Jan. 17, 1967 J. W. ALDEN, JR 3,298,358

VERTICAL STEAM GENERATOR WITH A CENTRAL DOWNCOMER

Filed Dec. 30, 1964 2 Sheets-Sheet 1

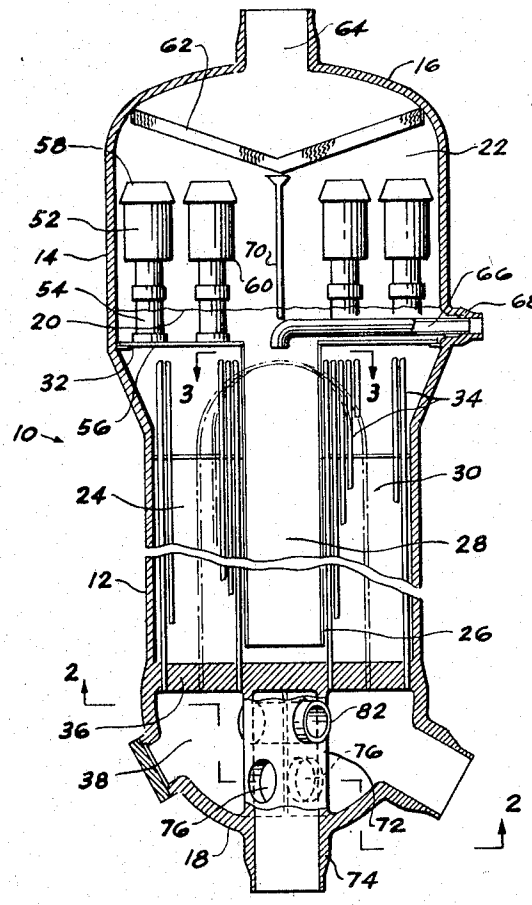


FIG-1

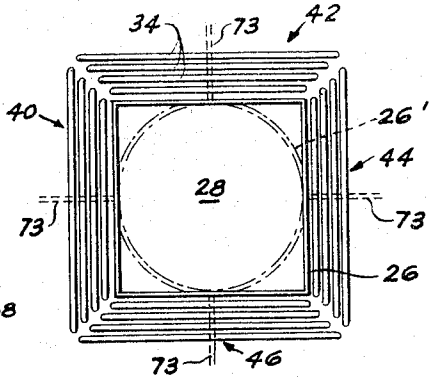


FIG-3

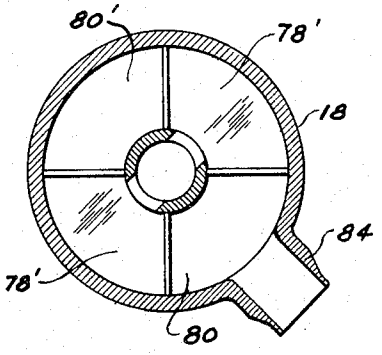


FIG-5

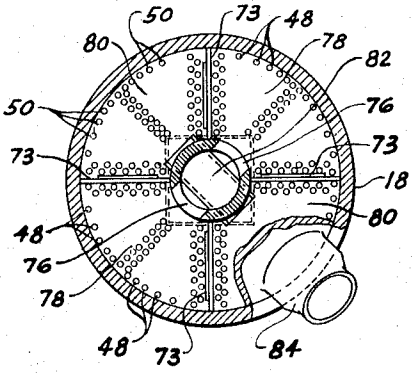


FIG-2

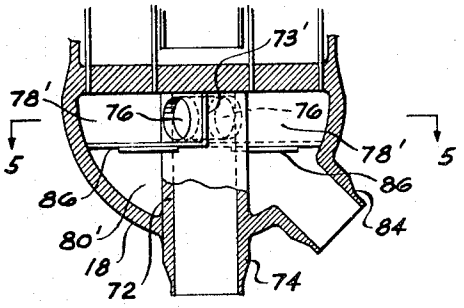


FIG-4

JOHN W. ALDEN JR.
INVENTOR
BY John F. Carney
ATTORNEY

Jan. 17, 1967 J. W. ALDEN, JR 3,298,358

VERTICAL STEAM GENERATOR WITH A CENTRAL DOWNCOMER

Filed Dec. 30, 1964 2 Sheets-Sheet 2

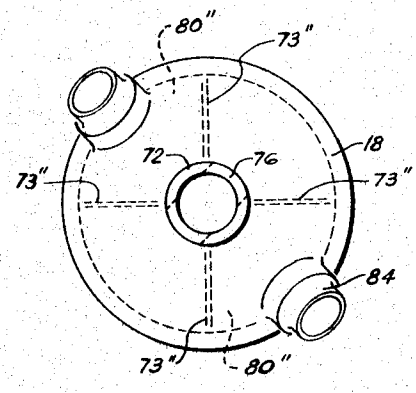


FIG. 7

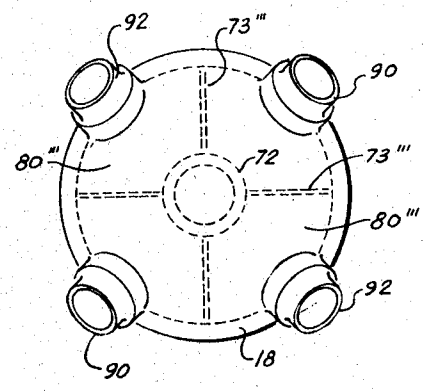


FIG. 9

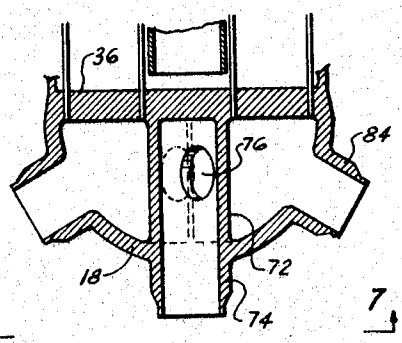


FIG. 6

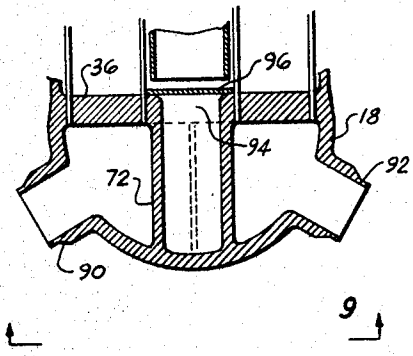


FIG. 8

JOHN W. ALDEN JR.
INVENTOR
BY John F. Carney
ATTORNEY

United States Patent Office 3,298,358 Patented Jan. 17, 1967

3,298,358

VERTICAL STEAM GENERATOR WITH A CENTRAL DOWNCOMER

John W. Alden, Jr., Chattanooga, Tenn., assignor to Combustion Engineering, Inc., Windsor, Conn., a corporation of Delaware

Filed Dec. 30, 1964, Ser. No. 422,298
16 Claims. (Cl. 122—34)

The present invention relates generally to a vapor generating unit of the shell and tube type in which heat is supplied by a heating fluid flowing through the tubes. More particularly, it relates to a shell and tube type vapor generating unit in which the tubes that conduct the heating fluid are U-tubes that are arranged in separate tube bundles with the tube bundles being located in circumferentially spaced positions about a central downcomer to form an annular vapor generation chamber.

In modern-day industries, such as petroleum refining, chemical manufacture and nuclear energy, there are available high temperature fluids from which heat may be extracted for useful purposes. The present invention is directed to a vapor generating unit which is operable to extract heat from such high temperature fluids for the purpose of transforming a vaporizable liquid into vapor. The unit is specifically arranged to occupy a minimum amount of space while transferring large quantities of heat. Moreover, the tubes that conduct the heating