Nov. 24, 1964 R. D. KUERSTON 3,158,010

TWO PHASE FLUID HEAT EXCHANGER

Filed Oct. 7, 1963 3 Sheets-Sheet 1

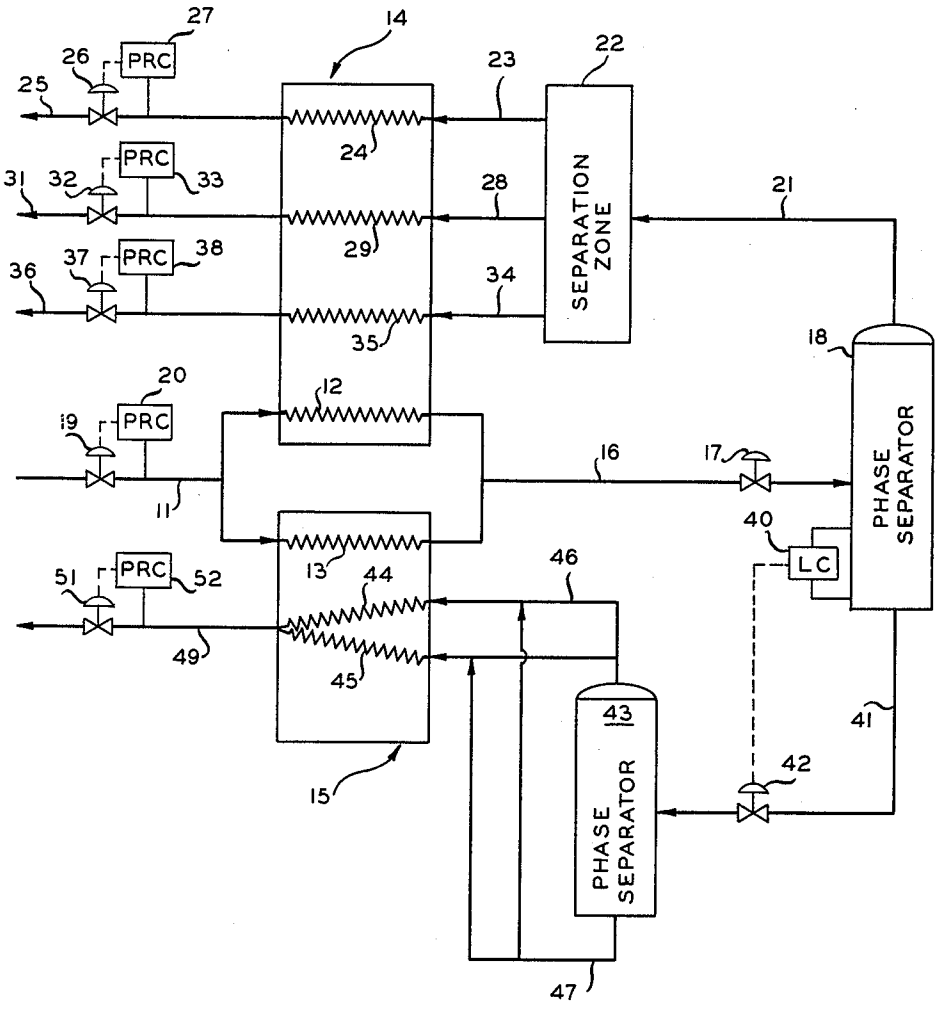

FIG. 1

