Oct. 11, 1955 H. E. JACOBY 2,720,259

GAS VENTING OF HEAT EXCHANGERS

Filed April 14, 1950 2 Sheets-Sheet 1

Fig. 1.

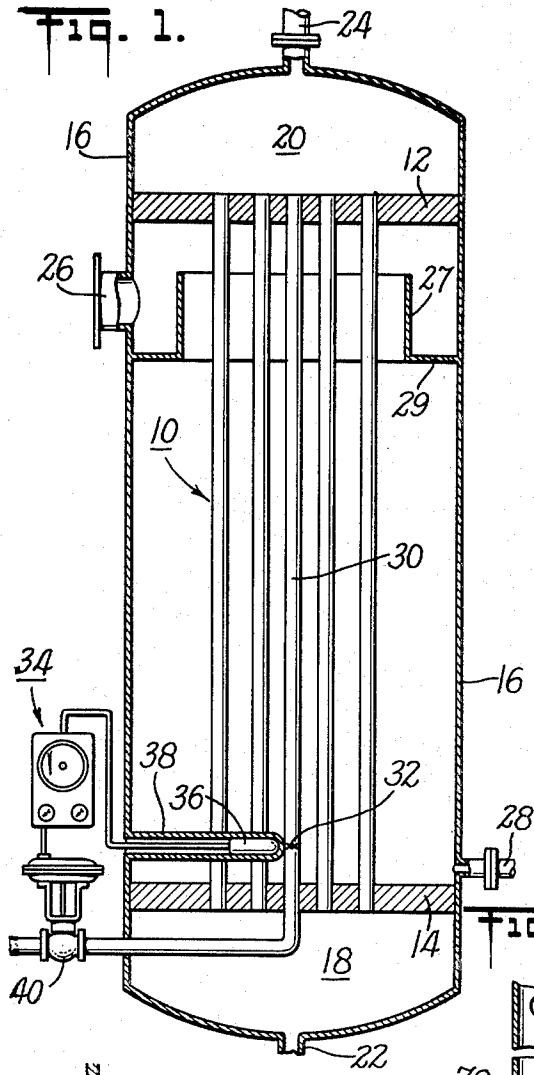


Fig. 2.

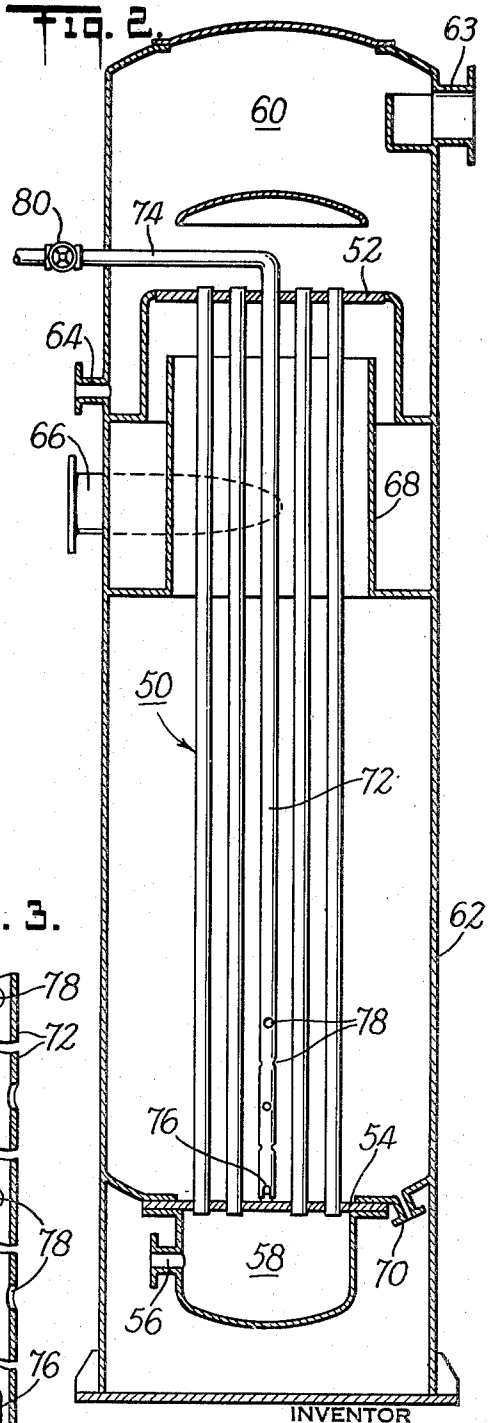


Fig. 3.

