

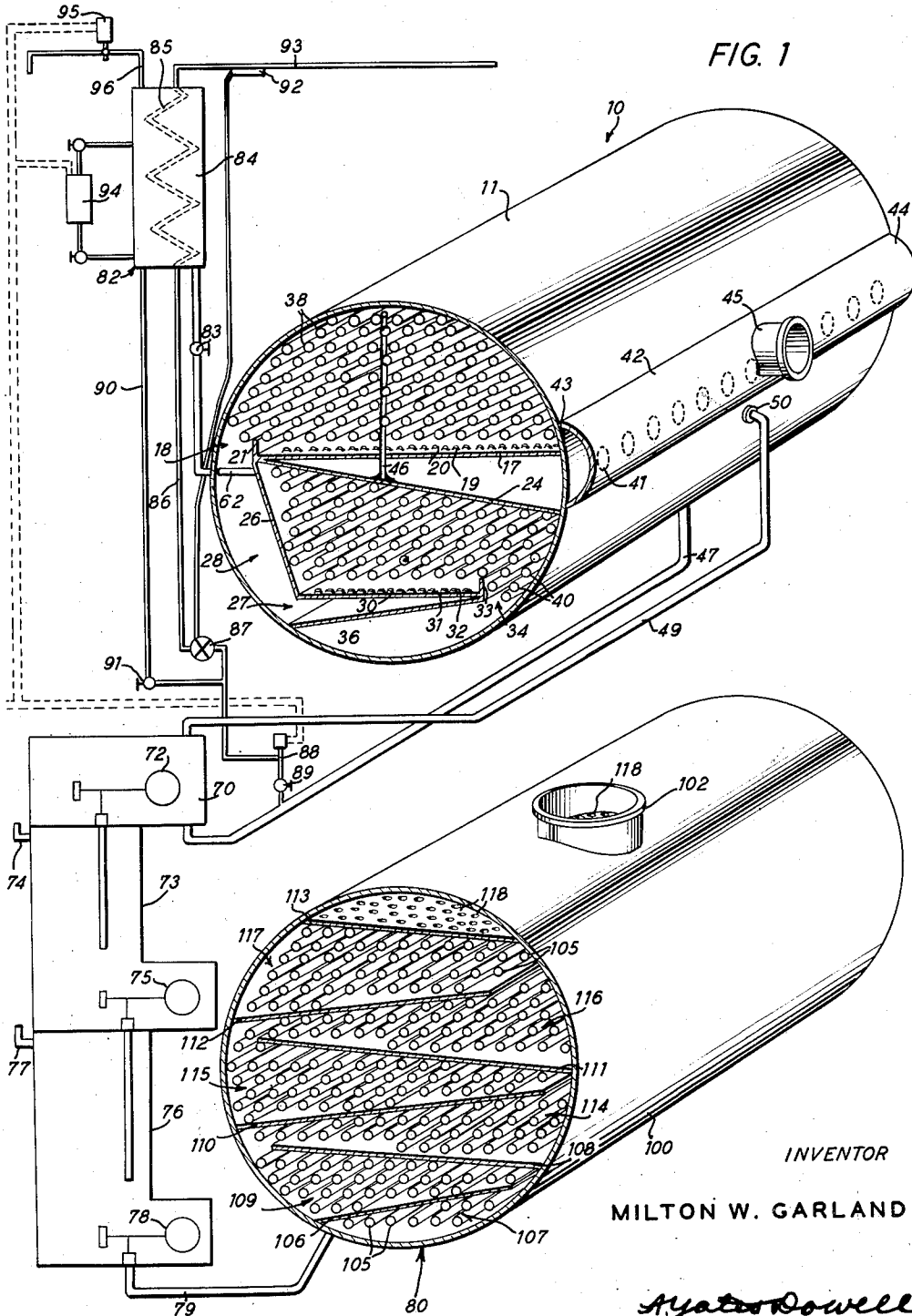
April 15, 1958

M. W. GARLAND
REFRIGERANT CONDENSER

2,830,797

Filed May 5, 1953

3 Sheets-Sheet 1



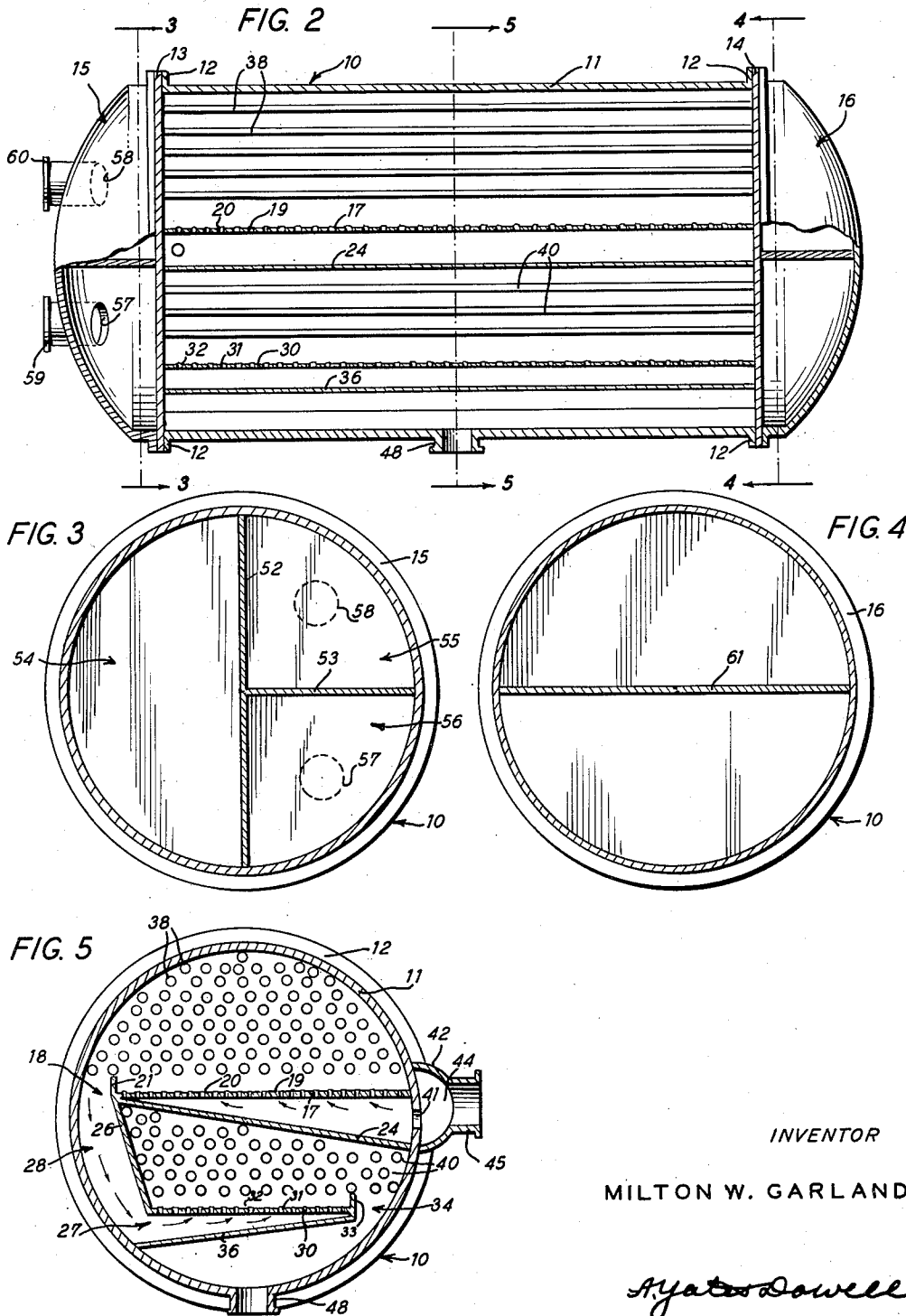
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3 Sheets-Sheet 2



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REFRIGERANT CONDENSER

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9 Claims. (Cl. 257—43)

This invention relates to refrigeration and more particularly to a commercial system adapted to operate at high efficiency. The invention particularly includes condensing and evaporating elements especially designed for efficient operation.