fluid are arranged in such a manner as to provide a large amount of heating surface within a minimum amount of space relative to heretofore known arrangements thereby enhancing the over-all economy of the unit. It is contemplated by this invention to arrange the U-tubes that provide the means for conducting heating fluid in separate groups or tube bundles that are arranged about a centrally located downcomer reservoir that is formed by plate means that coact with the wall of the vessel to form an interior downcomer reservoir and an exterior vapor generation chamber. In units of heretofore known design having conventionally arranged tube bundles it was impossible to employ a central downcomer reservoir without having to eliminate a wide swath of tubes to accommodate the plate means that form the reservoir. By means of the invention the tubes of the unit are so arranged as to conveniently provide for the mounting of such plate means without having to eliminate useful heating surface. Moreover, the tube bundles in the present unit are disposed such that the inlet ends and the outlet ends of the tubes of adjacent tube bundles are positioned adjacent one another such that the heating fluid chamber can be conveniently compartmentized in a manner as to obtain efficient separation of hot heating fluid and spent heating fluid within the chamber.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter wherein is described and illustrated the preferred embodiments of the invention.

In the drawings:

FIGURE 1 is a vertical side section of one embodiment of the present invention;

FIGURE 2 is a plan section taken along line 2—2 of FIGURE 1;

FIGURE 3 is a section taken along line 3—3 of FIGURE 1;

FIGURE 4 is a partial vertical section showing a modified form of heating fluid chamber;

FIGURE 5 is a section taken along line 5—5 of FIGURE 4;

FIGURE 6 is a partial side section of another embodiment of the heating fluid chamber;

FIGURE 7 is a plan section taken along line 7—7 of FIGURE 6;

FIGURE 8 is a partial vertical side section of yet another embodiment of the heating fluid chamber; and

FIGURE 9 is a plan section taken along line 9—9 of FIGURE 8.

