June 8, 1965 | J. H. AMMON | 3,187,807

HEAT EXCHANGER

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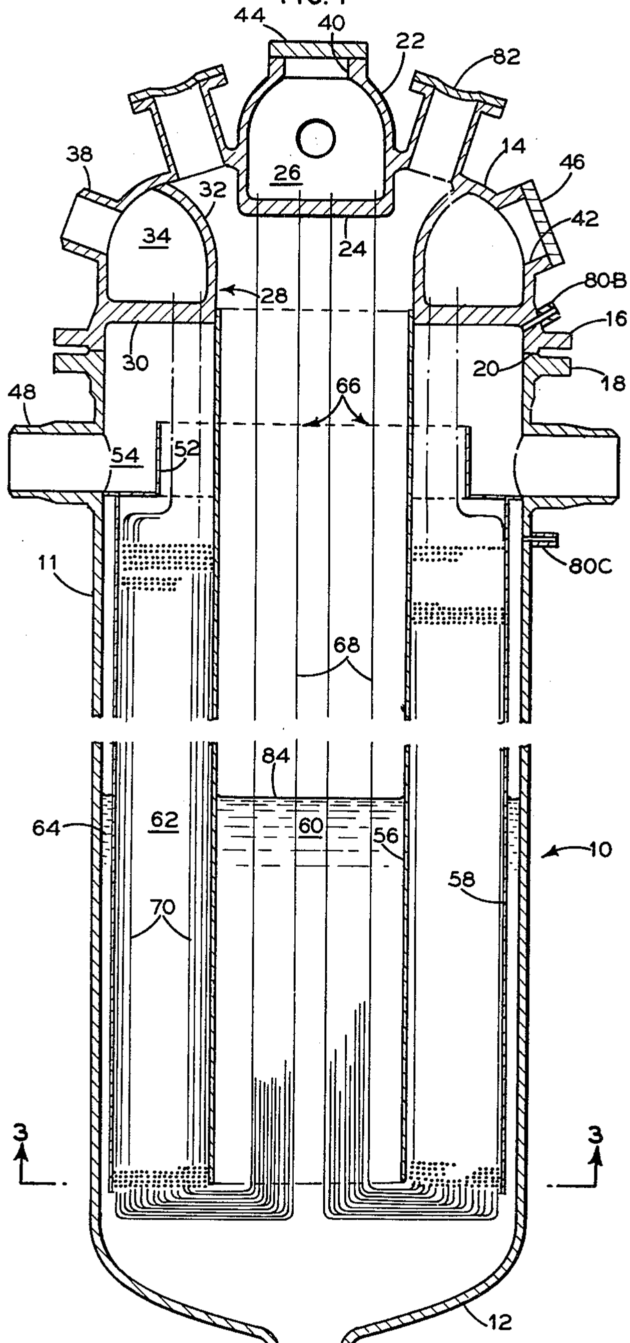
FIG. 1



INVENTOR.

Johannes H. Ammon

BY [signature]