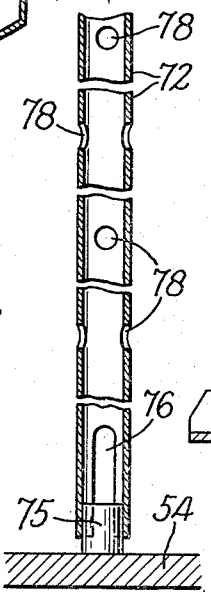
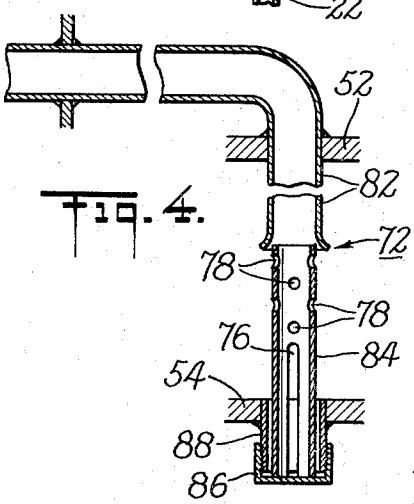


Fig. 4.



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Fig. 5.

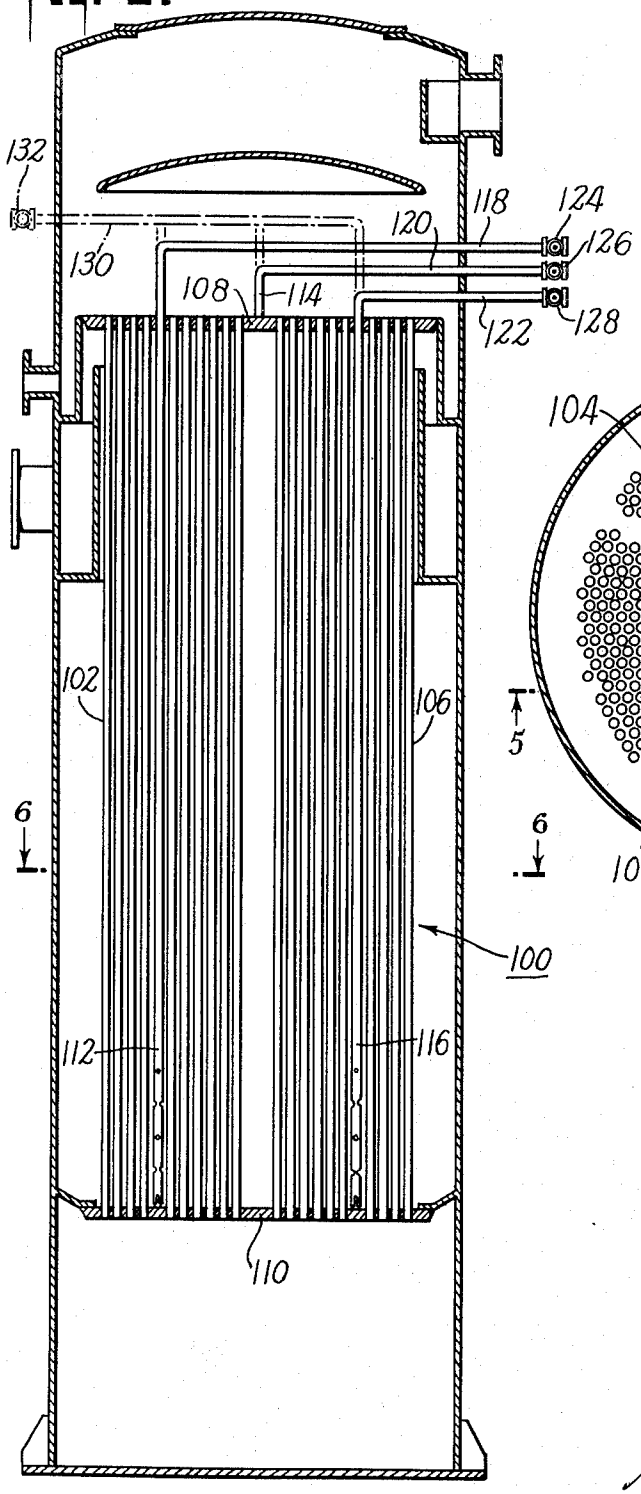
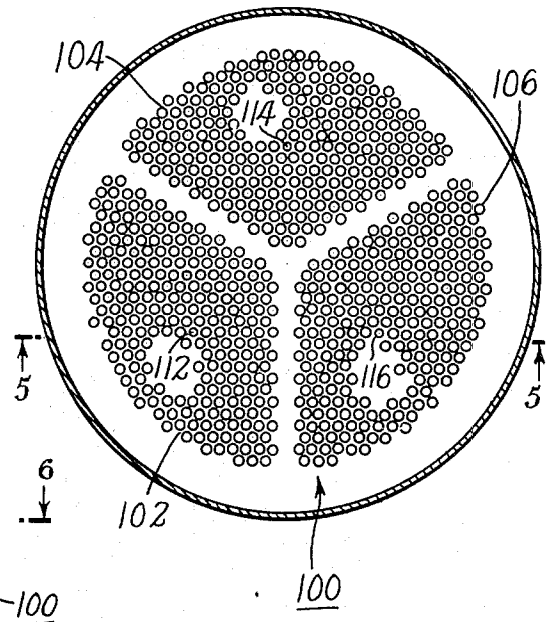


