April 12, 1966 J. H. AMMON ETAL **3,245,464**

LIQUID METAL HEATED VAPOR GENERATOR

Filed Feb. 28, 1963 3 Sheets-Sheet 1

FIG. 2

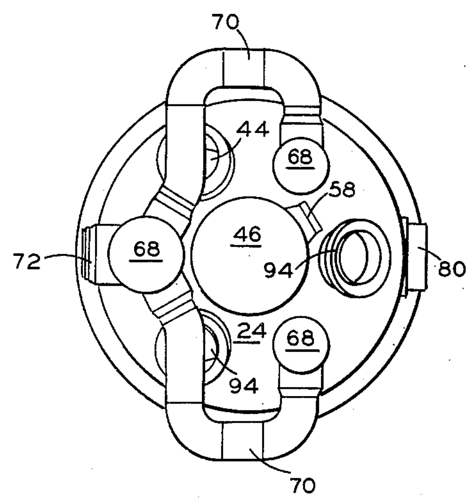


FIG. 7

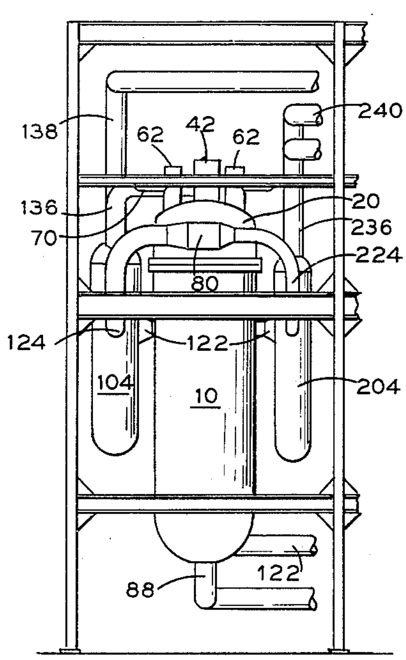
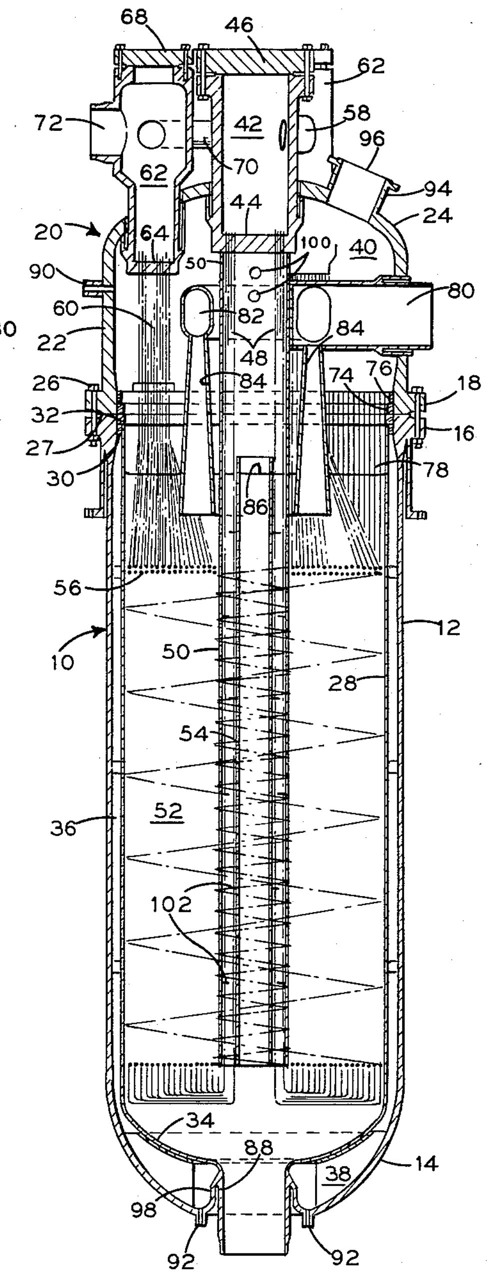


FIG. 1



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LIQUID METAL HEATED VAPOR GENERATOR