ATTORNEY

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HEAT EXCHANGER

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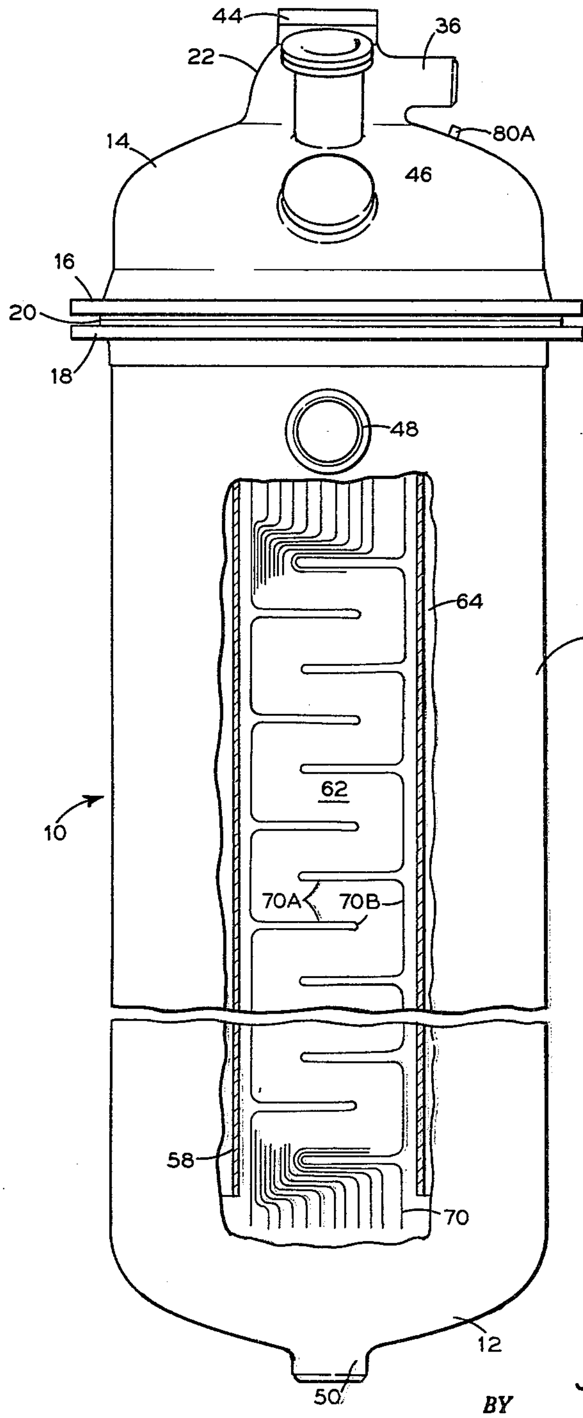

FIG. 2

INVENTOR.
Johannes H. Ammon
BY
[signature]
ATTORNEY

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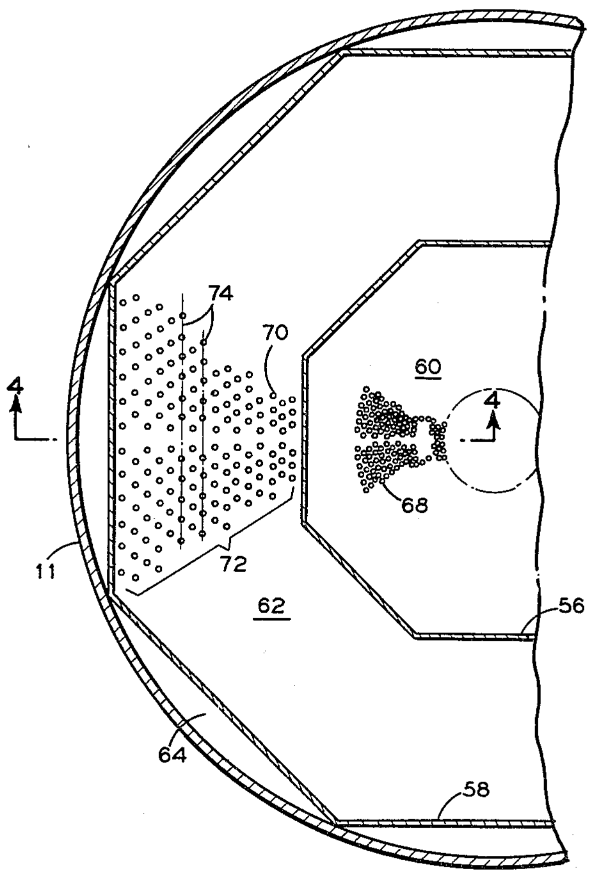