The vapor generating unit **10** comprises a vertically elongated pressure vessel including a cylindrical shell **12** and an integral vapor drum **14**. The vessel has an upper disc-shaped head **16** and a lower hemispherical head **18** closing the ends thereof. During normal operation of the vapor generating unit a body of liquid occupies a portion of the vessel establishing a liquid level **20** which forms an upper vapor space **22** and a lower liquid space **24**. Plate means including vertically disposed, rectangularly arranged baffle plates **26** in conjunction with the walls of the shell **12** coact to form an interior downcomer reservoir **28** and an exterior vapor generation chamber **30**. As shown in FIGURE 3 the rectangularly disposed baffle plates **26** can be replaced by a cylindrical baffle **26'** without departing from the inventive concept. Laterally disposed support plates **32** extend between the vessel wall and the plates **26** to support separator units **52**. The downcomer reservoir **28** is vertically elongated and of a cross sectional dimension that is less than the cross sectional dimension of the vessel shell **12**. Between it and the wall of the shell **12** is located the vapor generation chamber **30** that is substantially annular in shape and which houses a plurality of heating fluid conducting tubes **34** that substantially fill this chamber. The baffle plates **26** extend to substantially the bottom of the vapor generation chamber **30** but are spaced therefrom so as to provide fluid communication between the downcomer reservoir **28** and the vapor generation chamber.

A tube sheet **36** extends transversely across the bottom of the vapor generation chamber **30** integral with the wall of the shell **12** and forms a heating fluid chamber **38** in the bottom of the unit. The tubes **34** whose ends attach to the tube sheet **36** are generally U-shaped tubes that are arranged in rows lying in parallel planes that form separate tube bundles **40, 42, 44** and **46** with each tube bundle being shaped as shown best in FIGURES 2 and 3 as a truncated cylindrical segment and occupying substantially one quadrant of the vapor generation chamber **30**. As also shown in FIGURE 2 the tube bundles **40, 42, 44** and **46** are so arranged that the inlet ends **48** and the outlet ends **50** of all of the tubes in each tube bundle are arranged in groups with ends of tubes in adjacent tube bundles being grouped together to facilitate separation of incoming and outgoing heating fluid in the chamber **38**.

Such an arrangement of tubes has several manifest advantages. First of all, by positioning the tubes **34** in separate tube bundles that surround the central downcomer reservoir **28** there is achieved the economy of space that results from the elimination of the removal of a wide swath of U-tubes that would otherwise have to be removed in order to employ a central downcomer reservoir with a conventional tube bundle. With this arrangement therefore a greater amount of heating surface can be obtained from a unit of a given capacity. Secondly, in arranging the tube bundles such that the hotter inlet ends of all of the tubes in the unit are divided so as to occupy opposed quadrants of the vessel and likewise with the cooler outlet ends there is provided a more uniform generation of vapor throughout the transverse section of the unit that gives rise to more efficient use of separators

that are employed to separate the vapor-liquid mixture generated in the vapor generation chamber.

Within the vapor drum **14** that encloses the vapor space **22** is positioned a plurality of centrifugal separators **52** of known construction that are operable to separate the vapor and liquid components of the mixture generated in the vapor generation chamber **30**. The separators **52** are mounted in a double row atop the lateral support plates **32** in circumferentially spaced relation about the drum **14**. Vertical feed pipes **54** connect the separators **52** to the plates **32** and openings **56** in the plates establish fluid communication between the separators and the vapor generation chamber. The arrangement of the separators **52** is such that separated vapor passes out of the upper end thereof through corrugated steam scrubbers **58** into the vapor space **22** while separated liquid is discharged downwardly through liquid discharge openings **60** to the baffle plates **32** from whence it flows into the downcomer reservoir **28**. The vapor released into vapor space **22** is caused to flow through a screen dryer **62** that extends across the vapor outlet **64** where any entrained moisture can finally be removed prior to the vapor's passing out through the vapor outlet **64** to a point of use.

The makeup vaporizable liquid for the unit enters by the inlet pipe **66** that connects with nozzle **68** and directs the incoming liquid into the downcomer reservoir **28**. Liquid removed from the vapor by the secreen dryer **62** is discharged into the reservoir **28** by means of a discharge tube **70**.

As shown in FIGURE 1 the tube sheet **36** extends across the lower portion of the vessel and forms, along with the lower closure head **18**, the heating fluid chamber **38** that serves as the inlet and outlet manifold for the U-tubes **34**. A centrally located cylindrical conduit **72** aligned with the plate means **26** extends between, and attaches to, the tube sheet **36** and the inner surface of the closure head **18**. The conduit **72** is adapted to conduct heating fluid from source (not shown) to the heating fluid chamber **38** connecting to the source through an inlet nozzle **74**. Openings **76** in the conduit wall effect communication between the conduit and heating fluid compartments hereinafter described. The conduit **72** is further effective to strengthen the tube sheet **36** intermediate its peripheral edge in that it serves as a vertical staying device between the tube sheet **36** and the closure head **18**. By reason of this the required tube sheet thickness can be materially reduced.