Fig. 6.



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GAS VENTING OF HEAT EXCHANGERS

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Application April 14, 1950, Serial No. 155,848

8 Claims. (Cl. 159—27)

This invention relates to heat exchangers and more particularly to improved means for removing non-condensible gases from a heat exchanger, e. g., the heating element of a tubular evaporator. This application is a continuation-in-part of my copending application, Serial No. 712,810, filed November 29, 1946, now abandoned.

Heat exchangers of the type with which the present invention is concerned normally comprise a plurality of tubes arranged in a tube bundle and mounted at their ends in a pair of tube sheets. The tube bundle and associated tube sheets are encased in a shell or other suitable housing. The medium which is to be heated is caused to flow through the interior of the tubes and a heating medium comprising a condensible vapor is introduced into the shell and is caused to condense on the external surfaces of the tubes thereby delivering heat to the tubes and through the tube walls to the heated medium within the tubes. Heat exchangers of this type are commonly referred to as tube-in-shell heat exchangers and may be separate self-contained units or they may be heating elements incorporated in process equipment such as evaporators, crystallizers, re-boilers, waste heat boilers, and the like.

The steam or other condensible heating medium used in such a heat exchanger normally contains a small proportion of non-condensible gas and as the condensible vapors condense, the proportion of gas in the vapor-gas mixture tends to increase. If this non-condensible gas is not removed it tends to produce gas binding of the heating surface, i. e., it tends to blanket portions of the heating surface in such manner as to prevent fresh high quality steam from coming in contact with those surfaces. Hence it is essential for efficient operation that this non-condensible gas be effectively removed.

It has therefore been the practice to introduce the steam or other condensible heating medium at one point on the periphery of the shell of the heat exchanger and to attempt to remove non-condensible gases at another point on the periphery of the shell spaced from the point of admission of the heating medium. For example, in cases where the heat exchanger is arranged with its tubes in vertical position, steam has been admitted to the shell or casing of the heat exchanger at a point near the top of the tube bundle and non-condensible gas mixed with steam has been removed at a point on the periphery of the heat exchanger opposite the lower end of the tube bundle. This previous practice is objectionable from several points of view. Since the non-condensible gases are withdrawn at the periphery of the tube bundle there will be within the tube bundle a central core or cone of gas that is relatively inactive. This inactive core of non-condensible gas will accumulate around the central tubes of the heat exchanger and thus substantially reduce the effective heating surface available for heat transfer.

A further disadvantage of the usual venting arrangement is that it permits the incoming vapors to flow directly from their point of admission to the point of venting. Normally the shell or housing of the heat exchanger is appreciably spaced from the tube bundle and there is thus an annular space between the inner surface of the shell and the tube bundle which offers relatively little resistance to the flow of vapors. Since vapors will tend to flow at a higher rate through channels that offer less resistance to flow, an appreciable proportion of the incoming heating medium may flow through this annular space directly to the fixed gas vent and thereby bypass the heating surfaces of the heat exchanger. Thus the steam content of the vented gas is increased and the heating efficiency of the heat exchanger reduced.