FIG. 3

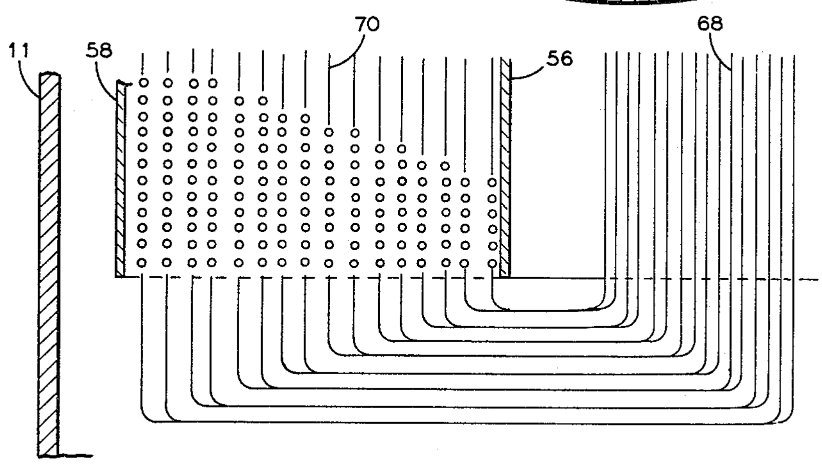

FIG. 4

INVENTOR.
Johannes H. Ammon

BY

ATTORNEY

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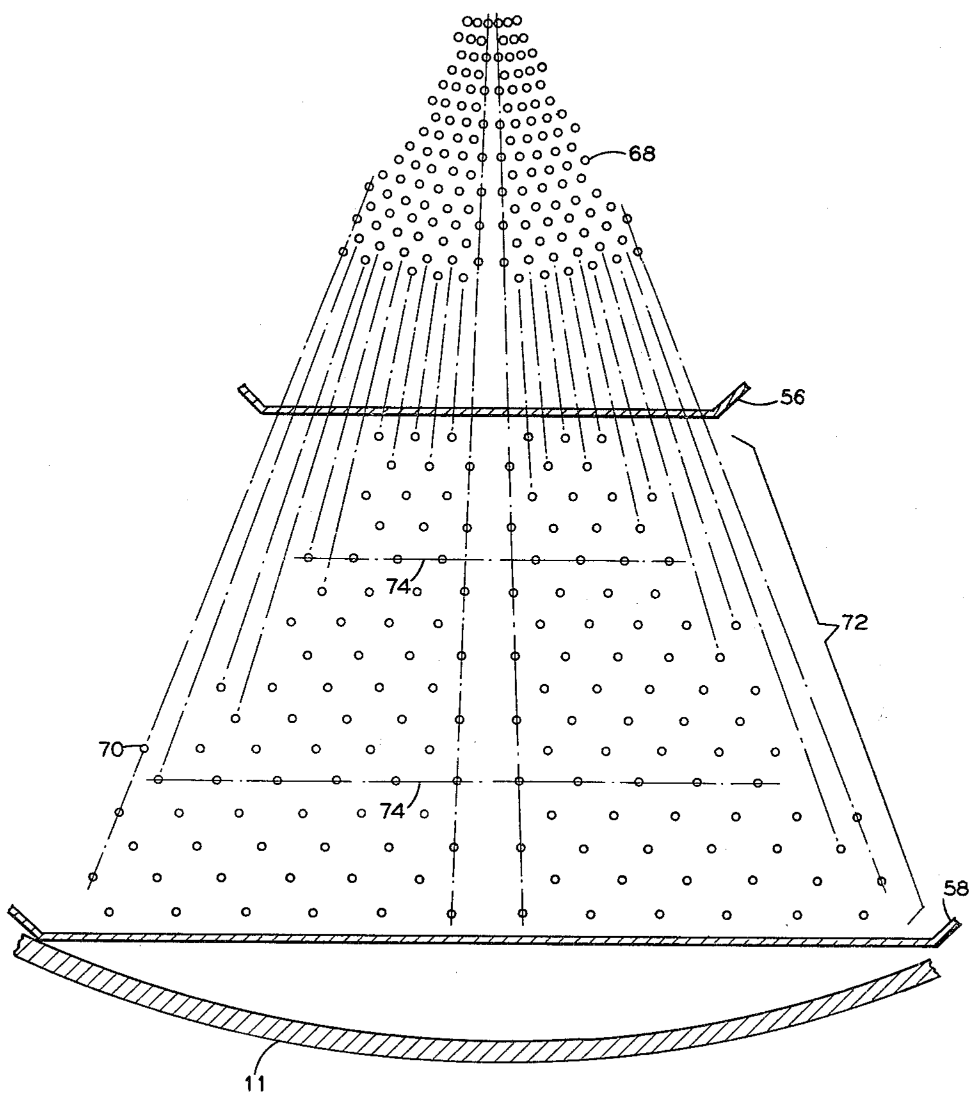
FIG. 5



INVENTOR.
Johannes H. Ammon

BY

ATTORNEY

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3,187,807
HEAT EXCHANGER

Johannes H. Ammon, Akron, Ohio, assignor to The Babcock & Wilcox Company, New York, N.Y., a corporation of New Jersey

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5 Claims. (Cl. 165—74)

This invention relates in general to heat exchangers and more particularly to heat exchangers utilizing liquid metal as a source for heat interchange.