The heating fluid chamber **38** is divided into fluid compartments by means of a plurality of vertically disposed, radially arranged divider plates **73** that are attached to the surface of the lower closure head **18**, the tube sheet **36** and the central conduit **72** thereby dividing the heating medium chamber into alternating heating fluid inlet and outlet compartments **78** and **80**, respectively, that serve as manifold devices for the inlet and outlet ends of the U-tubes. The central conduit openings **76** communicate with the heating fluid inlet compartments **78** for the purpose of supplying these compartments and the inlet ends **48** of the U-tubes **34** with heating fluid. The fluid that flows through the tubes of the tube bundles is deposited into the heating fluid outlet compartments **80** that communicate with the outlet ends **50** of the U-tubes. A cross-over pipe **82** penetrates the central conduit **72** and communicates at its end with the opposed outlet compartments **80** to direct the outlet fluid to a single compartment from whence it can be removed through the heating fluid outlet nozzle **84**.

In operation, feedwater is introduced to the unit through the feedwater nozzle **68** and feedwater pipe **66** and is discharged into the downcomer reservoir **28** from whence it flows into the vapor generation chamber **30** and there establishes a normal operating level **20**. At the same time heating fluid is supplied from a source (not shown) through the inlet nozzle **74** that connects with the cylindrical conduit **72** and passes through openings **76** therein into the opposed heating fluid inlet compartments **78** from whence it flows through the tubes **34** of the tube bundles **40, 42, 44** and **46**. After flowing through the tube bundles the heating fluid is discharged into the alternate heating fluid outlet compartments **80** from whence it is removed through the cross-over pipe **82** and outlet nozzle **84**, thereby recirculating through the source. The vaporizable liquid deposited into the vapor generation chamber **30** extracts heat from the heating fluid flowing through the U-tubes **34** and is transformed into a liquid-vapor mixture that flows through openings **56** in the plates **32** into vapor-liquid separators **52**. The separators **52** are arranged to deposit the vapor removed from the mixture into the vapor space **22** and the liquid therefrom into the downcomer reservoir **28** whence it is recirculated through the unit. The removed vapor is caused to flow through the screen dryer **62** where any mixture not removed by the separators is eliminated prior to the vapor's passing through the outlet nozzle **64** to be delivered to its point of use.

In FIGURES 4 and 5 is shown another embodiment of the present invention wherein the heating fluid chamber **38'** is compartmentized by means of vertically disposed, radially arranged plates **73'** and a pair of horizontally disposed plates **86** that attach to the wall of the closure head **18** and to the central conduit **72**. Lateral plates **86** extend between alternate spans formed by the plates **73'** to form the heating fluid inlet compartments **78'**. Openings **76** are provided in the central conduit communicating with the heating fluid inlet chambers so as to supply heating fluid thereto. From these compartments **78'** the heating fluid is caused to flow through the U-tubes **34** in a manner similar to that of the FIGURE 1 arrangement and is discharged from the outlet ends **50** of the tubes into the single heating fluid outlet compartment **80'** that occupies the remainder of the chamber from whence it may flow from the chamber through the heating fluid outlet nozzle **84**.

In the embodiment shown in FIGURES 6 and 7 the heating fluid chamber is divided into quadrants by means of baffle plates **73''** similar to those shown in the FIGURE 1 embodiment. Again, openings **76** in the central conduit **72** establish fluid communication between the heating fluid inlet compartments **78''** for the passage of heating fluid thereto. The alternate compartments **80''** are again those into which the heating fluid is discharged from the outlet ends **50** of the U-tubes **34**. In this embodiment an outlet nozzle **84** communicates with each of the outlet compartments **80''** for the removal of spent heating fluid from the unit.

In the embodiment shown in FIGURES 8 and 9, baffle plates **73'''** divide the heating fluid chamber **38** into alternate heating fluid inlet and outlet compartments **78'''** and **80'''** and individual inlet and outlet nozzles **90** and **92** communicate with each of the compartments whereby heating fluid is supplied to the inlet compartments **78'''** through nozzles **90** and removed from the outlet compartments **80'''** through nozzles **92**. In this embodiment the central conduit **72** has a continuous surface and is employed as a manway for access to the vapor generation chamber **30**. As shown the tube sheet **36** is provided with a central opening **94** that is closed by a cover **96** around which the upper end of the central conduit **72** attaches for the purpose of permitting access from outside the unit to the vapor generator interior.

While in accordance with the provisions of the statutes, there has been illustrated and described specific forms of the invention, it is to be understood that changes may be made in the forms of the apparatus disclosed without departing from the spirit of the invention covered by the appended claims, and that certain features of the invention sometimes be used to advantage without a corresponding use of other features.

