements and a plurality of downward passes out of contact with the heating elements and arranged to provide flow of liquid through a plurality of upward passes successively, the liquid flowing through upward and downward passes alternately, the upper portion of the interior of the shell constituting a vapor space in communication with the upper ends of the several upward passes and receiving the vapor formed therein.

3. In heat exchange apparatus, the combination of a shell, a tube nest therein, baffles disposed transversely of the tubes and providing a plurality of compartments, other baffles in the compartments providing first vertical passages through which the tubes extend and second vertical passages substantially without tubes, the vertical passages in each compartment being in communication at the upper ends whereby liquid flows upwardly in the first passages and then downwardly in the second passages, a plurality of said transverse baffles having a port providing communication between the lower ends of the second passage of one compartment and the first passage of the next compartment to provide flow of liquid successively through the compartments.

4. In heat exchange apparatus, the combination of a shell, a tube nest therein, baffles disposed transversely of the tubes and providing a plurality of compartments, the tubes being arranged to provide first vertical passages through which the tubes extend and second vertical passages substantially without tubes, the vertical passages in each compartment being in communication at the upper ends whereby liquid flows upwardly in the first passages and then downwardly in the second passages, a plurality of said transverse baffles having a port providing communication between the lower ends of the second passage of one compartment and the first passage of the next compartment to provide flow of liquid successively through the compartments.

5. In heat exchange apparatus, the combination of a shell, a tube nest therein, baffles disposed transversely of the tubes and providing a plurality of compartments, other baffles in the compartments providing first vertical passages through which the tubes extend and second vertical passages substantially without tubes, the vertical passages in each compartment being in communication at the upper ends whereby liquid flows upwardly in the first passages and then downwardly in the second passages, and means providing flow of liquid successively through the several compartments.

6. In heat exchange apparatus, the combination of a longitudinal shell, a tube nest within the lower portion of the shell, the upper portion of the shell constituting a vapor space, means for admitting liquid at one end of the shell, means for withdrawing liquid from the bottom at the other end of the shell, a vapor outlet communicating with said vapor space, and baffles arranged to provide flow of liquid successively upwardly in contact with said tubes and downwardly out of contact with said tubes while flowing longitudinally of the shell from the inlet to the liquid outlet.

7. In heat exchange apparatus, the combination of a shell, a tube nest within the lower portion of the shell, the upper portion of the shell constituting a vapor space, an inlet for admitting liquid adjacent one end of the shell, an outlet for withdrawing liquid adjacent the other end of the shell, a vapor outlet communicating with said vapor space, and a baffle or baffles disposed transversely of said tubes between said

liquid inlet and said liquid outlet and providing a plurality of compartments for the liquid flowing between said inlet and outlet, said tubes being arranged to provide lanes for flow of liquid from the top of the tube nest to the bottom thereof, and said baffles being formed to provide communication between adjacent compartments in such manner that the liquid flowing from the liquid inlet to the liquid outlet flows upwardly in contact with the tubes at least once in a plurality of said compartments.

8. In heat exchange apparatus, the combination of a shell, heating elements within the shell, baffle means within the shell providing a plurality of passages for flow of liquid upwardly in contact with said heating elements and a plurality of downward passages for flow of liquid downwardly out of contact with heating elements, said baffle means being arranged to provide flow of liquid through said heating and downward passages alternately and to provide flow of liquid upwardly at least once through each of a plurality of said heating passages, and means for removing vapor from the liquid at the upper end of each heating passage.

9. In heat exchange apparatus, the combination of a shell having a liquid inlet and a liquid outlet, a bundle of tubes arranged horizontally in the shell, baffles arranged transversely of the tubes and dividing the tube containing portion of the shell into compartments through which liquid flows successively from said liquid inlet to said liquid outlet, the liquid flowing upwardly through each compartment in contact with said tubes, and means providing a passage for flow of liquid within the shell and out of contact with tubes from the top of one compartment to the bottom of the next compartment, and means for removing vapor from the liquid at the top of each compartment.

10. In heat exchange apparatus, the combination of a shell, a tube bundle arranged horizontally within the shell, baffles arranged transversely of the tubes and providing a plurality of passes for flow of liquid upwardly in contact with heating tubes, and baffle means arranged to provide flow of liquid within the shell out of contact with tubes from the upper end of one heating pass to the lower end of the next heating pass.

11. A heat exchanger comprising a shell having a liquid inlet and a liquid outlet, a bundle of heating tubes arranged horizontally within the shell, baffles arranged transversely of the tubes and providing a plurality of passes for flow of liquid upwardly in contact with heating tubes to be heated thereby, said tubes being arranged to provide space for flow of liquid downwardly within the shell from the top to the bottom of the tube bundle substantially out of contact with tubes, means including transverse baffles in said space providing passages arranged to convey liquid from the top of one heating pass to the bottom of another heating pass to cause liquid to flow through a plurality of said heating passes successively in flowing from said liquid inlet to said liquid outlet, and means for removing vapor from the liquid at the top of each heating pass.

12. A heat exchanger comprising a shell having a liquid inlet and a vapor outlet, a bundle of heating tubes disposed horizontally therein, baffles disposed transversely of the tubes and dividing the tube containing portion of the shell into compartments through which liquid flows successively, said tubes being arranged to provide lanes for flow of liquid from the top to the bottom of the tube bundle out of contact with tubes, said baffles providing a liquid inlet for each of a plurality of said compartments only at the bottom thereof and a liquid outlet for each of said plurality of compartments only at the top thereof, whereby liquid is caused to flow upwardly at least once through each of said plurality of compartments in contact with the heating tubes therein.

13. In heat exchange apparatus, the combination of a shell having a liquid inlet, a liquid outlet, and a vapor outlet, a group of heating elements within the shell, and baffle means causing the liquid to flow from the bottom to the top of the group of heating elements a plurality of times in flowing from said liquid inlet to said liquid outlet.

JOHN P. RATHBUN.