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FIG. 4

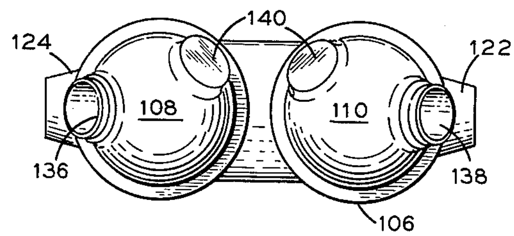

FIG. 3

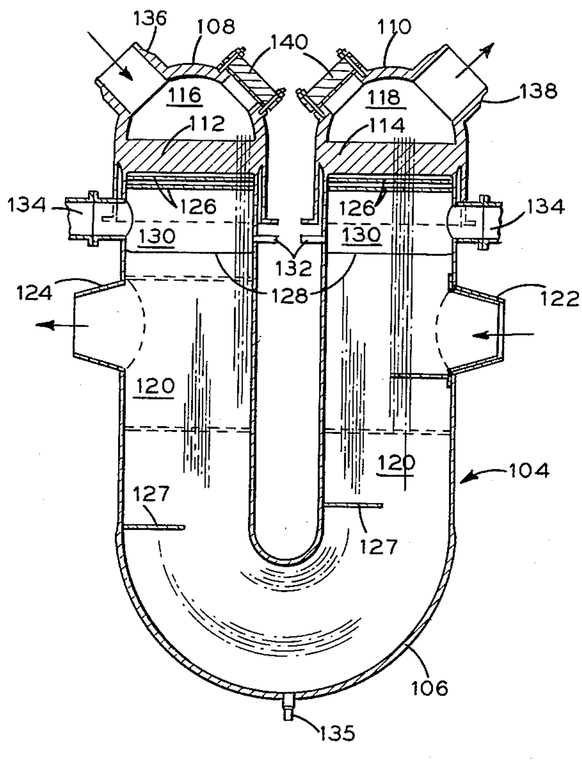

FIG. 6

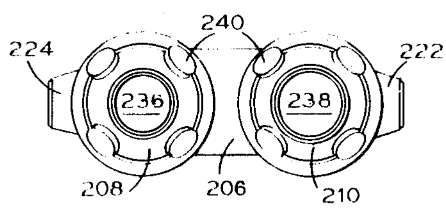
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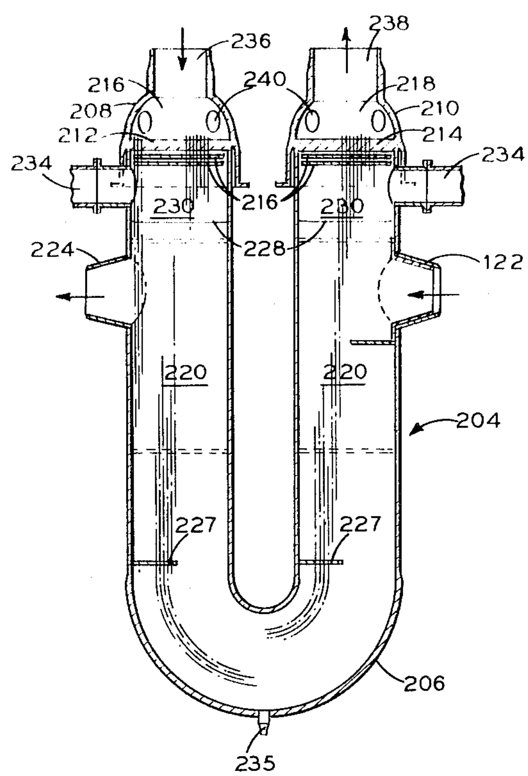
FIG. 5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LIQUID METAL HEATED VAPOR GENERATOR

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15 Claims. (Cl. 165—145)

This invention relates in general to a vapor generator and more particularly to a vapor generator utilizing a heated liquid metal as a source of heat.

The use of a heated liquid metal as a heat source in a vapor generator is well known. Vapor generators using mercury have been used for many years and more recently sodium, bismuth, and NaK, a compound of sodium and potassium, have found favor as heating fluids. In vapor generators employing the last three mentioned metals, and particularly sodium, special precautions are necessary to avoid the possibility of violent interaction of water and the heated metal. To guard against this danger a double tube arrangement has been used to provide an annular flow space through which a third fluid can be passed to act both as an intermediate heat transfer fluid and as a monitoring fluid to detect leaks between the water and the liquid metal circuits, and to prevent direct contact between the liquid metal and the water should a leak occur in one of the double tubes.

In vapor generators presently using heated liquid metals, liquid metal flow stratification has produced pronounced temperature unbalances which result in differential thermal stresses in the pressure shell of the vapor generator.

It is an object of the present invention to provide a vapor generator in which a liquid metal can be used as the heating medium while providing adequate safety provisions in the event of the interaction of the heated liquid metal and water. In addition, the construction of the vapor generator avoids the problem of flow stratification and the resultant differential thermal stressing of the pressure vessel.

The present invention also provides an arrangement whereby all of the areas containing the liquid metal may be drained, vented and cleaned, increasing the ease of maintenance and length of life of the unit. Furthermore, no areas of flow stagnation in either the water or the liquid metal flow paths are present thus minimizing temperature unbalances and stress corrosion resulting therefrom.

Complete protection of the pressure vessel and the tube-to-tube sheet connections of the water circuit from contact with the liquid metal is also provided by the present invention, thus preventing thermal shocks thereto as a result of violent changes in the liquid metal temperature during system power transients or emergencies. Furthermore, protection of these parts is provided against pressure waves which might develop from a liquid metal-water reaction.

Furthermore, the present invention makes possible an arrangement whereby the water tube ends may be readily reached for inspection, cleaning and plugging. This is in addition to the fact that the entire tube bundle may be relatively easily removed from the pressure vessel for inspection, maintenance, or replacement.

The present invention thus provides a heat exchanger comprising a vertically elongated cylindrical pressure vessel with heads closing each end and having a container arranged therein. The container is spaced from

the walls and heads of the vessel, thereby forming a continuous gas space which completely envelops the container. A bundle of heat exchange tubes is disposed within the container for the flow of a heat transfer fluid therethrough. Inlet and outlet means are provided through the upper end of the pressure vessel to supply the flow of the heat transfer fluid through the bundles of heat exchange tubes. Means are also provided to supply a heat transfer liquid to the container for flow therethrough in countercurrent indirect heat transfer relationship with the fluid within the tube bundle. A gas supply means is also provided for furnishing a gas to the gas space.

The container disposed within the pressure vessel may have a relatively thin wall as compared with the pressure vessel wall and is arranged so that the flow of heat exchange liquid is confined within this thin walled container so that it does not come into contact with the heavier walls of the pressure vessel. The inert gas in the gas space, which completely envelops the container, provides a cushioning effect for any pressure surges.

The tubes within the tube bundle may be helically coiled about a central core within the container in the manner disclosed in co-pending applications having Serial Nos. 80,880, filed March 30, 1959, now U.S. Patent No. 3,112,735, and 249,152 filed January 3, 1963.

Furthermore, the present invention is particularly adapted for use as a once-through vapor generator. The vertically arranged, helically coiled tube bundle permits high fluid-side mass flow which minimizes the possibility of rapid corrosion resulting from extreme tube wall temperature fluctuations associated with the transition from nucleate to film boiling. The equal length, helically wound, tube arrangement produces uniformly heated fluid and provides sufficient heat transfer surface without excessive tube bundle length.

In combination with the above described vapor generator, the present invention provides U-tube vapor superheater and reheater units having vertically extending legs which have the same provisions for liquid drainage and for protection of the tube-to-tube sheet connection from contact with the liquid metal. These units are also provided with a gas space for cushioning any pressure surges.

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 drawing and descriptive matter in which there is illustrated and described a preferred embodiment of the invention.

Of the drawings:

FIG. 1 is a vertical cross-sectional view of a vapor generator which embodies this invention;

FIG. 2 is a plan view of the vapor generator illustrated in FIG. 1;

FIG. 3 is a vertical cross-sectional view of the superheater portion of the present invention;

FIG. 4 is a plan view of the superheater shown in FIG. 3;

FIG. 5 is a vertical cross-sectional view of the reheater portion of the present invention;

FIG. 6 is a plan view of the reheater shown in FIG. 5, and

FIG. 7 is a vertical view of the present invention showing the relationship between the vapor generator, the superheater, and the reheater.