When liquid metal is used as a source of heat in a heat exchanger there is the danger that interaction between the liquid metal and the fluid, usually water, which it heats will result in a reaction damaging to the heat exchanger vessel. Another problem faced in such heat exchangers has been to provide the maximum amount of heat transfer surface while limiting the size of the vessel. The present invention affords a tube bank arrangement for a heat exchanger whereby the maximum amount of heat transfer surface is located within the heat exchanger vessel. Further, the heat exchanger is arranged so that any reaction resulting from the interaction of the liquid metal and the fluid it heats will not result in damage to the vessel.

Therefore, the present invention provides a heat exchanger comprising a vertically elongated pressure vessel of circular cross section. The interior of the vessel is divided by a dependently supported tubular shaped baffle into a centrally disposed inner chamber and an annular shaped outer chamber. Communication is provided between the inner and outer chambers at the lower end of the vessel by positioning the baffle above the bottom of the vessel. A plurality of tubes is disposed in the vessel with the first portion of each tube located in the inner chamber and the second portion located within the outer chamber. In the outer chamber the second portions of the tubes form a number of separate vertically extending tube banks. Each of these tube banks is made up of a plurality of horizontal spaced vertically extending tube platens arranged in a single vertical plane. The tubes in each platen are vertically spaced and extend horizontally back and forth across the platen joined by reverse bends. The second portions of the tubes forming the tube banks are arranged in counter-flow heat transfer relationship with the heating fluid flowing downwardly and the fluid to be heated flowing upwardly within the outer chamber.

Additionally, another baffle, similar in shape to the tubular shaped baffle, is positioned between the pressure vessel and the first mentioned baffle. This outer baffle forms the radially outer boundary of the outer chamber and in combination with the pressure vessel wall forms a thermal barrier space or spaces between the outer chamber and the pressure vessel wall.

Further a plate section, connected to the pressure vessel walls in the upper part of the outer chamber, forms a circular trough running about the inside of the vessel. The heating fluid on first entering the vessel flows into this trough and from there is distributed evenly into the outer chamber for its downward flow over the tubes.

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 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 heat exchanger embodying the present invention;

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FIG. 2 is an elevation view of the heat exchanger vessel shown in FIG. 1 with a part of the outer shell and the outer baffle broken away to show one of the tube platens in the outer chamber of the vessel;

FIG. 3 is an enlarged partial plan-section taken along line 3—3 of FIG. 1;

FIG. 4 is an enlarged partial vertical section of a tube bank shown at the bottom of the pressure vessel taken along line 4—4 of FIG. 3; and

FIG. 5 is a greatly enlarged view of a portion of the tube bank shown in FIG. 3.

Referring now to the drawings, FIG. 1 shows a heat exchanger 10 formed by a vertically elongated pressure vessel 11 of circular cross section having an integral lower head 12 and an upper head 14 which forms the end closure for the pressure vessel. Flange 16 on the upper head 14 is disposed opposite and combines with flange 18 on the pressure vessel to form closure joint 20.

A feedwater inlet chamber 26 for the heat exchanger 10 is formed by an upwardly extending wall 22 and a horizontally disposed wall 24. The inlet chamber 26 is positioned in the vertical axis of the pressure vessel and is connected about wall 22 to the upper head 14. Within the upper head wall means 28 comprising a horizontal leg 30 and a vertical leg 32 form an annularly shaped vapor outlet chamber 34 concentrically disposed about the vertical axis of the pressure vessel. The wall means 28 are integrally connected to the upper head 14 about the radially outer edge of leg 30 and about the upper edge of leg 32. Feedwater enters inlet chamber 26 through inlet 36 and vapor exits from outlet chamber 34 through outlet 38. Both the inlet and outlet chambers have access openings 40 and 42, respectively, closed by cover plates 44 and 46.

The heating fluid, preferably liquid metal, is admitted to the vessel 11 through multiple inlets 48 located in the vessel shell a short distance below the flange 18. After its passage through the vessel the heating fluid leaves through outlet 50 positioned centrally in the lower head of the vessel.