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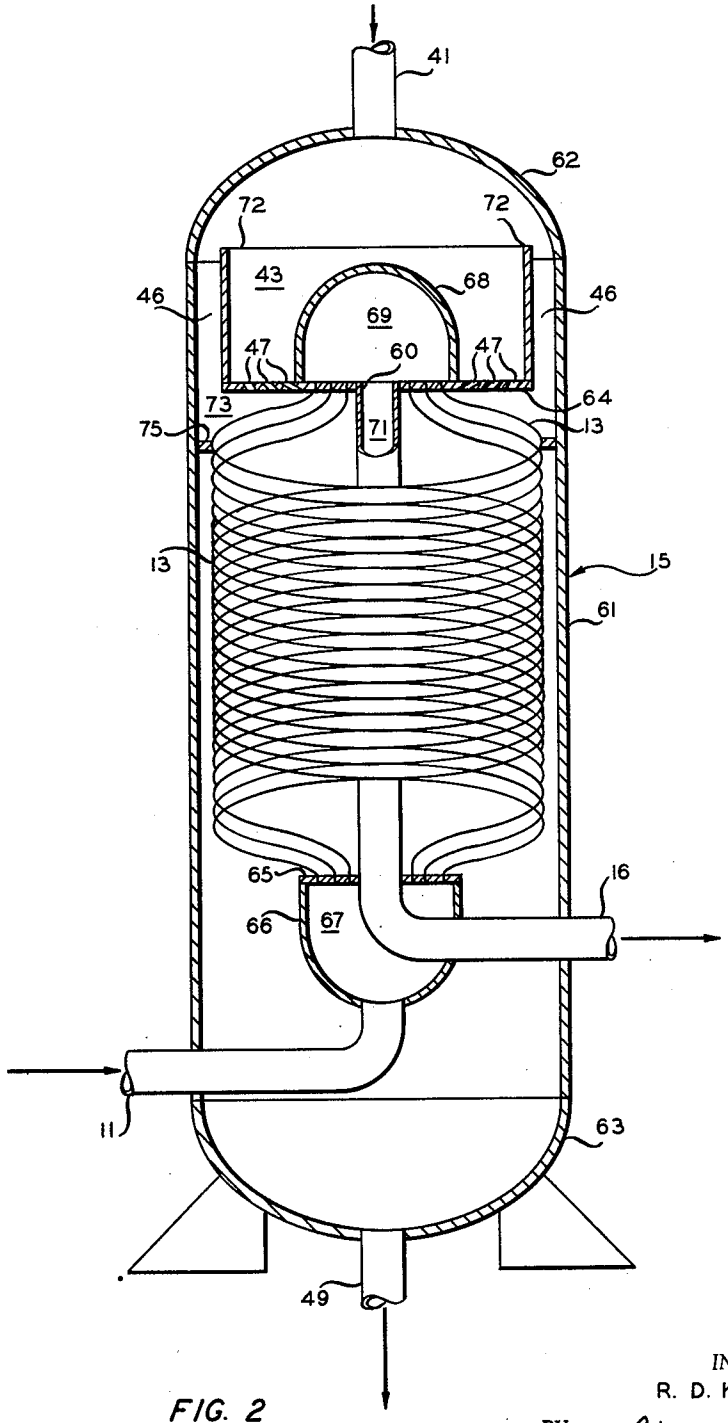

FIG. 2

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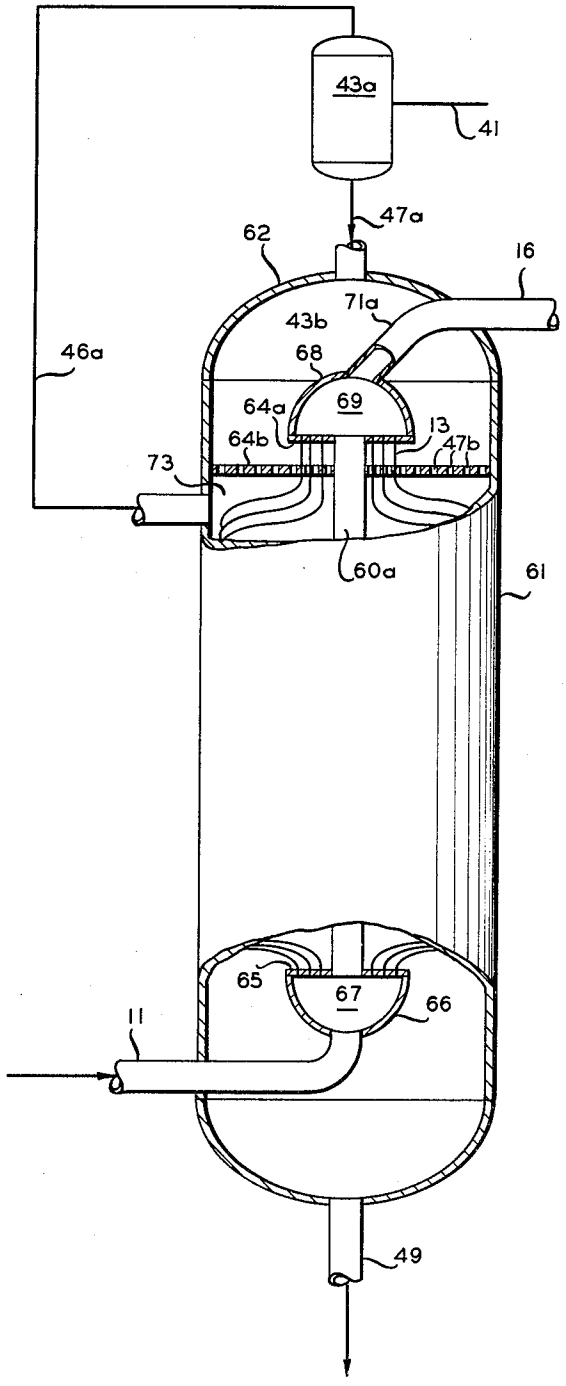