Referring now to the drawings, FIG. 1 shows the vapor generator 10 of the present invention comprising a vertically elongated cylindrical shell 12 having a generally hemispherical lower head 14 and an open upper end. A flange 16 encricles the upper end of the shell 12 which is adapted to mate with a matching flange 18 on the closure head 20 of the vessel. This closure head comprises a short cylindrical section 22 and a generally elliptical upper head 24. The closure head 20 is adapted to be removably and sealingly connected to the main shell 12 by a plurality of closure bolts 26 through mating flanges 16 and 18 and by a seal weld 27 at the circumscribing joint therebetween.

A cylindrically shaped container 28 is suspended concentrically within the pressure vessel by a ring 30 provided on the inner surface of flange 16. This container has an open upper end 32 and a closed elliptically shaped lower end 34 spaced above the inner surface of the lower head 14 of the pressure vessel. The wall thickness of the container is substantially less than that of the pressure vessel. The container is closely spaced throughout its height from the inner surface of the pressure vessel shell 12 to form a narrow annular space 36 between the container and the shell. This annular space in combination with the space 38 between the lower end 34 of the container and the lower head 14 of the pressure vessel and the space 40 above the open upper end 32 of the container form a continuous gas space which envelops the container.

A cylindrical inlet header 42 extends through and is integrally attached to the elliptical upper head 24 and terminates interior of the pressure vessel in a flat circular tube sheet 44. The outer end of the header, exterior of the pressure vessel, is provided with a flanged removable closure 46 which permits access to the interior of the header and the ends of the tubes 48 which are connected through the tube sheet 44. The tubes 48 are vertically extending and are arranged in an annular bundle extending to the lower portion of the container 28. A cylindrical conduit member 50 is connected to the tube sheet 44 and also extends to the lower portion of the container 28 surrounding tubes 48 and co-acting with the container to form an annular chamber 52 therein. An inner shroud member 54 encompasses the inner surface of the annular bundle of tubes 48 and serves to both align and support the tubes and to protect the tubes.

A bundle of closely spaced, helically wound tubes 56 is arranged within the annular chamber 52, coiling around the conduit 50. The vertical height of the tube bundle of tubes 56 is such that the bundle substantially fills the container 28. The tubes are disposed in a number of concentric vertically extending circular layers. Each of the tubes 56 is helically wound in one of these circular layers with the pitch of the helix increasing as the diameter of the circular layers increases, substantially as described in the above-identified copending applications. As there disclosed, it is possible, by properly correlating the diameter and pitch, to make each tube in the bundle substantially equal in length so that fluid entering any of the tubes will have the same length of flow. This permits a fluid passing in heat exchange relationship through any of the flow paths within the tube bundle, to receive or to give up substantially equal amounts of heat regardless of the flow path it takes.

While this tube bundle arrangement is understood to be that preferred, it is contemplated that any bundle configuration might be utilized, including straight tubes, or ordinary spiraled tubes.

The tubes 56 in the bundle within the annular chamber 52 are connected at the lower portion of the container with the lower ends of tubes 48. Thus, the tubes 56 are supplied with a heat transfer fluid from the inlet header 42 which in turn is provided with a feedwater inlet 58.

At the upper end of the tube bundle the tubes are divided into three groups 60 which connect to three out-

let headers 62 extending axially through the upper head 24 in a manner similar to inlet header 42. Each of the outlet headers terminates interior of the pressure vessel in a flat circular tube sheet 64. They are likewise provided with a flanged opening 68 exterior of the pressure vessel permitting access to the ends of the tubes in tube sheets 64. Two of the outlet headers are provided with outlets 70 leading to the third outlet header which acts as a mixing header. An outlet 72 is provided in the third header leading to a point of use or to a superheater as will be later described.

A support ring 74 attached to the inner surface of flange 18 carries a support ring 76 having radially extending bars from which depend tube hanger rods 78 such as described in the above-identified copending applications. These hanger rods serve to locate and support the tubes 56 in the annular bundle while still allowing for differential expansion of the various tubes.

With the arrangement described above it is possible to remove the entire tube bundle by removing the closure head after disconnecting various external lines. In this way it is possible to repair or replace the entire bundle with relative ease.

Extending horizontally through the closure head is a liquid metal supply line 80 which ends in a toroidal distribution header 82 which encircles the upper end of conduit 50. A plurality of feeder pipes 84 depend from the header 82 and distribute the incoming liquid metal to the annular chamber 52. The liquid metal in this chamber has a normal liquid level 86 above the lower end of the feeder pipes 84 and below the end of the inner shroud member 54. An outlet 88 is provided in the lower end of container 28 which passes through the lower head 14 of the pressure vessel.

The liquid metal thus enters through inlet 80 and flows through the toroidal header 82 to the feeder pipes 84 which discharge into the annular chamber 52 below liquid level 86. The liquid metal then flows downwardly through the annular chamber giving up heat by indirect heat transfer to the fluid flowing upwardly through tubes 56. The cooled liquid metal then leaves through outlet 88 to be returned to the heat source (not shown). The heat transfer fluid, preferably water, is supplied to the inlet header via line 58 and flows downwardly through tubes 48 to the bottom of the container where they join the lower end of the tube bundle filling chamber 52. The fluid then flows upwardly through tubes 56 absorbing heat from the down-flowing liquid metal. The heated fluid then flows into outlet headers 62 combining in a common mixing header via lines 70 from which it leaves by line 72. The arrangement of the present invention is especially suited for operation as a once-through unit whereby pressurized water enters by line 58 and slightly superheated steam leaves by line 72.

A gas inlet connection 90 is located through the pressure vessel wall at a point above the upper end 32 of container 28 to supply inert gases to the gas space enveloping the container. A drain connection 92 is provided through the lower head 14 of the pressure vessel to permit drainage of condensed liquid metal vapor which tends to collect in the bottom of the gas space. As a result of this gas space the heated liquid metal never comes into contact with the outer pressure vessel. Additionally, the gas space provides a buffer capable of absorbing pressure surges resulting from possible water-liquid metal reactions. The liquid level in the container is also regulated by controlling the pressure of the gas in the gas space.

Three blow out nozzles 94 are located in the closure head 24 and are provided with diaphragms 96 which will relieve excessive pressure build-ups within the pressure vessel by rupturing.