The system with which the condensing and evaporating elements are disclosed includes provision for automatic control of the refrigerant flow and for the removal with minimum refrigerant loss of non-condensable gases.

Various attempts have been made heretofore to produce a condenser affording maximum distribution of the fluid to be condensed and of its effective association with the cooling surfaces, and particularly in a shell and tube condenser of the general type contemplated. Similarly, efforts have been made to provide a shell and tube evaporator which permits flooded operation but without the excessive pressure drop which normally accompanies the non-baffled open type flooded shell.

Accordingly, it is an object of the present invention to provide novel condensing and evaporating elements in a refrigerating system especially designed to take maximum advantage of their improved operating characteristics.

A further object is to provide a shell and tube condenser affording maximum distribution of the fluid to be condensed, and adapted for two or more stages of condensing, and in which means is provided for improved contact between the condensed and the uncondensed fluid, and between the fluid and the heat transfer surfaces.

A further object is the provision of a condenser having improved distributing means without producing an intolerable impediment to the flow and adapted for counterflow between the gases and the cooling fluid, resulting in greater range in temperature of the cooling fluid.

A further object is to provide a shell and tube condenser affording counter flow heat exchange, improved distribution and heat transfer, and including two or more stages.

A further object is to provide a shell and tube evaporator of the semi-flooded type which affords maximum contact between the refrigerant and the tubes carrying the fluid being cooled, including counter flow therebetween.

A further object is the provision of an evaporator in which natural upward flow of the evaporated fluid through and across unevaporated fluid is afforded in order to provide efficient heat transfer and in which the fluid being cooled passes in counter flow thereto.

A further object is to efficiently discharge non-condensable gases from the condenser and to provide the evaporator with refrigerant precooled by an economizer in the liquid line between the condenser and the evaporator.

These and other objects of the invention will become apparent from the following description in conjunction with the accompanying drawings in which:

Fig. 1 is a diagrammatic perspective of a system embodying the invention including condensing, purging, economizing and evaporating elements;

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Fig. 2 is a vertical section of the condenser with portions of the heads broken away for greater clarity;

Fig. 3 is a section on the line 3—3 of Fig. 2;

Fig. 4 is a section on the line 4—4 of Fig. 2;

Fig. 5 is a section on the line 5—5 of Fig. 2;

Fig. 6 is a vertical longitudinal section of the evaporator with portions of the heads broken away for greater clarity;

Fig. 7 is a section on the line 7—7 of Fig. 6;

Fig. 8 is a section on the line 8—8 of Fig. 6; and

Fig. 9 is a section on the line 9—9 of Fig. 6.

Briefly stated, the invention includes a condenser of the shell and tube type in which the refrigerant gas enters the shell through a plurality of spaced apertures in its side. The refrigerant is further distributed by passing upwardly through a longitudinal partition plate before contacting a tube bundle constituting the first pass. Refrigerant condensing on the tubes drips onto the partition plate which maintains a small depth thereof, the entering apertures having raised edges and the side of the partition plate having a flange or weir over which liquid may overflow. From the first pass the refrigerant circulates around the side of the shell and comes up through a second partition plate parallel to the first and similarly constructed and arranged. Condensed refrigerant overflows the weir plate of the second pass partition and discharges from the condenser to a liquid line. The heads of the condenser are baffled so that the cooling fluid flows substantially counterflow to the refrigerant.