An L-shaped plate section 52 having the horizontal leg connected to the inner wall of the pressure vessel 11 is located immediately adjacent the inlets 48. The vertical leg of plate section 52 opposite the inlets 48 is spaced inwardly from the wall of the vessel, and extends upwardly to an elevation somewhat above that of the top of the inlets. This plate section 52 in combination with the pressure vessel 11 forms an annular shaped trough 54 around the inner periphery of the vessel.

An inner octagonally shaped baffle 56, connected about its upper end to wall means 28, extends downwardly to an elevation which corresponds to a horizontal plane spaced above and adjacent the lower head 12 of the vessel. Concentrically spaced about the inner baffle 56 is an outer baffle 58 also of octagonal shape. The outer baffle, attached at its upper end to the horizontal leg of plate section 52, extends downwardly and terminates in approximately the same horizontal plane as the baffle 56. Thus the inner baffle 56 forms a centrally disposed inner chamber 60 and, in combination with the outer baffle 58, provides an outer chamber 62 of annular form which at the lower end of the vessel is in communication with the inner chamber. The octagonal outer baffle 58 in combination with the vertical wall of the pressure vessel 11 forms a number of circular segments or thermal barrier spaces 64 about the inner periphery of the vessel. These thermal barrier spaces are closed at the top by the L-shaped plate section 52. They are open at the bottom and thus are in communication with the space which interconnects the inner chamber 60 with the outer chamber 62.

A plurality of heat exchange tubes 66 are arranged in parallel flow relationship within the pressure vessel 11 to conduct the vaporizable fluid, which is to be heated, through the heat exchanger 10. Each of the tubes is divided into a downcomer portion 68 located within the inner chamber 60 and a riser portion 70 positioned within the outer chamber 62. The inlet end of the downcomer portions 68 of the tubes are suitably attached to wall 24 which acts as a tube sheet for the water inlet chamber 26. From the inlet chamber the downcomer portions 68 extend downwardly through the inner chamber 60 into the space below the lower edge of the baffle 56, where they are radially extended for connection to the riser portions 70. The riser portions extend upwardly through the outer chamber 62 and are suitably attached to the horizontal leg 30 of the wall means 28 which acts as a tube sheet thereby permitting discharge into the vapor outlet chamber 34.

Within the inner chamber 60 the downcomer portions of the tubes are vertically aligned in parallel relationship with the vertical axis of the vessel. As can be noted in FIG. 3 the downcomer portions 68 of the tubes 66 form an annular bundle. Below the lower edge of the inner baffle 56 the downcomer portions of the tubes extend radially outward in horizontal planes to form the riser portions 70 of the tubes 66 into eight separate, similarly arranged, tube banks 72, one of which is illustrated in FIG. 3.

As can be seen in FIGS. 3, 4 and 5, each tube bank 72 contains sixteen chordally extending rows of tubes corresponding to a similar number of concentric rows within the inner chamber 60. FIG. 5 illustrates the pattern whereby the tubes extend radially from the inner chamber 60 to form the tube banks 72 in the outer chamber 62. The innermost tubes in the radial array within the inner chamber 60 become the tubes of the outermost rows in the outer chamber and conversely those tubes in the outer rows within the inner chamber become the tubes for the inner rows in the outer chamber. However, since the outermost row within the inner chamber has double the number of tubes in the innermost row in the outer chamber, it will be noted in FIG. 5 that certain of the tubes from the outermost row of the inner chamber extend into different rows in the outer chamber to afford a balanced distribution of tubes.

The riser portions 70 forming the tube banks 72 first extend vertically upward a short distance from the bottom of the outer chamber 62, then are bent into horizontal planes extending chordally across the outer chamber 62 to form vertically extending tube platens 74.

In FIG. 2 there is illustrated the manner in which the tubes in the outermost platen of the outer chamber are bent to provide a nested arrangement extending through the outer chamber to a point closely spaced below the trough 54 shown in FIG. 1. Just below the trough 54 the tubes are bent from the horizontal back into vertical alignment, finally terminating in leg 30 of wall means 28. Because of the projection of the trough 54 into the outer chamber 62, it is necessary for the tubes in the outer platens 74 to be bent inwardly in the vicinity of the trough to pass around the trough, and they then proceed vertically the remainder of their path through the outer chamber.