It should be noted that each connection passing through the pressure vessel wall is provided with a thermal sleeve, such as at 98, to minimize temperature shocks. Furthermore, since the entire space above the upper end of the container 28 is filled with an inert gas, the tube sheets and other elements projecting through the closure head are protected from the rapid temperature changes possible if they were in contact with the liquid metal.

The upper end of conduit 50 is provided with openings 100 to permit communication of the interior of the conduit with the gas space 40. In this way any surges occurring therein are accommodated, thus protecting the annular tube bundle 48. Since the lower end of conduit 50 is open to the container, flow of liquid metal therethrough is inhibited by baffles 102 to minimize heat transfer to the fluid flowing downwardly through the annular bundle 48. The fact that these inlet tubes 48 are arranged in an annular bundle aids in the fabrication of the tube bundle as adequate space is provided for the connection of tubes 48 with the lower end of tubes 56. The annular configuration of tubes 48 also determines the minimum inner diameter of the helically coiled tubes 56. With such a diameter it is possible to cold bend the tubes 56, while if a smaller diameter were incorporated, hot bending would be necessary to prevent crimping of the tubes during the fabrication thereof.

A superheater unit 104 is illustrated in FIG. 3 and comprises a U-shaped pressure vessel 106 having a pair of vertically extending legs terminating in heads 108 and 110, respectively. Tube sheets 112 and 114 cooperate with heads 108 and 110 to form inlet and outlet plenums 116 and 118 for the vapor being superheated. A plurality of tubes are connected through the tube sheets and form a U-shaped tube bundle 120 substantially filling the U-shaped pressure vessel. A liquid metal inlet 122 is provided in the upper end of one leg of the pressure vessel and an outlet 124 is in the upper end of the other leg. Thermal shields 126 are disposed adjacent the shell side of tube sheets 112 and 114. The liquid metal enters through inlet 122 and flows through the U-shaped pressure vessel around the tubes in bundle 120 and out through outlet 124 establishing a liquid level 128 in each leg. Liquid metal flow stratification is prevented by baffles 127 thus promoting even heat distribution throughout the tube bundle. The spaces 130 between the liquid level 128 and the tube sheets are provided with an inert pressurizing gas through lines 132 which serves the same function as it does in the vapor generator 10, i.e., protecting the tube sheets from thermal and pressure shocks. A blowout nozzle 134 is provided in each leg of the pressure vessel to permit the relief of any excessive pressure buildup should a severe liquid metal-water reaction occur. A drain 135 is provided in the bottom of the pressure vessel to permit drainage of the liquid metal therein.

The vapor to be superheated enters from the vapor generator through nozzle 136 in the head 108 and flows through tubes 120, absorbing heat from the liquid metal flowing thereover, to the outlet plenum 118 where it leaves through an outlet nozzle 138 through head 110 to be carried to a point of use (not shown). Each of the heads 108 and 110 is provided with a manhole opening 140 which permits access to the plenums 116 annd 118 for inspection or maintenance of the tubes extending through tube sheets 112 and 114.

A reheater unit 204 (shown in FIG. 5), is also provided and has substantially the same construction as does the superheater, similar parts being numbered with a prefix of 2 instead of 1. The basic difference between the reheater and the superheater is the fact that the vapor inlet and outlet are necessarily larger in diameter as a result of the lower pressure of the vapor flowing therethrough. It will also be noted that, due to the different vapor conditions encountered, and the desire to utilize the same liquid metal inlet and outlet temperatures, the tube bundle of the reheater unit is longer but smaller in diameter than that of the superheater bundle.

The assembled heat exchange unit is shown in FIG. 7 whereby the superheater 104 and the reheater 204 are vertically arranged adjacent the vapor generator 10. High temperature liquid metal is supplied in parallel flow paths through both the superheater and the reheater. After exiting from these units, the intermediate temperature liquid metal is combined to enter the vapor generator 10 via line 80. After flowing through the vapor generator the liquid metal is returned to the heat source through outlet 88. The fluid being vaporized is supplied through feedwater line 58 to the inlet header 42, from thence it is directed through the tube bundle in chamber 52 and is vaporized. The vaporized fluid is then collected in outlet headers 62 and is mixed in one of them via lines 70. The mixed vapor then leaves the header via line 72 to be introduced into the superheater 104 via line 136. The superheated vapor is then piped to a point of use through line 136.

The arrangement of the present invention provides a high degree of safety and reliability by minimizing the thermal stresses occurring in the various components. It also provides a large volume of inert gas to absorb any possible pressure surge resulting from a liquid metal-water reaction. Further, it provides upflow of the fluid being heated and downflow of the heating liquid thus providing the most desirable heat transfer characteristics of good flow stability and distribution along with high heat transfer coefficients to minimize tube temperature fluctuations. Due to the helical coil configuration of the vapor generation tubes a compact heat transfer tube bundle is achieved which affords a maximum of flexibility in determining tube and shell side fluid flow rates. The relatively few number of long tubes utilized in the tube bundle, with the tube sheets located in the top of the unit makes access and maintenance relatively easy. The use of multiple headers makes possible the utilization of thinner tube sheets and, since they are also not in contact with the liquid metal, thermal stresses are minimized.

While in accordance with the provisions of the statutes there is illustrated and described herein a specific embodiment of the invention, those skilled in the art will understand that changes may be made in the form of the invention covered by the claims, and that certain features of the invention may sometimes be used to advantage without a corresponding use of the other features.

What is claimed is:

1. A heat exchange apparatus comprising a vertically elongated cylindrical pressure vessel having an open upper end, a removable upper end closure arranged to close said opening, walls forming a vertically extending container open at its top and disposed within and spaced from said pressure vessel to form a gas space enveloping the container, a bundle of closely spaced heat exchange tubes arranged within said container, a cylindrical inlet header having a horizontal tube sheet extending coaxially through the upper end of said pressure vessel for supplying a heat transfer fluid to the lower end of said bundle of tubes, a cylindrical outlet header extending through the upper end of said pressure vessel for withdrawing said heat transfer fluid from the upper end of said bundle of tubes, means for supplying a heat transfer liquid to said container for passage therethrough out of contact with said pressure vessel and in indirect heat exchange relationship with said heat transfer fluid, the heat transfer liquid within said container forming a liquid level therein spaced below the top of the container and substantially covering the bundle of heat exchange tubes, and means for supplying gas under pressure to said gas space so that the gas envelops said container and is in communication with the heat transfer liquid at its liquid level within said container whereby the gas acts as a separating medium between said container and said pressure vessel while pressurizing the liquid level of said heat transfer liquid within said container, said tube bundle having an outer diameter smaller that that of said upper end opening and

being removable through said upper end opening of said pressure vessel.