What is claimed is:

1. A vapor generator comprising a vertical elongated cylindrical vessel arranged to operate with an upper vapor

space above a body of liquid therein; a vapor outlet from said vapor space; plate means coacting with the wall of said vessel to form an interior, vertically elongated downcomer reservoir and an annularly shaped vapor generation chamber exterior of said reservoir, said plate means extending downwardly to substantially the bottom of said vapor generation chamber but being spaced therefrom to establish fluid communication between said downcomer reservoir and said vapor generation chamber; means for supplying vaporizable liquid to said downcomer reservoir; at least three separate tube bundles each comprising a group of vertically elongated U-tubes arranged in rows lying in parallel planes, said tube bundles being located in circumferentially spaced positions about said plate means and substantially filling said vapor generation chamber; and heating fluid inlet and outlet means communicating with the tubes of said tube bundles for circulating heating fluid therethrough.

2. A vapor generator comprising a vertically elongated cylindrical vessel arranged to operate with an upper vapor space above a body of liquid therein; a vapor outlet from said vapor space; plate means coacting with the wall of said vessel to form an interior, vertically elongated downcomer reservoir and an annularly shaped vessel generation chamber exterior of said reservoir, said plate means extending downwardly to substantially the bottom of said vapor generation chamber but being spaced therefrom to establish fluid communication between said downcomer reservoir and said vapor generation chamber; means for supplying vaporizable liquid to said downcomer reservoir; at least three separate tube bundles each comprising a group of vertically elongated U-tubes arranged in rows lying in parallel planes and having upwardly disposed bends, said tube bundles being located in circumerentially spaced position about said plate means and subtantially filling said vapor generation chamber; and heating fluid inlet and outlet means communicating with the tubes of said tube bundles for circulating heating fluid therethrough.

3. A vapor generator comprising a vertically elongated cylindrical vessel arranged to operate with an upper vapor space above a body of liquid therein; a vapor outlet from said vapor space; plate means coacting with the wall of said vessel to form an interior, vertically elongated downcomer reservoir and an annularly shaped vapor generation chamber exterior of said reservoir, said plate means extending downwardly to substantially the bottom of said vapor generation chamber but being spaced therefrom to establish fluid communication between said downcomer reservoir and said vapor generation chamber; means for supplying vaporizable liquid to said downcomer reservoir; a plurality of separate tube bundles each comprising a group of vertically elongated U-tubes arranged in rows lying in parallel planes and having upwardly disposed bends, said tube bundles being located in circumferentially spaced positions about said plate means, and each occupying substantially one quadrant of said vapor generation chamber; and heating fluid inlet and outlet means communicating with the tubes of said tube bundles for circulating heating fluid therethrough.

4. A vapor generator comprising a vertically elongated cylindrical vessel arranged to operate with an upper vapor space above a body of liquid therein; a vapor outlet from said vapor space; plate means coacting with the wall of said vessel to form an interior, vertically elongated downcomer reservoir and an annularly shaped vapor generation chamber exterior of said reservoir, said plate means extending downwardly to substantially the bottom of said vapor generation chamber but being spaced therefrom to establish fluid communication between said downcomer reservoir and said vapor generation chamber; means for supplying vaporizable liquid to said downcomer reservoir; a plurality of separate tube bundles each comprising a group of vertically elongated U-tubes arranged in rows lying in parallel planes and having upwardly disposed bends, said tube bundles being located in circumferentially spaced positions about said plate means and each having the shape of a truncated cylindrical segment occupying substantially one quadrant of said vapor generation chamber.

5. A vapor generator comprising a vertically elongated cylindrical vessel arranged to operate with an upper vapor space above a body of liquid therein; a vapor outlet from said vapor space; plate means coacting with the wall of said vessel to form an interior, vertically elongated downcomer reservoir and an annularly shaped vapor generation chamber exterior of said reservoir, said plate means extending downwardly to substantially the bottom of said vapor generation chamber but being spaced therefrom to establish fluid communication between said downcomer reservoir and said vapor generation chamber; a plurality of separate tube bundles each comprising a group of vertically elongated U-tubes arranged in rows lying in parallel planes and having upwardly disposed bends, said tube bundles being located in circumferentially spaced positions about said plate means and each having the shape of a truncated cylindrical segment with corresponding tubes in each tube bundle lying in rectangularly disposed planes; and heating fluid inlet and outlet means communicating with the tubes of said tube bundles for circulating heating fluid therethrough.

6. A vapor generator comprising a vertically elongated cylindrical vessel arranged to operate with an upper vapor space above a body of liquid therein; a vapor outlet from said vapor space; a tube sheet disposed laterally of the axis of said vessel forming a heating fluid chamber in the bottom thereof; plate means coacting with the wall of said vessel to form an interior, vertically elongated downcomer reservoir and an annularly shaped vapor generation chamber exterior of said reservoir, said plate means extending downwardly to substantially the bottom of said vapor generation chamber but being spaced from said tube sheet to establish fluid communication between said downcomer reservoir and said vapor generation chamber; means for supplying vaporizable liquid to said downcomer reservoir; a plurality of separate tube bundles each comprising a group of vertically elongated U-tubes attached to said tube sheet in communication with said heating fluid chamber and arranged for the circulation of heating fluid therethrough, said U-tubes being arranged in rows lying in parallel planes and having upwardly disposed bends, said tube bundles being located in circumferentially spaced positions about said plate means and each occupying substantially one quadrant of said vapor generation chamber; means connecting the inlet ends and outlet ends of adjacent tube bundles for mutual parallel flow of heating fluid therethrough; and heating fluid inlet and outlet means communicating with said heating fluid chamber.