As seen in FIGS. 3 and 4 each tube platen 74 within the tube bank 72 is uniformly spaced from the adjoining platens throughout its height, with the riser portions 70 made up of a number of horizontally extending sections 70A joined by cooperating bend sections 70B as shown in FIG. 2. Because of the back and forth routing of the nested riser portions of the tubes as shown in FIG. 2 the bends 70B are of varying lengths depending on the position of the tube within the platen.

With this particular platen arrangement the average developed lengths of the tubes 70 which comprise the platen 74 are approximately the same. This is accomplished by maintaining the same vertical distance between adjacent horizontal tube runs for all of the tubes in the platens of tube bank 72, even though the number of tubes in a platen depends on its distance from the vertical centerline of the heat exchanger. Disparities in flow arising from varying pressure drops in the multiple parallel flow paths of the tubes within the tube bank are compensated for by installing orifice plates (not shown) at the entrances to the tubes in the inlet chamber 26.

Connections 80A, 80B, 80C are provided for supplying inert gas to the inner chamber 60, the outlet chamber 62 and the thermal barrier spaces 64, respectively. In the upper head relief diaphragm nozzles 82 are provided to relieve any sudden pressure build-up due to a liquid metal to water reaction in case of a tube failure.

For purposes of describing the operation of the heat exchanger 10 as a steam generating unit, sodium will be considered as the heating fluid and water as the fluid to be vaporized. The heated liquid sodium enters the pressure vessel 11 through inlets 48 flowing into the trough 54. From the trough, which acts as a weir, the sodium is distributed evenly into the outer chamber 62. After it flows downwardly through the outer chamber 62 in indirect counter-flow heat exchange relationship with the riser portions 70 of the tubes 66, the sodium leaves the heat exchanger through the outlet 50 in its lower head 12. The quantity of sodium introduced into the heat exchanger is regulated so that a heating fluid level 84 is maintained within the inner chamber 60 and the thermal barrier spaces 64.

Feedwater to be vaporized in the heat exchanger enters inlet chamber 26 through inlet 36. From the inlet chamber the water enters the downcomer portions of the tubes 66 where it is indirectly contacted by the sodium in the lower half of the inner chamber. However, substantially all of the heating of the water takes place as it flows upwardly through the outer chamber between the bottom of the vessel and trough 54. The water, which is vaporized and preferably superheated in its passage through the outer chamber, leaves the heat exchanger by way of the outlet chamber 34 and outlet 38.

In the event leakage occurs between the water passing through the tubes and the heating fluid flowing through the unit, any reaction which might result would be cushioned by the inert gas cover provided over the heating fluid-gas interface. Additionally, the relief diaphragm nozzles 82 in the upper part of the inner chamber 66 provide means whereby any sudden pressure build-up resulting from a reaction between the heating liquid and the fluid to be vaporized can be relieved.

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 exchanger comprising wall means forming a vertically elongated pressure vessel of circular cross section, a vertically arranged tubular shaped baffle extending downwardly from the upper end of said vessel to a horizontal plane spaced above and adjacent to the lower end of said vessel, said baffle spaced inwardly from the wall means of said pressure vessel dividing the interior of said vessel into a annular shaped outer chamber and a centrally disposed inner chamber in communication with said outer chamber at the lower end of said vessel, a plurality of heat exchange tubes disposed within said pressure vessel for parallel flow of a fluid to be heated therethrough, each of said tubes having a first downcomer portion positioned in said inner chamber and a second riser portion positioned in said outer chamber, the second portion of said tubes substantially filling said outer chamber and forming a number of vertically extending circumferentially spaced tube banks, each of said tube banks comprising a plurality of uniformly horizon-

tally spaced vertically extending tube platens each arranged in a single chordally disposed vertical plane, each of said tubes within said platens comprising a plurality of horizontally extending vertically spaced tube sections joined by reverse bends and arranged for counter-flow heat transfer, means for supplying fluid to be heated to the upper ends of the first downcomer portions of said tubes, means for collecting the fluid to be heated after its passage through the riser portions of said tubes, heating fluid inlet means located in the upper part of said outer chamber, and heating fluid outlet means located in the lower end of said pressure vessel whereby the heating fluid transfers heat to the fluid to be heated as it flows downwardly through the outer chamber passing over the second riser portions of said tubes within which the fluid to be heated flows.