A purger receives non-condensable gases from the passes of the condenser, liquid refrigerant being used to cool the purger. Automatic means is provided to return liquid from the purger and to maintain the desired pressure in the purger, at the same time holding its temperature down in order to facilitate condensation of refrigerant from the non-condensable gases.

The liquid line leads to an economizer which may be of the multi-stage type if a plurality of stages of compression are employed. The economizer is preferably of the float controlled type in which flash gas may be withdrawn to various stages of compression in order to sub-cool the liquid refrigerant and reduce the load on the lowest stages of compression.

The evaporator is of the shell and tube type, and has a plurality of upwardly sloping longitudinal baffles. Liquid refrigerant enters the bottom and is confined by a baffle to a group of tubes with which it passes in contact. The liquid collects in a portion of the confined area under the first baffle thus flooding the tubes in the area. Evaporated refrigerant and some of the liquid flows around the far side of the baffle and into contact with a second group of tubes confined between the first and second baffle. The refrigerant continues to zig-zag from the lower to the uppermost portion of the evaporator finally passing through an eliminator distributor plate to the suction line.

As all the baffles slope upwardly from the horizontal they permit natural upward flow of the gaseous refrigerant and also retain liquid on their upper surfaces to provide a semi-flooded condition. Starting at the bottom of the evaporator a progressively larger number of tubes is positioned between each succeeding pair of baffles in order to proportion the counterflow to the heat exchange.

The evaporator is provided with partitioned heads at the ends thereof which permits counterflow between the refrigerant and the fluid flowing through the tubes.

The condenser

Referring to the drawings, a condenser 10 is shown having a rolled cylindrical shell 11 having end flanges 12 connected to the periphery of end plates 13 and 14 to which is attached the flanges of the heads 15 and 16.

Within the shell a distributor plate 17 is mounted substantially horizontally and a little above the axis or mid-point of the shell. The distributor plate has its ends attached to the end plates 13, 14 and has one side along the side of the shell. The opposite side of the plate 17 is spaced from the opposite wall of the shell to provide a passage 18 around the side of the plate within the shell.

Plate 17 has a multiplicity of spaced apertures 19 over its entire area. The apertures are formed by punching the plate from its underside, thus creating a raised edge 20 about each on the upper side of the plate. Along the longitudinal edge of the plate 17 next to the space 18 a substantially vertical flange or weir 21 extends, for purposes to be described.

A partition plate 24 is attached along one longitudinal edge to the longitudinal edge of the transfer plate 17 adjacent to the space 18. It extends at an angle to plate 17, forming a V therewith, its opposite longitudinal edge being connected to the side of the shell 11 below the corresponding edge of the plate 17. The ends of plate 24 are attached to the end plates 13 and 14.

Another partition plate 26 of substantially less width than the plates 17 and 24 has a side edge connected to the junction of these plates and extends downwardly at a small angle to the vertical. Its ends are attached to the end plates 13, 14, and its side opposite that attached to the plates 17 and 24 is spaced from the wall of the cylinder 11 approximately the same as its other side to provide a space 27 communicating with space 28 between the body of the plate and the wall of the cylinder and the space 18 between the weir and the wall.

A second pass distributor plate 30 extends longitudinally of the cylinder substantially parallel to plate 17. Its ends are attached to the end plates 13, 14 and its left side edge as viewed in Fig. 1 is attached to the lower edge of the plate 26. Plate 30 has a multiplicity of apertures 31 with raised edges 32 similar to plate 17 and has a flange or weir 33 at its free edge which is spaced from the wall of the cylinder to provide a passage 34 between the wall and the weir.

A further partition plate 36 has an edge attached to the free edge of plate 30 and its opposite longitudinal edge to the shell 11, the plate being angularly disposed to the plate 30 and forming a V therewith. The ends of plate 36 are attached to the end plates 13, 14.

A first pass tube bundle 38 is mounted in the shell above the level of the distributor plate 17 and a second pass tube bundle 40 within the space bounded by the plates 24, 26, 30 and a portion of the shell above plate 30 and below the partition plate 24.