7. A vapor generator comprising a vertically elongated cylindrical vessel arranged to operate with an upper vapor space above a body of liquid therein; a vapor outlet from said vapor space; a tube sheet disposed laterally of the axis of said vessel forming a heating fluid chamber in the bottom thereof; plate means coacting with the wall of said vessel to form an interior, vertically elongated downcomer reservoir and an annularly shaped vapor generation chamber exterior of said reservoir, said plate means extending downwardly to substantially the bottom of said vapor generation chamber but being spaced from said tube sheet to establish fluid communication between said downcomer reservoir and said vapor generation chamber; means for supplying vaporizable liquid to said downcomer reservoir; a plurality of separate tube bundles each comprising a group of vertically elongated U-tubes attached to said tube sheet in communication with said heating fluid chamber and arranged for the circulation of heating fluid therethrough, said U-tubes being arranged in rows lying in parallel planes and having upwardly disposed bends, said tube

bundles each having the shape of a truncated cylindrical segment and being located in circumferentially spaced positions about said plate means; means connecting the inlet ends and outlet ends of adjacent tube bundles for mutual parallel flow of heating fluid therethrough; and heating fluid inlet and outlet means communicating with said heating fluid chamber.

8. A vapor generator comprising a vertically elongated cylindrical vessel arranged to operate with an upper vapor space above a body of liquid therein; a vapor outlet from said vapor space; a tube sheet disposed laterally of the axis of said vessel forming a heating fluid chamber in the bottom thereof; plate means coacting with the wall of said vessel to form an interior, vertically elongated downcomer reservoir and an annularly shaped vapor generation chamber exterior of said reservoir, said plate means extending downwardly to substantially the bottom of said vapor generation chamber but being spaced from said tube sheet to establish fluid communication between said downcomer reservoir and said vapor generation chamber; means for supplying vaporizable liquid to said downcomer reservoir; a plurality of separate tube bundles each comprising a group of vertically elongated U-tubes attached to said tube sheet in communication with said heating fluid chamber and arranged for the circulation of heating fluid therethrough, said U-tubes being arranged in rows lying in parallel planes and having upwardly disposed bends, said tube bundles each having the shape of a truncated cylindrical segment and being located in circumferentially spaced positions about said plate means with corresponding tubes in each tube bundle lying in rectangularly disposed planes about said plate means; means connecting the inlet ends and outlet ends of adjacent tube bundles for mutual parallel flow of heating fluid therethrough; and heating fluid inlet and outlet means communicating with said heating fluid chamber.

9. A vapor generator comprising a vertically elongated cylindrical vessel arranged to operate with an upper vapor space above a body of liquid therein; a vapor outlet from said vapor space; a tube sheet disposed laterally of the axis of said vessel forming a heating fluid chamber in the bottom thereof; plate means coacting with the wall of said vessel to form an interior, vertically elongated downcomer reservoir and an annularly shaped vapor generation chamber exterior of said reservoir, said plate means extending downwardly to substantially the bottom of said vapor generation chamber but being spaced from said tube sheet to establish fluid communication between said downcomer reservoir and said vapor generation chamber; means for supplying vaporizable liquid to said downcomer reservoir; a plurality of separate tube bundles each comprising a group of vertically elongated U-tubes attached to said tube sheet in communication with said heating fluid chamber and arranged for the circulation of heating fluid therethrough, said U-tubes being arranged in rows lying in parallel planes and having upwardly disposed bends, said tube bundles each having the shape of a truncated cylindrical segment occupying substantially one quadrant of said vapor generation chamber; means connecting the inlet ends and outlet ends of adjacent tube bundles for mutual parallel flow of heating fluid therethrough; and heating fluid inlet and outlet means communicating with said heating fluid chamber.

10. A vapor generator comprising a vertically elongated cylindrical vessel arranged to operate with an upper vapor space above a body of liquid therein; a vapor outlet from said vapor space; a tube sheet disposed laterally of the axis of said vessel forming a heating fluid chamber in the bottom thereof; plate means coacting with the wall of said vessel to form an interior, vertically elongated downcomer reservoir and an annularly shaped vapor generation chamber exterior of said reservoir, said plate means extending downwardly to substantially the bottom of said vapor generation chamber but being spaced from said tube sheet to establish fluid communication between said downcomer reservoir and said vapor generation chamber; means for supplying vaporizable liquid to said downcomer reservoir; a plurality of separate tube bundles each comprising a group of vertically elongated U-tubes attached to said tube sheet in communication with said heating fluid chamber and arranged for the circulation of heating fluid therethrough, said U-tubes being arranged in rows lying in parallel planes and having upwardly disposed bends, said tube bundles each having the shape of a truncated cylindrical segment occupying substantially one quadrant of said vapor generation chamber with corresponding tubes in each tube bundle lying in rectangularly disposed planes about said plate means; means connecting the inlet ends and outlet ends of adjacent tube bundles for mutual parallel flow of heating fluid therethrough; and heating fluid inlet and outlet means communicating with said heating fluid chamber.