FIG. 3

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3,158,010

TWO PHASE FLUID HEAT EXCHANGER

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5 Claims. (Cl. 62—525)

This invention relates to method and apparatus for providing a substantially uniform distribution of a fluid which has two phases. In one aspect the invention relates to method and apparatus for feeding a uniform concentration of both liquid and vapor into a plurality of flow paths. In another aspect the invention relates to method and apparatus for feeding a substantially uniform concentration of liquid and vapor into a multiple passage heat exchanger. In a still further aspect the invention relates to method and apparatus for flashing a liquid, recovering the flashed liquid and the flashed vapors, and passing a substantially uniform concentration of the flashed liquid and flashed vapors into a plurality of flow paths.

In the liquefaction of natural gas by low temperature refrigeration for the production of liquefied natural gas or for recovery of gaseous helium therefrom, it is desirable in some instances to reduce the pressure on the liquefied gases before the separated liquids are passed through a heat exchanger in order to have the liquefied gases at a pressure at which substantially all of the liquefied gases will be vaporized by passage through the heat exchanger. When the pressure is reduced, flashing occurs, and it is difficult to pass a uniform concentration of the resulting two phase fluid into the various passages of the heat exchanger. If most of the flashed liquid is allowed to pass through some of the passages and the flashed vapor is allowed to pass through the other passages, the amount of liquid vaporized will be decreased, resulting in less heat being transferred as well as an unequal distribution of the heat. For a maximum transfer of heat, it is desirable for a uniform concentration of the various constituents of the fluid to pass into each of the passages in the heat exchanger.

It has been discovered that these difficulties can be overcome by separating the two phase fluid into a liquid portion and a vapor portion, introducing a substantially equal portion of the liquid portion into each of the plurality of flow paths through the heat exchanger, and introducing substantially equal portions of the vapor portion into each of the plurality of flow paths. Systems which have been proposed in accordance with this discovery have been primarily directed to distributing a two phase fluid through a plurality of tubular passageways, for example, through the tubes of a shell and tube indirect heat exchanger. However, the problems of two phase fluid distribution are also encountered, and are even more troublesome, when the two phase fluid is passed through the shell and around the tubes, particularly when the heat exchanger is of the wrapped bundle or wound tube type.

In accordance with the invention there is provided means for separating the two phase fluid into a liquid component and a vapor component in combination with means for introducing the vapor component into the shell section of the heat exchanger at one or more locations, and means for distributing the liquid component across the upper portion of the tube bundle in such a manner as to provide substantially uniform horizontal distribution of

the liquid component in the spaces between the tubes at any given level in the length of the tube bundle.

Accordingly it is an object of the invention to provide method and means for obtaining a substantially uniform horizontal distribution of a two phase fluid in the space outside of the tubes in a heat exchanger tube bundle. Another object of the invention is to provide maximum transfer of heat in a heat exchanger. Yet another object of the invention is to provide for an equal heat transfer with a plurality of flow paths.

Other aspects, objects, and advantages of the invention will become apparent to those skilled in the art from a study of the disclosure, the drawing and the appended claims to the invention.