In order to overcome this difficulty it has been proposed that the center tube of the exchanger be omitted and that fixed gases be withdrawn at a point on or near the axis of the tube bundle. However, when the center tube is omitted a space is left at the center of the tube bundle through which channeling of the vapors can occur and hence, an excessive amount of steam is withdrawn from the heat exchanger with the fixed gases.

It is accordingly an object of the present invention to provide an improved method of removing non-condensible gases from a heat exchanger. It is another object of the invention to provide fixed-gas removal means which when incorporated in the heat exchanger increases the efficiency of heat transfer therein. It is still another object of the invention to provide fixed-gas removal means that minimizes steam losses with the fixed gas. Other objects of the invention will be in part obvious and in part pointed out hereinafter.

The many objects and advantages of the present invention may best be appreciated by referring to the accompanying drawing which illustrates apparatus incorporating a preferred embodiment and a modification of the invention and wherein:

Figure 1 is a vertical sectional view of a self-contained heat exchange unit incorporating the apparatus of the present invention;

Figure 2 is a vertical sectional view of an evaporator having incorporated therein a heat exchanger embodying a modification of the present invention;

Figure 3 is an enlarged detailed view of the fixed-gas removal tube shown in Figure 2;

Figure 4 is a view similar to Figure 3 but showing a tube having a section that is detachable for cleaning;

Figure 5 is a vertical section of an evaporator body similar to that of Figure 2 but having a heat exchanger with three spaced tube bundles; and

Figure 6 is a horizontal section taken on the line **6—6** of Figure 5 and illustrating the central arrangement of the vent tube in each of the several tube bundles.

Referring to the drawings, and more particularly to Figure 1 thereof, the numeral **10** designates a tube bundle comprising a plurality of tubes (only a few of which are shown in Figure 1) arranged in a cylindrical bundle and mounted at their upper ends in the tube sheet **12** and at their lower ends in the tube sheet **14**. Surrounding the tube bundle **10** and tube sheets **12** and **14** there is a shell or casing **16** that extends beyond the ends of the tube bundle to form with the lower tube sheet **14** an inlet chamber **18** and with the upper tube sheet **12** an outlet chamber **20**. The fluid to be heated is admitted through the inlet pipe **22** to the chamber **18** and flows through the tubes of tube bundle **10** wherein it is heated by condensation of a condensible heating medium outside the tubes. The heated fluid then flows into outlet chamber **20** and leaves the exchanger through outlet pipe **24**.

Steam or other condensible vapor is admitted to the exchanger through an inlet pipe **26** and flows into contact with the tubes of tube bundle **10** and in a generally down-

ward direction along the tubes in such manner that it condenses on the tube surfaces and gives up its latent heat which is transferred to the heating medium within the tubes. In the upper part of the exchanger there is provided a cylindrical baffle **27** mounted on an annular plate **29** fixed to the inner surface of the shell **16**. The baffle **27**, plate **29** and shell **16** cooperate to define an annular passage through which the inlet steam may flow before coming into contact with the tubes of the tube bundle. The baffle **27** operates to prevent inlet steam from impinging directly on the tube bundle and to improve the distribution of steam around the periphery of the tube bundle. Condensate is removed near the bottom of the tube bundle through condensate pipe **28**.

As previously pointed out the condensible heating medium normally contains a small proportion of non-condensible gases. To effect removal of such gases the tube bundle **10** is provided at its center with a vent pipe **30** which extends between the tube sheets **12** and **14** in a manner similar to the other tubes of the tube bundle but is blanked off at one end (in this case the upper end) so that gases may flow from only one end of the tube. The open end of vent tube **30** passes through the tube sheet **14**, chamber **18** and shell **16** out of the exchanger. At a point near the lower end of the tube bundle the vent tube **30** is provided with one or more holes **32** through which gas may flow into the vent tube and thence out of the heat exchanger.