11. A vapor generator comprising a vertically elongated cylindrical vessel arranged to operate with an upper vapor space above a body of liquid therein; a vapor outlet from said vapor space; a tube sheet disposed laterally of the axis of said vessel forming a heating fluid chamber in the bottom thereof; first plate means coacting with the wall of said vessel to form an interior, vertically elongated downcomer reservoir and an annularly shaped vapor generation chamber exterior of said reservoir, said first plate means extending downwardly to substantially the bottom of said vapor generation chamber but being spaced from said tube sheet to establish fluid communication between said downcomer reservoir and said vapor generation chamber; means for supplying vaporizable liquid to said downcomer reservoir; vapor liquid separating means arranged to separate a vapor-liquid mixture received from said vapor generation chamber and for discharging separated liquid to said downcomer reservoir and vapor to said vapor space; second plate means extending between said first plate means and said vessel wall for supporting said separating means; opening means in said second plate means communicating said separator means with said vapor generation chamber; a plurality of separate tube bundles each comprising a group of vertically elongated U-tubes attached to said tube sheet in communication with said heating fluid chamber and arranged for the circulation of heating fluid therethrough, said U-tubes being arranged in rows lying in parallel planes and having upwardly disposed bends, said tube bundles being located in circumferentially spaced positions about said first plate means and each occupying substantially one quadrant of said vapor generation chamber; means connecting the inlet ends and the outlet ends of adjacent tube bundles for mutual parallel flow of heating fluid therethrough, and heating fluid inlet and outlet means communicating with said heating fluid chamber.

12. A vapor generator comprising a vertically elongated cylindrical vessel arranged to operate with an upper vapor space above a body of liquid therein; a vapor outlet from said vapor space; a tube sheet disposed laterally of the axis of said vessel forming a heating fluid chamber in the bottom thereof; first plate means coacting with the wall of said vessel to form an interior, vertically elongated downcomer reservoir and an annularly shaped vapor generation chamber exterior of said reservoir, said first plate means extending downwardly to substantially the bottom of said vapor generation chamber but being spaced from said tube sheet to establish fluid communication between said downcomer reservoir and said vapor generation chamber; means for supplying vaporizable liquid to said downcomer reservoir; vapor liquid separating means arranged to separate a vapor-liquid mixture received from said vapor generation chamber and for discharging separated liquid to said downcomer reservoir and vapor to said vapor space; second plate means extending between said first plate means and said vessel

wall for supporting said separating means; opening means in said second plate means communicating said separator means with said vapor generation chamber; a plurality of separate tube bundles each comprising a group of vertically elongated U-tubes attached to said tube sheet in communication with said heating fluid chamber and arranged for the circulation of heating fluid therethrough, said U-tubes being arranged in rows lying in parallel planes and having upwardly disposed bends, said tube bundles each having the shape of a truncated cylindrical segment and being located in circumferentially spaced positions about said first plate means; means connecting the inlet ends and the outlet ends of adjacent tube bundles for mutual parallel flow of heating fluid therethrough, and heating fluid inlet and outlet means communicating with said heating fluid chamber.

13. A vapor generator comprising a vertically elongated cylindrical vessel arranged to operate with an upper vapor space above a body of liquid therein; a vapor outlet from said vapor space; a tube sheet disposed laterally of the axis of said vessel forming a heating fluid chamber in the bottom thereof; first plate means coacting with the wall of said vessel to form an interior, vertically elongated downcomer reservoir and an annularly shaped vapor generation chamber exterior of said reservoir, said first plate means extending downwardly to substantially the bottom of said vapor generation chamber but being spaced from said tube sheet to establish fluid communication between said downcomer reservoir and said vapor generation chamber; means for supplying vaporizable liquid to said downcomer reservoir; vapor liquid separating means arranged to separate a vapor-liquid mixture received from said vapor generation chamber and for discharging separated liquid to said downcomer reservoir and vapor to said vapor space; second plate means extending between said first plate means and said vessel wall for supporting said separating means; opening means in said second plate means communicating said separator means with said vapor generation chamber; a plurality of separate tube bundles each comprising a group of vertically elongated U-tubes attached to said tube sheet in communication with said heating fluid chamber and arranged for the circulation of heating fluid therethrough, said U-tubes being arranged in rows lying in parallel planes and having upwardly disposed bends, said tube bundles each having the shape of a truncated cylindrical segment and being located in circumferentially spaced positions about said first plate means with corresponding tubes in each tube bundle lying in rectangularly disposed planes about said first plate means; means connecting the inlet ends and the outlet ends of adjacent tube bundles for mutual parallel flow of heating fluid therethrough, and heating fluid inlet and outlet means communicating with said heating fluid chamber.