In the drawings FIGURE 1 is a diagrammatic representation of a low temperature refrigeration separation process embodying the invention; FIGURE 2 is an elevation view of one embodiment of apparatus for carrying out the invention; and FIGURE 3 is an elevation view of another apparatus suitable for carrying out the invention.

While the invention is applicable to various processes for liquefying a portion or all of a gas feed stream, for purposes of illustration the invention will be described in terms of a process for the recovery of helium from a natural gas stream. It is equally applicable to a process for substantially complete liquefaction of natural gas and also for liquefaction of air, hydrogen, ammonia, chlorine, etc.

Referring now to the drawing in detail and to FIGURE 1 in particular, natural gas containing hydrocarbons, nitrogen, and helium is passed through line 11 into and through parallel flow paths 12 and 13 of indirect heat exchangers 14 and 15, respectively, wherein the gas is substantially cooled. The thus cooled gas from flow paths 12 and 13 is passed through line 16, which can contain expansion valve 17, into a phase separator 18. The gas can be partially or totally liquefied in passing through flow paths 12 and 13 or upon the expansion of the gas when passed through expansion valve 17. A valve 19 can be positioned in line 11 and manipulated by a pressure recorder controller 20 responsive to the pressure of the gas in line 11 downstream of valve 19 to maintain such pressure substantially constant.

The vapors from phase separator 18 are withdrawn through line 21 and passed to a separation zone 22 wherein a further separation can be made if desired. Separation zone 22 can be any suitable means, such as, for example, a series of heat exchangers and liquid gas separators. The details of suitable means for separation zone 22 in a helium recovery system are set forth in copending application Serial No. 218,985, filed August 23, 1962, by L. G. Kitchen. Exemplary of such further process, a crude helium stream, a low B.t.u. gas, and a residue gas can be obtained in separation zone 22. The crude helium stream is passed through line 23 into and through flow path 24 of indirect heat exchanger 14 wherein the crude helium stream is passed in indirect heat exchanging relationship with additional natural gas passing through flow path 12. The warmed crude helium stream passes from flow path 24 into line 25 and can be withdrawn from the system. A valve 26 can be positioned in line 25 and manipulated by a pressure recorder controller 27 to maintain the pressure in line 25 upstream of valve 26 substantially constant, if desired. The low B.t.u. gas obtained

in separation zone 22 can be passed through line 28 into and through flow path 29 of indirect heat exchanger 14 wherein the low B.t.u. gas is passed in indirect heat exchanging relationship with additional natural gas passing through flow path 12. The thus warmed low B.t.u. gas passing from flow path 29 can be withdrawn from the system by way of line 31. A valve 32 can be positioned in line 31 and manipulated by pressure recorder controller 33 to maintain the pressure of the fluid in line 31 upstream of valve 32 substantially constant, if desired. The residue gas obtained in separation zone 22 can be passed through line 34 into and through flow path 35 of indirect heat exchanger 14 wherein the residue gas is passed in indirect heat exchanging relationship with additional natural gas passing through flow path 12. The thus warmed residue gas passes from flow path 35 into line 36 and can be withdrawn from the system. A valve 37 can be positioned in line 36 and manipulated by a pressure recorder controller 38 to maintain the pressure of the fluid in line 36 upstream of valve 37 substantially constant, if desired.

The liquid in liquid gas separator 18 is withdrawn therefrom by way of line 41. A throttle valve 42 is positioned in line 41 to effect a reduction in the pressure of the liquid passing through line 41 and thus a further cooling of such liquid. If desired throttle valve 42 can be manipulated by a liquid level controller 40 to maintain the liquid level in liquid gas separator 18 substantially constant. When the liquid passes through throttle valve 42, flashing occurs resulting in a two phase fluid downstream of valve 42. This two phase fluid is passed into separation means 43 which is utilized to effect an even distribution of each of the two phases through parallel flow paths 44 and 45 of heat exchanger 15. The vapor phase is withdrawn from separator 43 by way of flow path 46 and introduced into flow paths 44 and 45 while the liquid is withdrawn from phase separator 43 and introduced into flow paths 44 and 45 by means of flow path 47. The introduction of the two phase fluid into flow paths 44 and 45 is in such a manner that the amount of liquid passing into each of flow paths 44 and 45 is substantially the same, and similarly the amount of vapor passing through each of flow paths 44 and 45 is substantially the same. The effluent from flow paths 44 and 45 is collected and withdrawn from the system by way of line 49. A valve 51 can be positioned in line 49 and manipulated by a pressure recorder controller 52 to maintain the pressure in line 49 upstream of valve 51 substantially constant, if desired. The flow conditions through flow paths 44 and 45 are such that substantially all of the liquid passing therethrough is vaporized by the transfer of heat thereto from the natural gas feed stream passing through flow path 13. By this transfer of heat the natural gas is substantially cooled and/or partially liquefied depending upon the conditions of temperature and pressure imposed on the system.