2. A heat exchanger comprising wall means forming a vertically elongated pressure vessel of circular cross section, a vertically arranged tubular shaped inner baffle extending downwardly within said vessel from the upper end thereof to a horizontal plane spaced above and adjacent to the lower end of said vessel, a vertically arranged tubular shaped outer baffle extending downwardly within said vessel from the upper end thereof and terminating in approximately the same horizontal plane as said inner baffle and concentrically disposed about and spaced from said inner baffle, said inner baffle forming a centrally positioned inner chamber and in combination with said outer baffle a concentrically arranged outer chamber in communication with said inner chamber at the lower end of said vessel, a plurality of heat exchange tubes disposed within said pressure vessel for parallel flow of a fluid to be heated therethrough, each of said tubes having a first downcomer portion positioned in said inner chamber and a second riser portion positioned in said outer chamber, the second portion of said tubes substantially filling said outer chamber and forming a number of vertically extending circumferentially spaced tube banks, each of said tube banks comprising a plurality of uniformly horizontally spaced vertically extending tube platens each arranged in a single chordally disposed vertical plane, each of said tubes within said platens comprising a plurality of horizontally extending vertically spaced tube sections joined by reverse bends and arranged for cross flow heat transfer, means for supplying fluid to be heated to the upper ends of the first downcomer portions of said tubes, means for collecting the fluid to be heated after its passage through the riser portions of said tubes, heating fluid inlet means located in the upper part of said outer chamber, and heating fluid outlet means located in the lower end of said pressure vessel whereby the heating fluid transfers heat to the fluid to be heated as it flows downwardly through the outer chamber passing over the second riser portions of said tubes within which the fluid to be heated flows.

3. A heat exchanger comprising wall means forming a vertically elongated pressure vessel of circular cross section, a vertically arranged tubular shaped inner baffle extending downwardly within said vessel from the upper end thereof to a horizontal plane spaced above and adjacent to the lower end of said vessel, a vertically arranged tubular shaped outer baffle extending downwardly within said vessel from the upper end thereof and terminating in approximately the same horizontal plane as said inner baffle and concentrically disposed about and spaced from said inner baffle, said inner baffle forming a centrally positioned inner chamber and in combination with said outer baffle a concentrically arranged outer chamber in communication with said inner chamber at the lower end of said vessel, a plurality of heat exchange tubes disposed within said pressure vessel for parallel flow of a fluid to be heated therethrough, each of said tubes having a first downcomer portion positioned in said inner chamber and a second riser portion positioned in said outer chamber, the second portion of said tubes substantially filling said outer chamber and forming a number of vertically extending circumferentially spaced tube banks, each of said tube banks comprising a plurality of horizontally spaced vertically extending tube platens each arranged in a single chordally disposed vertical plane, each of said tubes within said platens comprising a plurality of horizontally extending vertically spaced tube sections joined by reverse bends, an inlet in said pressure vessel for supplying heating fluid into the upper end of said other chamber, and means for evenly distributing the heating fluid into said outer chamber for flow downwardly therethrough in counter-flow heat transfer relationship with the tubes disposed therein, means for supplying fluid to be heated to the upper ends of the first downcomer portions of said tubes, means for collecting the fluid to be heated after its passage through the riser portions of said tubes, heating fluid inlet means located in the upper part of said outer chamber, and heating fluid outlet means located in the lower end of said pressure vessel whereby the heating fluid transfers heat to the fluid to be heated as it flows downwardly through the outer chamber passing over the second riser portions of said tubes within which the fluid to be heated flows.