2. A heat exchange apparatus comprising a vertically elongated cylindrical pressure vessel having an open upper end, a removable upper end closure arranged to close said opening, walls forming a vertically extending container open at its top and disposed within and spaced from said pressure vessel to form a gas space enveloping the container, a relatively small diameter conduit disposed co-axially within said container, a bundle of closely spaced heat exchange tubes arranged within said container, a cylindrical inlet header having a horizontal tube sheet extending co-axially through the upper end of said pressure vessel for supplying a heat transfer fluid to the lower end of said bundle of tubes, a cylindrical outlet header having a horizontal tube sheet extending axially through the upper end of said pressure vessel for withdrawing said heat transfer fluid from the upper end of said bundle of tubes, means for supplying a heat transfer liquid to said container for passage therethrough out of contact with said pressure vessel and in indirect heat exchange relationship with said heat transfer fluid, the heat transfer liquid within said container forming a liquid level therein spaced below the top of the container and substantially covering the bundle of heat exchange tubes, and means for supplying gas under pressure to said gas space so that the gas envelops said container and is in communication with the heat transfer liquid at its liquid level within said container whereby the gas acts as a separating medium between said container and said pressure vessel while pressurizing the liquid level of said heat transfer liquid within said container, said tube bundle having an outer diameter smaller than that of said upper end opening and being suspended in said container from and removable with said removable upper end closure.

3. A heat exchange apparatus comprising a vertically elongated cylindrical pressure vessel having an open upper end, a removable upper end closure arranged to close said opening, walls forming a vertically extending container open at its top and disposed within and spaced from said pressure vessel to form a gas space enveloping the container, a relatively small diameter conduit disposed co-axially within said container to form an annular flow space therebetween, a bundle of closely spaced heat exchange tubes arranged within said annular flow space, a cylindrical inlet header having a horizontal tube sheet extending co-axially through the upper end of said pressure vessel for supplying a heat transfer fluid to said bundle of tubes, a plurality of inlet tubes extending from said inlet header tube sheet through said conduit to the lower end of said tube bundle in said annular flow space, a cylindrical outlet header having a horizontal tube sheet extending axially through the upper end of said pressure vessel for withdrawing said heat transfer fluid from the upper end of said bundle of tubes, means for supplying a heat transfer liquid to said container for passage therethough out of contact with said pressure vessel and in indirect heat exchange relationship with said heat transfer fluid, the heat transfer liquid within said container forming a liquid level therein spaced below the top of the container and substantially covering the bundle of heat exchange tubes, and means for supplying gas under pressure to said gas space so that the gas envelops said container and is in communication with the heat transfer liquid at its liquid level within said container whereby the gas acts as a separating medium between said container and said pressure vessel while pressurizing the liquid level of said heat transfer liquid within said container, said tube bundle having an outer diameter smaller than that of said upper end opening and being suspended in said container from and removable with said removable upper end closure.

4. A heat exchange apparatus comprising a vertically elongated cylindrical pressure vessel having an open upper end, a removable upper end closure arranged to close said opening, walls forming a vertically extending container open at its top and disposed within and spaced from said pressure vessel to form a gas space enveloping the container, a relatively small diameter conduit disposed co-axially within said container to form an annular flow space therebetween, a bundle of helically wound closely spaced heat exchange tubes arranged within said annular flow space and coiled about said conduit for the flow therethrough of a heat transfer fluid, a cylindrical inlet header having a horizontal tube sheet extending co-axially through the upper end of said pressure vessel for supplying the heat transfer fluid to said bundle of tubes, a plurality of inlet tubes extending from said inlet header tube sheet through said conduit to the lower end of said helical tube bundle in said annular flow space, a cylindrical outlet header having a horizontal tube sheet extending axially through the upper end of said pressure vessel for withdrawing said heat transfer fluid from the upper end of said helical bundle of tubes, means for supplying a heat transfer liquid to said container for passage therethrough out of contact with said pressure vessel and in indirect heat exchange relationship with said heat transfer fluid, the heat transfer liquid within said container forming a liquid level therein spaced below the top of the container and substantially covering the helical bundle of heat exchange tubes, and means for supplying gas under pressure to said gas space so that the gas envelops said container and is in communication with the heat transfer liquid at its liquid level within said container whereby the gas acts as a separating medium between said container and said pressure vessel while pressurizing the liquid level of said heat transfer liquid within said container, said tube bundle having an outer diameter smaller than that of said upper end opening and being suspended in said container from and removable with said removable upper end closure.

5. A heat exchanger apparatus comprising a vertically elongated cylindrical pressure vessel having an open upper end, a removable upper end closure arranged to close said opening, walls forming a vertically extending container open at its top and disposed within and spaced from said pressure vessel to form a gas space enveloping the container, a relatively small diameter conduit disposed co-axially within said container to form an annular flow space therebetween, a bundle of helically wound closely spaced heat exchanger tubes arranged within said annular flow space and coiled about said conduit for the flow therethrough of a heat transfer fluid, each of said tubes having a correlated pitch and coil diameter whereby each tube is of equal length, a cylindrical inlet header having a horizontal tube sheet extending co-axially through the upper end of said pressure vessel for supplying the heat transfer fluid to said bundle of tubes, a plurality of inlet tubes extending from said inlet header tube sheet through said conduit to the lower end of said helical tube bundle in said annular flow space, a cylindrical outlet header having a horizontal tube sheet extending axially through the upper end of said pressure vessel for withdrawing said heat transfer fluid from the upper end of said helical bundle of tubes, means for supplying a heat transfer liquid to said container for passage therethrough out of contact with said pressure vessel and in indirect heat exchange relationship with said heat transfer fluid, the heat transfer liquid within said container forming a liquid level therein spaced below the top of the container and substantially covering the helical bundle of heat exchange tubes, and means for supplying gas under pressure to said gas space so that the gas envelops said container and is in communication with the heat transfer liquid at its liquid level within said container whereby the gas acts as a separating medium between said container and said pressure vessel while pressurizing the liquid level of said heat transfer liquid within said container, said tube bundle having an outer diameter smaller than that

of said upper end opening and being suspended in said container from and removable with said removable upper end closure.