Referring now to FIGURE 2, indirect heat exchanger 15 is exemplified as being a shell and tube heat exchanger of the wound bundle type having a cylindrical shell 61 and vessel heads or closure means 62 and 63. A tube bundle comprising a plurality of tubes 13 helically wrapped or coiled around hollow core member 60 is positioned within and substantially coaxial with shell 61. Tube sheets 64 and 65 are positioned within shell 61 and substantially perpendicular to the axis of shell 61. Core member 60 passes through the center of each of tube sheets 64 and 65. Head or closure means 66 is connected to tube sheet 65 to form a feed distribution chamber 67 which is in fluid communication with the internal passages of tubes 13. Head or closure means 68 is connected to tube sheet 64 to form a second chamber 69. Tubes 13 are connected to tube sheets 64 and 65 to provide a plurality of flow paths for fluid communication between chambers 67 and 69. Feed gas passes through conduit 11 into chamber 67 and then into and through tubes 13 into chamber 69. The cooled feed gas is withdrawn from chamber 69 by way of the passageway 71 through hollow core means 60 and passes into conduit 16.

The two phase fluid in conduit 41 is introduced into phase separation chamber 43 which is located in the upper portion of heat exchanger 15. Chamber 43 is the space bounded by closure means 62, vertical cylindrical wall 72, head 68 and an outer or peripherial portion of tube sheet 64. Cylindrical wall 72 is smaller than the inside diameter of shell 61 and is spaced therefrom to form an annular passageway or flow path 46 between chamber 43 and heat exchange chamber 73, that is the interior of that portion of shell 61 containing the tube bundle. The fluid from conduit 41 upon entering chamber 43 separates into a vapor portion and a liquid portion. The vapor portion passes through flow path 46 into chamber 73 while the liquid portion collects in the container formed by wall 72, head 68 and tube sheet 64. The outer portion of tube sheet 64 which forms the bottom of chamber 43 is provided with a plurality of openings or passageways 47 to permit the flow of liquid from chamber 43 into chamber 73. The angle from the vertical of flow paths 73 increases from approximately zero at a point near wall 72 to approximately 45° adjacent closure means 68 to provide a spraying of the liquid from chamber 43 onto the tube bundle in such a manner as to effect a substantially even distribution of the liquid among the various paths between tubes 13. The vapor portion will, by its nature, seek to travel through each flow path between tubes 13, and the distribution of vapor among the various flow paths between tubes 13 will be substantially equal as long as the pressure drops are substantially the same. The vapor and vaporized liquid is withdrawn from chamber 73 by way of conduit 49. A liquid seal, such as solder or gasket means, 75 can be provided on the upper surface of the tube bundle adjacent shell 61 to prevent the passage of liquid through the annulus between the tube bundle and shell 61. Referring now to FIGURE 3 there is illustrated a modification of the apparatus of FIGURE 2. Core member 60*a* can be hollow, but does not provide fluid communication with either chambers 67 or 69. The cooled fluid in chamber 69 is withdrawn therefrom by way of conduits 71*a* and 16. The two phase fluid in conduit 41 is introduced into a phase separator 43*a*. Liquid is passed from phase separator 43*a* by way of conduit 47*a* into chamber 43*b*. Chamber 43*b* is the space bounded by vessel head 62, distribution sheet 64*b* and shell 61, excluding chamber 69 and its associated tubes and conduit. Instead of a single sheet 47 serving as both a tube sheet and a liquid distribution means, tube sheet 64*a* is provided for connecting tubes 13 into chamber 69 and a liquid distribution sheet 64*b* having a plurality of openings 47*b* therein, is provided for spraying liquid across the upper surface of the tube bundle. The vapor from separator 43*a* is passed by way of one or more conduits 46*a* into shell 61 below plate 64*b* and above the main portion of the tube bundle, that is into chamber 73. As openings 47*b* can be provided in sheet 64*b* in the area between individual tubes 13, such openings 47*b* can all be substantially perpendicular to the plane of sheet 64*b*. However, if desired, some or all of openings or passageways 47*b* can be included at suitable angles to the vertical to provide a more uniform distribution of liquid among the flow paths between tubes 13. The liquid level in chambers 43 and 43*b* would be self regulating, that is, as the level increases the pressure head increases resulting in an increased flow through openings 47 or 47*b*.