The shell 11 has a series of distributor apertures 41 along its longitudinal edge and between the edges of the plates 17 and 24 welded to the shell. A semicircular header 42 extends along the shell over the apertures 41 and has semicircular end plates 43 and 44 to enclose the space between the header and the outside of the shell. A connector 45 is provided midway of the header, to which the line from the compressor or other equivalent device (not shown) may be attached.

A conduit 46 of restricted diameter engages plate 24 at the conduit's lower extremity and extends vertically adjacent to the top of the shell, in order to provide communication from the second pass space to the upper portion of the first pass space.

A liquid line 47 is attached to a coupling 48 at the lower central portion of the shell and a gas pressure equalization line 49 it attached to a coupling 50 in the side of the shell and communicates with the space within the second pass portion of the shell which is below the intersection of the plate 24 and the shell wall.

The tubes 38 and 40 are connected to the end plates 13 and 14 in a manner well known in the art, and are used to carry cooling fluid such as water for removing heat from the compressed refrigerant gas passing in contact with the tubes. In order to improve the efficiency of heat

transfer the arrangement of flow through the tubes is such that substantial counterflow occurs between the refrigerant and the cooling fluid.

Referring more particularly to Figs. 2, 3, and 4, the head 15 has a central vertical partition 52 and, as viewed in Fig. 3, a central horizontal partition 53 extending to the right of partition 52. Thus the partitions confine the head into areas or spaces 54, 55, and 56. The head 15 has an inlet opening 57 in the portion thereof over the space 56, and an outlet opening 58 in the portion thereof above space 55. Couplings 59 and 60, respectively, extend from the openings.

At the opposite end of the cylinder the head 16 has a horizontal partition plate 61 at the same level as partition plate 53 in the head 15.

A purge line 62 communicates with the highest portion of the second pass, adjacent to the intersection of plates 24 and 26. Any non-condensable gases accumulating in the second pass may escape through the purge line 62.

In the operation of the condenser compressed gas enters the header 42 by the coupling 45. The gas passes through the spaced openings 41 and into the space between plates 17 and 24, being distributed lengthwise of the condenser. Because of the apertures 41 being spaced above the lower edge of the header a space is provided externally of the shell within the header in which pipe scale and other foreign matter may collect.

The gas rises upwardly through the apertures in the plate 17 and is thus distributed for better contact with the tube bundle 38 in the upper portion of the shell constituting the first pass. Refrigerant condenses in the first pass on the tubes and drips onto the plate 17 but the liquid is restrained from drainage over the edge by the weir 21. After operation is underway the weir maintains a small depth of condensate on the plate 17 in order that the incoming gas will pass therethrough. The raised edges 20 around the apertures in the plate assist in the trapping of condensate on top of the plate and in its distribution in order to promote contact between incoming gas and the condensate. Non-condensed refrigerant and excess condensate from the first pass flow over the weir 21 through spaces 18, 28, and 27 to the under side of the distributor plate 30. Flow is upward through the plate 30 in the same manner as that through the plate 17. Condensation is completed in the second pass and the liquid refrigerant flows over the weir 33 through the space 34 to the liquid line 47. Liquid refrigerant collected on the tops of the distributor plates 17 and 30 to a depth sufficient to overflow the weirs contacts the lower rows of the respective tube bundles resulting in heat transfer from the liquid to the tubes, thus further cooling such liquid, including removing heat therefrom received from the incoming gas.

Non-condensable gases trapped in the upper portion of the shell in the first pass flow downwardly through the conduit 46 to the upper portion of the second pass.