6. A heat exchange apparatus comprising a vertically elongated cylindrical pressure vessel having a closed lower end and an open upper end, a closure member removably closing said open upper end of said pressure vessel, walls forming a vertically extending container open at its top and disposed within and spaced from said pressure vessel to form a gas space enveloping the container, a relatively small diameter conduit disposed coaxially within said container to form an annular flow space therebetween, a bundle of helically wound closely spaced heat exchange tubes arranged within said annular flow space and coiled about said conduit, a cylindrical inlet header having a horizontal tube sheet extending coaxially through the upper end of said pressure vessel for supplying a heat transfer fluid to said bundle of tubes, a plurality of inlet tubes arranged as an annular bundle within said conduit communicating with said inlet header and the lower end of said helical tube bundle in said annular flow space, a plurality of outlet headers each having a horizontal tube sheet extending axially through the upper end closure of said pressure vessel for withdrawing said heat transfer fluid from the upper end of said helical bundle of tubes, means for supplying a heat transfer liquid to said container for passage therethrough out of contact with said pressure vessel and in indirect heat exchange relationship with said heat transfer fluid, the heat transfer liquid within said container forming a liquid level therein spaced below the top of the container and substantially covering the helical bundle of heat exchange tubes, and means for supplying gas under pressure to said gas space so that the gas envelops said container and is in communication with the heat transfer liquid at its liquid level within said container whereby the gas acts as a separating medium between said container and said pressure vessel while pressurizing the liquid level of said heat transfer liquid within said container, said tube bundle having an outer diameter smaller than that of said upper end opening and being suspended in said container from and removable with said removable upper end closure member.

7. A heat exchange apparatus comprising a vertically elongated cylindrical pressure vessel having a closed lower end and an open upper end, a closure member removably closing said open upper end of said pressure vessel, walls forming a vertically extending container open at its top and disposed within and spaced from said pressure vessel to form a gas space enveloping the container, a relatively small diameter conduit disposed co-axially within said container to form an annular flow space therebetween, a bundle of helically wound closely spaced heat exchange tubes arranged within said annular flow space and coiled about said conduit, a cylindrical inlet header having a horizontal tube sheet extending co-axially through the upper end of said pressure vessel for supplying a heat transfer fluid to said bundle of tubes, said conduit being suspended from said inlet header, said container being suspended in said pressure vessel from the open upper end thereof, a plurality of inlet tubes arranged as an annular bundle within said conduit communicating with said inlet header and the lower end of said helical tube bundle in said annular flow space, a plurality of outlet headers each having a horizontal tube sheet extending axially through the upper end closure of said pressure vessel for withdrawing said heat transfer fluid from the upper end of said helical bundle of tubes, means for supplying a heat transfer liquid to said container for passage therethrough out of contact with said pressure vessel and in indirect heat exchange relationship with said heat transfer fluid, the heat transfer liquid within said container forming a liquid level therein spaced below the top of the container and substantially covering the helical bundle of heat exchange tubes, and means for supplying gas under pressure to said gas space so that the gas envelops said container and is in communication with the heat transfer liquid at its liquid level within said container whereby the gas acts as a separating medium between said container and said pressure vessel while pressurizing the liquid level of said heat transfer liquid within said container, the interior of said conduit communicating at its lower end with said heat transfer liquid in said container and at its upper end with said gas space above said liquid level, said tube bundle having an outer diameter smaller than that of said upper end opening and being suspended in said container from and removable with said removable upper end closure member.

8. A heat exchange apparatus comprising a vertically elongated cylindrical pressure vessel having a closed lower end and an open upper end, a closure member removably closing said open upper end of said pressure vessel, walls forming a vertically extending container open at its top and disposed within and spaced from said pressure vessel to form a gas space enveloping the container, a relatively small diameter conduit disposed co-axially within said container to form an annular flow space therebetween, a bundle of helically wound closely spaced heat exchange tubes arranged within said annular flow space and coiled about said conduit, a cylindrical inlet header having a horizontal tube sheet extending co-axially through the upper end of said pressure vessel for supplying a heat transfer fluid to said bundle of tubes, said conduit being suspended from said inlet header, said container being suspended in said pressure vessel from the open upper end thereof, a plurality of inlet tubes arranged as an annular bundle within said conduit communicating with said inlet header and the lower end of said helical tube bundle in said annular flow space, an inner shroud encompassing the inner surface of said annular bundle of inlet tubes and extending from substantially the lower end of said conduit to the upper end of said container to align and support said inlet tubes, a plurality of outlet headers each having a horizontal tube sheet extending axially through the upper end closure of said pressure vessel for withdrawing said heat transfer fluid from the upper end of said helical bundle of tubes, means for supplying a heat transfer liquid to said container for passage therethrough out of contact with said pressure vessel and in indirect heat exchange relationship with said heat transfer fluid, the heat transfer liquid within said container forming a liquid level therein spaced below the top of the container and substantially covering the helical bundle of heat exchange tubes, and means for supplying gas under pressure to said gas space so that the gas envelops said container and is in communication with the heat transfer liquid at its liquid level within said container whereby the gas acts as a separating medium between said container and said pressure vessel while pressurizing the liquid level of said heat transfer liquid within said container, the interior of said conduit communicating at its lower end with said heat transfer liquid in said container and at its upper end with said gas space above said liquid level, said tube bundle having an outer diameter smaller than that of said upper end opening and being suspended in said container from and removable with said removable upper end closure member.