In order to regulate the removal of condensible gas an automatic controller **34** is provided which may be of the conventional pneumatic type and may comprise a temperature responsive element **36** located in a thermometer well **38** near the point at which the non-condensible gases enter the vent tube **30**, a pneumatically operated regulating valve **40** and the controller **34** proper, which positions the valve to maintain the exit gases at a predetermined temperature. Since the temperature of the exit vapors varies in accordance with the steam content thereof the temperature controller may be so adjusted as to maintain the steam content of the exit vapors at a desired predetermined value and thus minimize the steam losses in the vented gas.

With the construction shown in Figure 1, bypassing of steam from the steam inlet to the vent gas outlet is precluded since all of the steam must necessarily come in contact with the tube bundle before it reaches the vent gas outlet. Furthermore, there is no chance for an inactive core of non-condensible gas to build up within the exchanger as would be the case if the vent gas were removed from the periphery of the exchanger rather than at a point near the longitudinal axis of the exchanger. Also since the spaces between the vent pipe **30** and adjacent heating tubes are substantially the same as the spaces between adjacent heating tubes, there is no reduced pressure drop path through which channeling of steam can occur to increase the proportion of steam in the vent gas and thereby reduce the heating efficiency of the exchanger.

Referring now to Figure 2 of the drawings, there is illustrated in this figure an evaporator of the general type disclosed in my co-pending U. S. application, Serial No. 650,468, filed February 27, 1946, now Patent 2,544,885, but provided with a vent tube constructed and arranged in accordance with the present invention. The evaporator of Figure 2 is provided with a tube bundle **50** similar to the tube bundle **10** of Figure 1, and extending between the upper tube sheet **52** and lower tube sheet **54**. The medium to be heated, e. g., a solution that is to be evaporated, enters at the bottom of the evaporator through a connection **56** and passes through a chamber **58** and the tubes of the tube bundle **50** to a vapor disengaging space **60** defined by the shell **62** and upper tube sheet **52**, thence out of the evaporator through a connection **63**. Concentrated liquor leaves the evaporator body through a discharge connection **64**. Condensible vapor, which may be either steam or water vapor that has been vaporized in a previous effect, enters the heat exchange portion of the evaporator through a tangential connection **66** and comes into contact with the tubes in the tube bundle **50**. The vapor flows over the top of a baffle **68** and along the tubes of the tube bundle in a generally downward direction and condenses to give up its latent heat to the fluid within the tubes. Condensate is removed near the bottom of the tube bundle through the connection **70**.

As in the structure of Figure 1, as the vapors condense fixed gas tends to accumulate in the lower central portion of the tube bundle. To remove this fixed gas a central tube **72** is provided that extends between and is mounted at its ends in the tube sheets **52** and **54**. The upper end of tube **72** is connected by a conduit **74** extending through the vapor space **60** to the exterior of the shell **62**.

Referring now to Figure 3, the lower end of tube **72** is closed by a plug **75** which acts as a guide and anchor to secure the lower end of the vent tube in desired position with respect to the tube sheet. Formed in the side wall of tube **72** near the lower end thereof, there is a drain slot **76** through which any condensate forming within the tube **72** will drain into the vapor space of the heat exchanger and be removed through the connection **70**. The lower portion of tube **72** is also provided with vertically spaced pairs of aligned openings **78**, alternate pairs of openings being located at right angles to one another. Fixed gases pass through the openings **78** and thence through conduit **74** to the exterior of the evaporator body. The pairs of aligned openings are arranged at right angles to one another to provide more uniform removal of the fixed gas. The vertical spacing of the openings is such that fixed gas may flow to the interior of the tube **72** even though a certain amount of sludge and/or condensate has accumulated at the bottom of the tube bundle. Removal of the fixed gas through tube **72** may be manually regulated by means of a valve **80** in the conduit **74**.