Viewing the apparatus as arranged in Fig. 1, the flow of refrigerant is through the first pass from substantially right to left, and through the second pass from substantially left to right, or in other words in a generally counter-clockwise movement. The cooling fluid enters connector 59 and flows first through the portion of the tube bundle in direct communication with the space 56. Arriving at the far end, the flow passes horizontally across the end plate 14 for return but is prevented from reaching the upper level tubes by the partition 61. Upon reaching the head 15 the flow goes vertically into the tubes at the upper portion of the space 54 but is prevented by partition 52 from reaching those at its right. Upon entering the head 16 again, the flow returns through the tubes having their ends within the space 55 and flows out connector 60. It will be apparent therefore that the cooling fluid enters at the lower right hand bundle of tubes as viewed in Fig. 1 and progresses clockwise, in opposition to the flow of refrigerant previously discussed.

While a two pass arrangement has been disclosed, it is obvious that the invention is not restricted to any particular number of passes.

The refrigeration system

Referring particularly to Fig. 1, it will be noted that the liquid line 47 enters the first shell 70 of a multi-stage economizer. When the level within the first shell is sufficient the float 72 will open, permitting liquid to flow into the shell 73 constituting the first stage of the economizer. From the first stage flash gas from the refrigerant may be returned by a conduit 74 to an intermediate stage of compression (not shown). A further stage of cooling of the liquid refrigerant may be used if desired. In the schematic illustration liquid in the shell 73 may raise the float 75 to permit flow into the second stage shell 76 from which flash gas may pass by conduit 77 to the next lower stage of compression. From the last stage of the economizer float 78 regulates flow into the conduit 79 leading to the evaporator 30.

In order to efficiently remove non-condensables from the condenser with least loss of refrigerant, a purger 82 is preferably employed. In Fig. 1 the purger is schematically illustrated and for details of it not contained in this description reference is made to the patent to Buehler, 2,062,697.

In brief, non-condensables from the second pass of the condenser flow through conduit 62 and valve 83 therein and into the lower portion of shell 84. Shell 84 is cooled by coil 85 which receives refrigerant from line 86. Line 86 has an expansion valve 87, an electrically controlled shutoff valve 88, and a manual valve 89 and is attached to the liquid line 47 from the condenser. A liquid return line 90 has one end attached to the lower portion of the shell and the other to the refrigerant line 86 between the expansion valve 87 and the electrically controlled valve, a manual shutoff valve 91 being provided in the line 90. The expansion valve is controlled by a conventional sensing bulb 92 on the discharge line 93 of the coil 85. The level of liquid within the shell 84 is controlled by the float 94.

Due to the cooling of the shell 84 and condensation taking place, the liquid level therein will gradually rise, the pressure in the shell being less than in the line 86 to which the line 90 is connected as a result of the cooling of the shell. As the non-condensable gases collect in the top of the shell 84 the liquid is forced downwardly through the conduit 90. When the liquid drops below the half-way point, float switch 94 causes valve 95 on the purger escape line 96 to open, thus permitting non-condensables to escape. Both valves 95 and 89 are connected to a control circuit to the compressor (not shown) so that they remain closed at all times during non-operation of the compressor.

The evaporator

Referring particularly to Figs. 1, and 6 through 9, the evaporator includes an outer cylindrical, horizontal shell 100 having an intake connection 101 located intermediate the ends and spaced a few degrees from the lowermost portion thereof as shown in Fig. 9. The discharge connection 102 is located intermediate the ends and in the uppermost portion of the shell. End plates 103 and 104 enclose the ends of the shell and receive a plurality of spaced tubes 105 which engage the end plates in the conventional manner.

Within the shell and between the end plates a plurality of baffles are mounted, the baffles being attached by welding or the like to the shell and end plates. The lowermost baffle 106, as viewed in Fig. 9, has its left side attached to the shell just above the intake opening and extends across the lower portion of the shell at a slight angle above the horizontal. The baffle extends the full length of the shell and has its ends attached to the end plates 103, 104. The opposite side of the baffle is spaced from the wall of the shell to permit flow thereby. Liquid

refrigerant entering the intake of the evaporator is initially restrained within the space 107 defined by the baffle 106 and the portion of the shell thereunder.