9. A heat exchange apparatus comprising a vertically elongated cylindrical pressure vessel having a closed lower end and an open upper end, a closure member removably closing said open upper end of said pressure vessel, walls forming a vertically extending container open at its top and suspended from the open upper end within and spaced from said pressure vessel to form a gas space enveloping the container, a relatively small diameter conduit disposed co-axially within said container to form an annular flow space therebetween, a bundle of helically wound closely spaced heat exchange tubes arranged within said annular flow space and coiled about said conduit, a cylindrical inlet header having a horizontal tube sheet extending co-axially through the upper end of said pressure

vessel for supplying a heat transfer fluid to said bundle of tubes, said conduit being suspended from said inlet header, a plurality of inlet tubes arranged as an annular bundle within said conduit communicating with said inlet header and the lower end of said helical tube bundle in said annular flow space, a plurality of outlet headers each having a horizontal tube sheet extending axially through the upper end closure of said pressure vessel for withdrawing said heat transfer fluid from the upper end of said helical bundle of tubes, a toroidal inlet header horizontally disposed around the upper end of said conduit for supplying a heat transfer liquid to said container for passage therethrough out of contact with said pressure vessel and in indirect heat exchange relationship with said heat transfer fluid, the heat transfer liquid within said container forming a liquid level therein spaced below the top of the container and substantially covering the helical bundle of heat exchange tubes, and means for supplying gas under pressure to said gas space so that the gas envelops said container and is in communication with the heat transfer liquid at its liquid level within said container whereby the gas acts as a separating medium between said container and said pressure vessel while pressurizing the liquid level of said heat transfer liquid within said container, said tube bundle having an outer-diameter smaller than that of said upper end opening and being suspended in said container from and removable with said removable upper end closure member.

10. A heat exchange apparatus comprising a vertically elongated cylindrical pressure vessel having a closed lower end and an open upper end, a closure member removably closing said open upper end of said pressure vessel, walls forming a vertically extending container open at its top and suspended from the open upper end within and spaced from said pressure vessel to form a gas space enveloping the container, a relatively small diameter conduit disposed co-axially within said container to form an annular flow space therebetween, a bundle of helically wound closely spaced heat exchange tubes arranged within said annular flow space and coiled about said conduit, a cylindrical inlet header having a horizontal tube sheet extending co-axially through the upper end of said pressure vessel for supplying a heat transfer fluid to said bundle of tubes, said conduit being suspended from said inlet header, a plurality of inlet tubes arranged as an annular bundle within said conduit communicating with said inlet header and the lower end of said helical tube bundle in said annular flow space, a plurality of outlet headers each having a horizontal tube sheet extending axially through the upper end closure of said pressure vessel for withdrawing said heat transfer fluid from the upper end of said helical bundle of tubes, a toroidal inlet header horizontally disposed around the upper end of said conduit for supplying a heat transfer liquid to said container for passage therethrough out of contact with said pressure vessel and in indirect heat exchange relationship with said heat transfer fluid, the heat transfer liquid within said container forming a liquid level therein spaced below the top of the container and substantially covering the helical bundle of heat exchange tubes, said toroidal inlet header disposed within said pressure vessel above said liquid level, a plurality of liquid feeder pipes communicating with said toroidal header and opening to said container below said liquid level, and means for supplying gas under pressure to said gas space so that the gas envelopes said container and is in communication with the heat transfer liquid at its liquid level within said container whereby the gas acts as a separating medium between said container and said pressure vessel while pressurizing the liquid level of said heat transfer liquid within said container, said tube bundle having an outer diameter smaller than that of said upper end opening and being suspended in said container from and removable with said removable upper end closure member.

11. A heat exchange apparatus comprsing a vertically elongated cylindrical pressure vessel having a closed lower end and an open upper end, a closure member removably closing said open upper end of said pressure vessel, walls forming a vertically extending container open at its top and suspended from the open upper end within and spaced from said pressure vessel to form a gas space enveloping the container, a relatively small diameter conduit disposed co-axially within said container to form an annular flow space therebetween, a bundle of helically wound closely spaced heat exchange tubes arranged within said annular flow space and coiled about said conduit, each of said tubes having a correlated pitch and coil diameter whereby each tube is of equal length, a cylindrical inlet header having a horizontal tube sheet extending co-axially through the upper end of said pressure vessel for supplying a heat transfer fluid to said bundle of tubes, said conduit being suspended from said inlet header, a plurality of inlet tubes arranged as an annular bundle within said conduit communicating with said inlet header and the lower end of said helical tube bundle in said annular flow space, a plurality of outlet headers each having a horizontal tube sheet extending axially through the upper end closure of said pressure vessel for withdrawing said heat transfer fluid from the upper end of said helical bundle of tubes, a toroidal inlet header horizontally disposed around the upper end of said conduit for supplying a heat transfer liquid to said container for passage therethrough out of contact with said pressure vessel and in indirect heat exchange relationship with said heat transfer fluid, the heat transfer liquid within said container forming a liquid level therein spaced below the top of the container and substantially covering the helical bundle of heat exchange tubes, said toroidal inlet header disposed within said pressure vessel above said liquid level, a plurality of liquid feeder pipes communicating with said toroidal header and opening to said container below said liquid level, and means for supplying gas under pressure to said gas space so that the gas envelops said container and is in communication with the heat transfer liquid at its liquid level within said container whereby the gas acts as a separating medium between said container and said pressure vessel while pressurizing the liquid level of said heat transfer liquid within said container, said tube bundle having an outer diameter smaller than that of said upper end opening and being suspended in said container from and removable with said removable upper end closure member

12. A heat exchange apparatus comprising a vertically elongated cylindrical pressure vessel having an open upper end, a removable upper end closure arranged to close said opening, walls forming a vertically extending container open at its top and disposed within and spaced from said pressure vessel to form a gas space enveloping the container, a bundle of closely spaced heat exchange tubes arranged within said container, means including a cylindrical inlet header having a horizontal tube sheet extending co-axially through the upper end of said pressure vessel for supplying a heat transfer fluid to the lower end of said bundle of tubes, a plurality of cylindrical outlet headers extending axially through the upper end of said pressure vessel for withdrawing said heat transfer fluid from the upper end of said bundle of tubes, a heat transfer liquid inlet to said container for passage of said liquid therethrough out of contact with said pressure vessel and in indirect heat exchange relationship with said heat transfer fluid to vaporize said fluid within said tubes, the heat transfer liquid within said container forming a liquid level therein spaced below the top of the container and substantially covering the bundle of heat exchange tubes, means for supplying gas under pressure to said gas space so that the gas envelops said container and is in communication with the heat transfer liquid at its liquid level within said container whereby the gas acts as a separating medium between said container and said pressure vessel while pressurizing the liquid level of said heat transfer liquid within said container, said tube bundle having an outer diameter smaller than that of said upper end opening and being removable through said upper end of said pressure vessel, a U-shaped pressure vessel having a U-shaped tube bundle arranged therein as a superheater for said vapor generated in said bundle of tubes, means for supplying said heat transfer liquid to one leg of said U-shaped pressure vessel, means for connecting the second leg of said pressure vessel to said liquid inlet, and means connecting said outlet headers to one leg of said U-shaped tube bundle.