In certain cases, as for example, where the heat exchange portion of the evaporator is "boiled out" to remove accumulated solids from the outer surfaces of the tubes of the tube bundle, the quantity of solids collecting at the bottom of the tube bundle may be sufficient to plug up the holes **78** and in such cases it is desirable to provide some means whereby at least a portion of the vent tube may be removed for cleaning. A structure adapted to accomplish this purpose is shown in Figure 4. Referring to Figure 4, the vent tube **72** is formed in two telescoping sections comprising an upper section **82** that is mounted in upper tube sheet **52** and a lower section **84** supported from the lower tube sheet **54**. The lower section **84** is provided with drain slot **76** and vent holes **78**, as in Figure 3, and rests on the inner surface of a cap **86** threaded onto a nipple **88** secured to the lower tube sheet **54**. When it is desired to clean the holes **78** the cap **86** is removed and the section **84** is withdrawn from the tube bundle. After cleaning the section **84** and cap **86** are replaced. The lower end of upper section **82** is flared outwardly to facilitate re-insertion of section **84** therein. It will be noted that in the embodiment of Figure 2, the vented gas is withdrawn through the upper end of the vent tube, whereas in Figure 1 the vent gas is withdrawn through the lower end of the vent pipe. Removal of the vent gas through the upper end of the vent pipe is usually preferable since it precludes accumulation, in the fixed gas removal conduit, of a body of condensate which may interfere with a smooth flow of the withdrawn vent gas.

From the foregoing description it will be seen that the apparatus of the present invention increases the efficiency of utilization of the heating surface within a heat exchanger and reduces steam losses due to venting of the non-condensible gases from the heat exchanger. By locating the vent gas outlet near the center of the tube bundle dead spaces within the heat exchanger are eliminated and there is no chance for a core or cone of non-condensible gas to build up and blanket the heating sur-

face of the tube bundle. Furthermore, all of the entering condensible vapors must pass through some portion of the tube bundle before they reach the vent gas outlet and therefore bypassing of steam directly to the vent gas outlet is reduced. Also the special arrangement of the vent pipe in the tube bundle is such that there is no reduced pressure drop path between the vapor inlet and vent gas outlet permitting bypassing or channeling of the condensible vapor. Removal of the vent gas may be controlled by a temperature controller as disclosed or by a controller directly responsive to the water content of the vapors or in other suitable ways to minimize steam losses through the vent line. The present vent system is particularly useful in vertical tube bundles, although it may also be used in horizontal tube bundles as well.

It is to be understood that the foregoing description is illustrative only and that various modifications may be made within the scope of the invention. For example, the tubes within the heat exchanger may be arranged in a number of individual bundles instead of a single bundle and the individual bundles may be separated from one another by a baffle or wall or merely by an open passage. In such a case it is desirable that vent gas pipes be provided near the central longitudinal axes of the separate bundles within the exchanger.

This modification is illustrated in Figures 5 and 6 of the drawings. Referring to these figures, the heat exchanger **100** of the evaporator body there shown is composed of three spaced tube bundles **102**, **104** and **106** that are supported at their ends in the tube sheets **108** and **110**. It is evident that the exchanger **100** may be composed of any number of tube bundles greater than one and three are shown for illustrative purposes only.

Near the center of each of the tube bundles **102**, **104** and **106** are the vent tubes **112**, **114** and **116** respectively which are similar in construction to each other and to the tube **72** of Figure 2. The three vent tubes are closed at their lower ends and connected at their upper ends to the pipes **118**, **120** and **122** respectively which lead through the evaporator body and are provided externally thereof with regulating valves **124**, **126** and **128** respectively. If desired the three vent tubes can be connected within the evaporator body to a manifold **130**, shown in dotted lines in Figure 5, which is provided outside the evaporator with a regulating valve **132**.

It is evident that the vent tubes **112**, **114** and **116**, due to their central location within their respective tube bundles, function in the same manner as tube **72** of Figure 2. In order to reach the vent tube in each bundle, condensible vapor must pass through the other tubes of the bundle and hence by-passing of condensible vapor to the vent is avoided. Moreover the vent tubes extend from one tube sheet to the other and hence channeling of the condensible vapors along the axes of the tube bundles is eliminated. Other modifications within the scope of the invention will be apparent to those skilled in the art.

What is claimed is:

1. In heat exchange apparatus of the tube-in-shell type, in combination, a pair of spaced tube sheets, a plurality of tube bundles mounted in said tube sheets and each having a length substantially greater than its diameter, a shell encasing said tube bundles, a vapor inlet connection near one end of said shell and remote from the other end thereof for introducing into said shell condensible vapor to flow along said tubes and be condensed on the exterior surface thereof, said vapor containing a small proportion of fixed gas, a condensate removal conduit in said shell, fixed-gas removal tubes located one each near the centers of each of said tube bundles and extending substantially from one of said tube sheets to the other tube sheet, the walls of said gas removal tubes at the ends of said tubes most remote from said inlet connection being provided, within said shell, with one or more openings and a conduit connecting one end of each of said gas removal tubes with the exterior of said shell, whereby fixed gas may pass through said tubes and conduit to the exterior of said shell.