14. A vapor generator comprising a vertically elongated cylindrical vessel arranged to operate with an upper vapor space above a body of liquid therein; a vapor outlet from said vapor space; a tube sheet disposed laterally of the axis of said vessel forming a heating fluid chamber in the bottom thereof; first plate means coacting with the wall of said vessel to form an interior, vertically elongated downcomer reservoir and an annularly shaped vapor generation chamber exterior of said reservoir, said first plate means extending downwardly to substantially the bottom of said vapor generation chamber but being spaced from said tube sheet to establish fluid communication between said downcomer reservoir and said vapor generation chamber; means for supplying vaporizable liquid to said downcomer reservoir; vapor liquid separating means arranged to separate a vapor-liquid mixture received from said vapor generation chamber and for discharging separated liquid to said downcomer reservoir and vapor to said vapor space; second plate means extending between said first plate means and said vessel wall for supporting said separating means; opening means in said second plate means communicating said separator means with said vapor generation chamber; a plurality of separate tube bundles each comprising a group of vertically elongated U-tubes attached to said tube sheet in communication with said heating fluid chamber and arranged for the circulation of heating fluid therethrough, said U-tubes being arranged in rows lying in parallel planes and having upwardly disposed bends, said tube bundles each having the shape of a truncated cylindrical segment occupying substantially one quadrant of said vapor generation chamber; means connecting the inlet ends and the outlet ends of adjacent tube bundles for mutual parallel flow of heating fluid therethrough, and heating fluid inlet and outlet means communicating with said heating fluid chamber.

15. A vapor generator comprising a vertically elongated cylindrical vessel arranged to operate with an upper vapor space above a body of liquid therein; a vapor outlet from said vapor space; a tube sheet disposed laterally of the axis of said vessel forming a heating fluid chamber in the bottom thereof; first plate means coacting with the wall of said vessel to form an interior, vertically elongated downcomer reservoir and an annularly shaped vapor generation chamber exterior of said reservoir, said first plate means extending downwardly to substantially the bottom of said vapor generation chamber but being spaced from said tube sheet to establish fluid communication between said downcomer reservoir and said vapor generation chamber; means for supplying vaporizable liquid to said downcomer reservoir; vapor liquid separating means arranged to separate a vapor-liquid mixture received from said vapor generation chamber and for discharging separated liquid to said downcomer reservoir and vapor to said vapor space; second plate means extending between said first plate means and said vessel wall for supporting said separating means; opening means in said second plate means communicating said separator means with said vapor generation chamber; a plurality of separate tube bundles each comprising a group of vertically elongated U-tubes attached to said tube sheet in communication with said heating fluid chamber and arranged for the circulation of heating fluid therethrough, said U-tubes being arranged in rows lying in parallel planes and having upwardly disposed bends, said tube bundles each having the shape of a truncated cylindrical segment occupying substantially one quadrant of said vapor generation chamber with corresponding tubes in each tube bundle lying in rectangularly disposed planes about said first plate means; means connecting the inlet ends and the outlet ends of adjacent tube bundles for mutual parallel flow of heating fluid therethrough, and heating fluid inlet and outlet means communicating with said heating fluid chamber.

16. A vapor generator comprising a vertically elongated cylindrical vessel arranged to operate with an upper vapor space above a body of liquid therein; upper and lower closure heads closing the ends of said vessel; a vapor outlet from said vapor space; a tube sheet disposed laterally of the axis of said vessel forming a heating fluid chamber in the bottom thereof; plate means coacting with the wall of said vessel to form an interior, vertically elongated downcomer reservoir and an annularly shaped vapor generation chamber exterior of said reservoir, said plate means extending downwardly to substantially the bottom of said vapor generation chamber but being spaced from said tube sheet to establish fluid communication between said downcomer reservoir and said vapor generation chamber; means for supplying downcomer liquid to said downcomer reservoir; an even number of separate tube bundles each comprising a group of vertically elongated U-tubes having inlet ends and outlet ends attached to said tube sheet in communication with said heating fluid chamber, said U-tubes being arranged in rows lying in parallel planes and having upwardly disposed bends, said tube bundles

substantially filling said vapor generation chamber and being located in circumferentially spaced positions about said plate means, the inlet ends and the outlet ends of adjacent tube bundles being arranged in adjacent, grouped relation; an axially disposed cylindrical conduit attached at one end to said lower closure head and at the other end to said tube sheet means; divider means arranged within said heating fluid chamber forming heating fluid inlet and outlet compartments corresponding to the U-tube inlet end and outlet end groups; and means communicating with said heating fluid inlet and outlet compartments for circulating heating fluid through said U-tubes.

References Cited by the Examiner

UNITED STATES PATENTS

2,774,575	12/1956	Walter	165—158 X

FOREIGN PATENTS

521,080	5/1940	Great Britain.
876,308	8/1961	Great Britain.

CHARLES J. MYHRE, *Primary Examiner.*