13. A heat exchange apparatus comprising a vertically elongated cylindrical pressure vessel having an open upper end, a removable upper end closure arranged to close said opening, walls forming a vertically extending container open at its top and disposed within and spaced from said pressure vessel to form a gas space enveloping the container, a bundle of closely spaced heat exchange tubes arranged within said container, means including a cylindrical inlet header having a horizontal tube sheet extending co-axially through the upper end of said pressure vessel for supplying a heat transfer fluid to the lower end of said bundle of tubes, a plurality of cylindrical outlet headers extending axially through the upper end of said pressure vessel for withdrawing said heat transfer fluid from the upper end of said bundle of tubes, a heat transfer liquid inlet to said container for passage of said liquid therethrough out of contact with said pressure vessel and in indirect heat exchange relationship with said heat transfer fluid to vaporize said fluid within said tubes, the heat transfer liquid within said container forming a liquid level therein spaced below the top of the container and substantially covering the bundle of heat exchange tubes, means for supplying gas under pressure to said gas space so that the gas envelops said container and is in communication with the heat transfer liquid at its liquid level within said container whereby the gas acts as a separating medium between said container and said pressure vessel while pressurizing the liquid level of said heat transfer liquid within said container, said tube bundle having an outer diameter smaller than that of said upper end opening and being removable through said upper end of said pressure vessel, a U-shaped pressure vessel having a U-shaped tube bundle arranged therein as a superheater for said vapor generated in said bundle of tubes, the legs of said U-shaped vessel extendiing vertically upward, a transverse tube sheet disposed in the upper end of each leg of said vessel and each connected to an end of said tube bundle, means for supplying said heat transfer liquid to one leg of said U-shaped pressure vessel, said liquid forming a liquid level in each leg of said vessel below said tube sheets, means for supplying gas under pressure to the spaces between said liquid level and said tube sheets to act as a separating medium between said liquid and said tube sheets, means for connecting the second leg of said pressure vessel to said liquid inlet, and means connecting said outlet headers to one leg of said U-shaped tube bundle.

14. A heat exchange apparatus comprising a vertically elongated cylindrical pressure vessel having an open upper end, a removable upper end closure arranged to close said opening, walls forming a vertically extending container open at its top and disposed within and spaced from said pressure vessel to form a gas space enveloping the container, a bundle of closely spaced heat exchange tubes arranged within said container, means including a cylindrical inlet header having a horizontal tube sheet extending co-axially through the upper end of said pressure vessel for supplying a heat transfer fluid to the lower end of said bundle of tubes, a plurality of cylindrical outlet headers extending axially through the upper end of said pressure vessel for withdrawing said heat transfer fluid from the upper end of said bundle of tubes, a heat transfer liquid metal inlet to said container for passage of said liquid metal therethrough out of contact with said pressure vessel and in indirect heat exchange relationship with said heat transfer fluid to vaporize said fluid within said tubes, the heat transfer liquid metal within said container forming a liquid level therein spaced below the top of the container and substantially covering the bundle of heat exchange tubes, means for supplying gas under pressure to said gas space so that the gas envelops said container and is in communication with the heat transfer liquid metal at its liquid level within said container whereby the gas acts as a separating medium between said container and said pressure vessel while pressurizing the liquid level of said heat transfer liquid metal within said container, said tube bundle having an outer diameter smaller than that of said upper end opening and being removable through said upper end of said pressure vessel, a U-shaped pressure vessel having a U-shaped tube bundle arranged therein as a superheater for said vapor generated in said bundle of tubes, the legs of said U-shaped vessel extending vertically upward, a transverse tube sheet disposed in the upper end of each leg of said vessel and each connected to an end of said tube bundle, means for supplying said heat transfer liquid metal to one leg of said U-shaped pressure vessel, said liquid metal forming a liquid level in each leg of said vessel below said tube sheets, means for supplying gas under pressure to the spaces between said liquid level and said tube sheets to act as a separating medium between said liquid metal and said tube sheets, means for connecting the second leg of said pressure vessel to said liquid metal inlet to said container, means joining said outlet headers into a single mixing header, and means connecting said mixing header to one leg of said U-shaped tube bundle.

15. A heat exchange apparatus comprising a vertically elongated cylindrical pressure vessel having an open upper end, a removable upper end closure arranged to close said opening, walls forming a vertically extending container open at its top and disposed within and spaced from said pressure vessel to form a gas space enveloping the container, a bundle of closely spaced heat exchange tubes arranged within said container, means including a cylindrical inlet header having a horizontal tube sheet extending co-axially through the upper end of said pressure vessel for supplying a heat transfer fluid to the lower end of said bundle of tubes, a plurality of cylindrical outlet headers extending axially through the upper end of said pressure vessel for withdrawing said heat transfer fluid from the upper end of said bundle of tubes, a heat transfer liquid inlet to said container for passage of said liquid therethrough out of contact with said pressure vessel and in indirect heat exchange relationship with said heat transfer fluid to vaporize said fluid within said tubes, the heat transfer liquid within said container forming a liquid level therein spaced below the top of the container and substantially covering the bundle of heat exchange tubes, means for supplying gas under pressure to said gas space so that the gas envelops said container and is in communication with the heat transfer liquid at its liquid level within said container whereby the gas acts as a separating medium between said container and said pressure vessel while pressurizing the liquid level of said heat transfer liquid within said container, said tube bundle having an outer diameter smaller than that of said upper end opening and being removable through said upper end of said pressure vessel, a U-shaped pressure vessel having a U-shaped tube bundle arranged therein as a superheater for said vapor generated in said bundle of tubes, a second U-shaped pressure vessel having a U-shaped tube bundle arranged therein as a reheater for said vapor generated in said bundle of tubes, means for supplying said heat transfer liquid to one leg of each of said U-shaped pressure vessels, means for connecting the second leg of each of said pressure vessels to said liquid inlet, and means connecting said outlet headers to one leg of said superheater tube bundle.

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