A second baffle 108 has its right longitudinal edge attached to the shell just above the portion of the shell which baffle 106 would intersect if extended. Baffle 108 extends across the shell and slopes slightly above the horizontal similarly to baffle 106, space 109 being between the baffles. The opposite side of baffle 108 is spaced from the wall of the shell to permit the flow of refrigerant therearound.

Similarly, baffles 110, 111, 112, and baffle or partition 113 extend from alternate sides of the shell and slope slightly above the horizontal. The baffles are so arranged and spaced that the space 109 contains more tubes than space 107; the space 114, between baffle 110 and 108 contains more tubes than space 109. Similarly, the succeeding spaces 115, 116, and 117 each house progressively larger numbers of tubes.

Partition 113 is attached at both of its sides to the shell, its ends being attached to the end plates. The partition has a multiplicity of openings 118 which are preferably formed by punching the partition from its top side in order to create the raised edge portions 119. The raised edge portions trap liquid which is entrained in the refrigerant gas as it impinges on the partition, the partition thus serving both as an eliminator and as a gas distributor means.

The evaporator shell has heads 120 and 121 at the ends thereof for controlling the flow through the tubes 105 of the fluid to be cooled. The head 120 has an inlet 122 at its uppermost portion and an outlet 123 at its lowermost portion. Between the outlet and inlet baffles 124, 125, and 126 extend diagonally across the head in coincidence with the baffles 112, 110, and 106 respectively between the end plates. The head 121 similarly has baffles 127 and 128 which extend diagonally thereacross and in coincidence with the baffles 111 and 108, respectively, between the end plates.

In the operation of the evaporator liquid refrigerant enters the inlet 101 and is initially restrained in space 107 beneath the baffle 106. The liquid refrigerant flows from the inlet across the lower portion of the shell in a slightly upward direction, the flow being substantially at right angles to the axis of the tubes. From the space 107 the liquid refrigerant and any that has gasified flows around the right edge of baffle 106 and into space 109 between the baffle 108 and 106. From this space the liquid refrigerant and gas zig-zag upwardly back and forth across the shell until they reach the partition 113 at which liquid is removed from the refrigerant before it escapes through the discharge 102.

Because of the slope of the baffles the tubes positioned near the lowermost portion of the upper side of each of the baffles may be flooded by liquid carried along by the evaporated gases, the number of the tubes in each space which are flooded depending on the level of liquid contained on the top surfaces of each baffle at any given instant. It will be seen therefore that the baffle arrangement provides for a natural upward flow of relief gas and, at the same time, a flooding of the lower tubes in each space. Such baffling provides for a semi-flooded, high velocity refrigerant flow without the excessive pressure drop which is found in a non-baffled open type flooded shell.

Because of the arrangement of the baffles between the end plates and the baffles in the heads the fluid to be cooled enters the tubes at the upper portion of the shell, namely those in the space 117, flowing first through these tubes and then back through the tubes in the space 116, and so on, progressively through the tubes in the spaces 115, 114, 109, and 107 in counterflow to the refrigerant. The successive passes of the fluid being cooled is thus arranged to provide a true counterflow proportioned to the heat exchange value of the tubes in each of the spaces.

Although the construction illustrated discloses six passes, the invention is not restricted to any particular number thereof as it is obvious that various numbers may be employed within the scope of the invention.

Although a particular embodiment of the invention has been described, it will be apparent to those skilled in the art that various modifications and substitutions are within the scope thereof and therefore the invention is not limited to the specific embodiment but only as defined in the following claims.

What is claimed is:

1. In a condenser, a cylindrical shell, a first tube bundle in the upper portion of the shell, a first distributor plate beneath the first tube bundle, said plate extending horizontally from one side of the shell to a position adjacent the other side of the shell, means maintaining a minimum depth of condensate on the plate, a second tube bundle beneath the first, a partition plate over the second tube bundle and connected at one side edge to the distributor plate and at the other to the shell and angularly disposed to the distributor plate, means for admitting refrigerant to the shell between the distributor plate and the partition plate, a second distributor plate mounted horizontally beneath the second tube bundle, means directing flow from the first tube bundle around the first distributor plate to beneath the second distributor plate, means maintaining a minimum depth of condensate on the second distributor plate, outlet means, and means for preventing the flow beneath the second distributor plate from passing directly to the outlet means.