4. A heat exchanger employing heated liquid metal as the heating fluid and comprising walls forming a vertically elongated pressure vessel of circular cross section, a flanged upper head forming a closure for said pressure vessel, first wall means attached to said upper head forming an inlet chamber located on the vertical axis of said vessel, second wall means in combination with said head forming an annular shaped outlet chamber disposed concentrically about the vertical axis of said vessel, an annular shaped plate section disposed within and connected to said vessel at a point closely spaced below said head, said plate section forming in combination with said wall means of said vessel a circular trough about the inside of said vessel, an inner vertically extending tubular shaped baffle disposed within and in co-axial alignment with the vertical axis of said vessel, an outer vertically extending tubular shaped baffle disposed within and in co-axial alignment with the vertical axis of said vessel, said inner baffle dependently supported from said head and extending downwardly to a horizontal plane spaced above and adjacent the lower end of said vessel, said outer baffle disposed between said inner baffle and the wall means of said pressure vessel and attached to said plate section and extending downwardly therefrom and terminating in approximately the same horizontal plane as said inner baffle, said inner baffle forming a centrally arranged inner chamber and in combination with said outer baffle an annular shaped outer chamber concentrically disposed about and in communication with said inner chamber at the lower end of said vessel, said outer baffle in combination with said pressure vessel wall means forming a space therebetween open at its lower end, a plurality of heat exchange tube disposed within said pressure vessel for parallel flow therethrough, each of said tubes having a downcomer portion positioned within said inner chamber and extending downwardly therethrough from said inlet chamber to below said inner baffle and a riser portion positioned within said outer chamber and connected to said downcomer portion below said inner baffle and extending upwardly therethrough to said outlet chamber, the riser portion of said tubes forming a number of vertically extending circumferentially spaced tube banks, each of said tube banks comprising a plurality of horizontally spaced vertically extending tube platens each arranged in a single chordally disposed vertical plane, each of said tubes within said platents comprising a plurality of horizontally extending vertically spaced tube sections joined by reverse bends, and an inlet in said pressure vessel closely spaced above said plate section for delivering heated liquid metal to the trough formed by said plate section whereby the heated liquid metal is evenly distributed into said outer chamber for passage downward-

ly therethrough in counterflow heat transfer with said tubes therein, and connections in said pressure vessel for supplying inert gas to said inner chamber, said outer chamber and said space between said outer baffle and pressure vessel walls.

5. A heat exchanger employing heated liquid metal as the heating fluid and comprising walls forming a vertically elongated pressure vessel of circular cross section, a flanged upper head forming a closure for said pressure vessel, first wall means attached to said upper head forming an inlet chamber located on the vertical axis of said vessel, second wall means in combination with said head forming an annular shaped outlet chamber disposed concentrically about the vertical axis, of said vessel, an annular shaped plate section disposed within and connected to said vessel at a point closely spaced below said head, said plate section forming in combination with said wall means of said vessel a circular trough about the inside of said vessel, an inner multi-sided vertically extending tubular shaped baffle disposed within and in co-axial alignment with the vertical axis of said vessel, an outer multi-sided vertically extending tubular shaped baffle disposed within and in co-axial alignment with the vertical axis of said vessel, said inner baffle attached to said head and extending downwardly therefrom to a horizontal plane spaced above and adjacent the lower end of said vessel, said other baffle disposed between said inner baffle and the wall means of said pressure vessel and attached to said plate section and extending downwardly therefrom and terminating in approximately the same horizontal plane as said inner baffle, said inner baffle forming a centrally arranged inner chamber and in combination with said outer baffle an annular shaped outer chamber concentrically disposed about and in communication with said inner chamber at the lower end of said vessel, said outer baffle in combination with said pressure vessel wall means forming a space therebetween open at its lower end and closed at its upper end by said plate section, a plurality of heat exchange tubes disposed within said pressure vessel for parallel flow therethrough, each of said tubes having a

downcomer portion positioned within said inner chamber and extending downwardly therethrough from said inlet chamber to below said inner baffle and a riser portion positioned within said outer chamber and connected to said downcomer portion below said inner baffle and extending upwardly therethrough to said outlet chamber, the riser portion of said tubes forming a number of vertically extending circumferentially spaced tube banks, each of said tube banks comprising a plurality of horizontally spaced vertically extending tube platens each arranged in a single chordally disposed vertical plane, each of said tubes within said platens comprising a plurality of horizontally extending vertically spaced tube sections joined by reverse bends, each of said tubes within said tube banks being of substantially equal length, and an inlet in said pressure vessel closely spaced above said plate section for delivering heated liquid metal to the trough formed by said plate section whereby the heated liquid metal is evenly distributed into said outer chamber for passange downwardly therethrough in cross and counter flow heat transfer with said tubes therein whereby the fluid passing through said tubes is vaporized and superheated, connections in said pressure vessel for supplying inert gas to said inner chamber, said outer chamber and said space between said outer baffle and pressure vessel walls, and a heated liquid metal outlet located in the bottom of said pressure vessel below said heat exchange tubes.

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CHARLES SUKALO, *Primary Examiner.*

HERBERT L. MARTIN, FREDERICK L. MATTESON, PERCY L. PATRICK, *Examiners.*