2. In heat exchange apparatus of the tube-in-shell type, in combination, a tube bundle having tubes mounted in a pair of spaced tube sheets and having a length substantially greater than its diameter, a shell encasing said tube bundle, a vapor inlet connection near one end of said shell and remote from the other end thereof for introducing into said shell a condensible vapor to flow along said tubes and be condensed on the external surfaces thereof, said vapor containing a small proportion of fixed gas, a condensate removal connection in said shell, a fixed gas removal tube located at the longitudinal axis of said tube bundle and extending substantially from one of said tube sheets to the other tube sheet, the wall of said tube near the end most remote from said inlet connection being provided, within said shell, with one or more openings, a conduit connecting one end of said tube with the exterior of said shell, whereby fixed gas may pass through said tube and conduit to the exterior of said shell, and means responsive to the temperature of said condensible vapor near said opening for controlling the rate of removal of said fixed gas.

3. In heat exchange apparatus of the tube-in-shell type, in combination, a tube bundle having tubes mounted in a pair of spaced tube sheets and having a length substantially greater than its diameter, a shell encasing said tube bundle, a vapor inlet connection near one end of said shell and remote from the other end thereof for introducing into said shell a condensible vapor to flow along said tubes and be condensed on the external surfaces thereof, said vapor containing a small proportion of fixed gas, a condensate removal connection in said shell, a fixed gas removal tube located near the center of said tube bundle and extending substantially from one of said tube sheets to the other, said gas removal tube being formed in two sections and the section more remote from said inlet connection being provided, within said shell, with one or more openings, the gas removal tube section containing said openings being detachable from said tube bundle for cleaning, and a conduit connecting one end of said gas removal tube with the exterior of said shell.

4. An evaporator body comprising in combination a tube bundle having vertically arranged tubes mounted in a pair of spaced horizontal tube sheets, the length of said tube bundle being substantially greater than its diameter, a shell encasing said tube bundle and defining with the upper of said tube sheets a vapor disengaging space, a vapor inlet connection to said shell near the upper end of said tube bundle and remote from the lower end thereof for introducing into said shell a condensible vapor to flow downwardly along said tubes and be condensed on the exterior surfaces thereof, said vapor containing a small proportion of fixed gas, a condensate removal connection in said shell near the lower end of said tube bundle, a fixed gas removal tube located near the center of said tube bundle and extending substantially from one of said tube sheets to the other, said gas removal tube being formed in two sections and the lower section being provided with one or more openings, said lower section being removable through said lower tube sheet for cleaning, and a conduit connected to the upper end of said gas removal tube and extending through said vapor disengaging space to the exterior of said shell whereby fixed gas may pass through said gas removal tube and conduit to the exterior of said shell.

5. In heat exchange apparatus of the tube-in-shell type, in combination, an elongated tube bundle having tubes mounted in a pair of spaced horizontal tube sheets, an elongated shell encasing said tube bundle, a vapor inlet connection in said shell near the upper end of said tube bundle for introducing into said shell a condensible vapor to flow axially along said tubes and be condensed on the

exterior surfaces thereof, said vapor containing a small proportion of fixed gas, a condensate removal connection in said shell near the lower end of said tube bundle, a fixed gas removal tube located at the longitudinal axis of said tube bundle and extending from one of said tube sheets to the other tube sheet, the lower end only of said gas removal tube being provided within said shell with one or more openings and a conduit connecting one end of said gas removal tube with the exterior of said shell, whereby fixed gas may pass through said tube and conduit to the exterior of said shell.

6. Heat exchange apparatus according to claim 5 and wherein said conduit connects the upper end of the gas removal tube with the exterior of said shell.

7. Heat exchange apparatus according to claim 6 and wherein the lower end of the gas removal tube is closed and provided within said shell with a drain slot for removal of condensate therefrom and the lower portion of the wall of said tube above said drain slot is provided with

vertically spaced pairs of horizontally aligned openings with alternate pairs of openings being located at right-angles to one another.

8. Heat exchange apparatus according to claim 5 and wherein said conduit connects the lower end of said gas removal tube with the exterior of said shell.

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