2. In a condenser, a cylindrical shell, a first tube bundle in the upper portion of the shell, a first distributor plate beneath the first tube bundle, said plate having a first side attached to a wall of the shell and a second side spaced from the opposite wall of the shell, means maintaining a minimum depth of condensate on the plate, a second tube bundle beneath the first, a partition plate over the second tube bundle and connected at one edge to the first side of the distributor plate and at the other to the shell beneath said second side, said partition plate being angularly disposed to the distributor plate, means for admitting refrigerant to the shell between the distributor plate and the partition plate, a second distributor plate beneath the second tube bundle, means directing flow from the first tube bundle around the first distributor plate to beneath the second distributor plate, means maintaining a minimum depth of condensate on the second distributor plate, outlet means, and means for preventing the flow beneath the second distributor plate from passing directly to the outlet means.

3. In a condenser, a cylindrical shell, a first tube bundle in the upper portion of the shell, a first distributor plate beneath the first tube bundle, said plate having a first side attached to a wall of the shell and a second side spaced from the opposite wall of the shell, a second tube bundle beneath the first, a partition plate over the second tube bundle and connected at one side edge to the second side of the distributor plate and at the other to the shell beneath said first side, said partition plate being angularly disposed to the distributor plate, means for admitting refrigerant to the shell between the distributor plate and the partition plate, a second distributor plate beneath the second tube bundle, means directing flow from the first tube bundle around the first distributor plate and beneath the second distributor plate, outlet means, and means for preventing the flow beneath the second distributor plate from passing directly to the outlet means.

4. The structure of claim 3, means for permitting non-condensables in the upper portion of the shell in prox-

imity to the first tube bundle to escape to the upper portion of that part of the shell containing the second tube bundle, said means comprising a tube having its lower end in engagement with the partition plate and in communication with the space therebeneath, and extending upwardly through the first distributor plate to the upper portion of the shell, and means for permitting non-condensables to escape from that part of the shell containing the second tube bundle.

5. The structure of claim 3, the distributor plates having a multiplicity of spaced apertures and raised edges above the apertures in order to facilitate the collection of liquid on the distributor plates.

6. The structure of claim 3, the distributor plates each having a weir flange along their second side for maintaining a minimum level of liquid thereon.

7. The structure of claim 3, the shell having an end plate and a head at each end thereof, baffle means in each head between the head and the end plate, inlet and outlet means in the heads, the baffles being so constructed and arranged that the flow of the cooling fluid through the tube bundle is substantially counter to the flow of the refrigerant.

8. The structure of claim 3, the shell having an end plate and a head at each end thereof, baffle means in each head between the head and the end plate, inlet and outlet means in the heads, one head having a vertical partition substantially bisecting the head and a horizontal partition extending from the central portion of the vertical partition to one side only of the head, the other head having a horizontal partition substantially bisecting it.

9. In a heat exchanger condenser, a first tube bundle, a first distributor plate therebeneath and having a plurality of spaced apertures, means directing incoming gas to be condensed to the underside of said first distributor plate, a second tube bundle, a second distributor plate therebeneath and having a plurality of spaced apertures, said second distributor plate being positioned at a lower level than said first tube bundle, means directing uncondensed gas and the flow of condensed liquid from the first tube bundle to the underside of said second distributor plate for flow upwardly therethrough, an outlet, and means directing condensed liquid from above said second distributor plate to said outlet, said last mentioned means including separator means above said second tube bundle and preventing the passage of gas or liquid into the space with the incoming gas beneath said first distributor plate.

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