EXAMPLE

A heat exchanger of the type illustrated in FIGURE 2 is utilized in the refrigeration separation system of FIGURE 1 with the conditions set forth in Table I.

The resulting heat transfer rate between the mixture of vapors and liquid from line 41 and the feed stream in tubes 13 is considerably better in comparison to a system wherein there is a maldistribution of the liquid and vapor of any consequence.

Table I

Component	Composition, Mol percent							Temperature, ° F.	Pressure, p.s.i.a.	Flow, lbs./hr.
	He	N_2	C_1	C_2	C_3	C_4	C_5			
11	0.75	14.84	71.72	6.19	4.09	1.68	0.73	90	350	250,813
16	0.75	14.84	71.72	6.19	4.09	1.68	0.73	−80	348	250,813
18	0.75	14.84	71.72	6.19	4.09	1.68	0.73	−80	348	250,813
21	0.84	16.54	77.43	4.29	0.77	0.11	0.02	−80	345	200,508
23	55.01	40.83	4.16					−90	71	2,305
25	55.01	40.83	4.16					81	69	2,305
28	0.03	57.68	42.29					−90	72	26,829
31	0.03	57.68	42.29					81	71	26,829
34	0.01	10.99	83.14	4.88	0.84	0.12	0.01	−90	223	171,374
36	0.01	10.89	83.14	4.88	0.84	0.12	0.01	81	222	171,374
41		1.40	26.52	21.24	30.37	14.07	6.40	−80	348	50,305
43		1.40	26.52	21.24	30.37	14.07	6.40	−130.5	20	50,305
46		4.35	79.20	14.19	1.87	0.36	0.03	−130.5	20	8,228
47		0.03	2.07	24.51	43.60	20.44	9.35	−130.5	20	42,077
49		1.40	26.52	21.24	30.37	14.07	6.40	81	18	50,305

Reasonable variation and modification are possible within the scope of the foregoing disclosure, the drawing and the appended claims to the invention.

I claim:

1. Heat exchanging apparatus comprising a housing having a substantially cylindrical casing, an upper closure member and a lower closure member; a hollow core member positioned inside of and substantially coaxial with said casing; an upper tube sheet and a lower tube sheet positioned inside of said casing and substantially perpendicular to the axis of said casing and connected to said core member, said core member passing through the center of each of said upper and lower tube sheets; said upper tube sheet having a first inner portion and a second outer portion; a first head connected to the lower side of said lower tube sheet to form a first chamber; a second head connected to the upper side of said first portion of said upper tube sheet to form a second chamber; a plurality of tubes helically wound around said core member and connected between said upper and lower tube sheets and in fluid communication with said first and second chambers; a first conduit passing through said housing and connected to the lower end of said core member, the upper end of said core member being connected to said upper tube sheet to provide fluid communication between said second chamber and said first conduit; a second conduit passing through said housing and said first head to provide fluid communication with said first chamber; a vertical wall member positioned above said upper tube sheet and connected to the periphery of said upper tube sheet; said wall member being spaced from said housing to form an annular passageway therebetween; said upper tube sheet having a plurality of openings therethrough in said outer portion, the angle from the vertical of said plurality of openings being greater adjacent said second head than adjacent said wall member; a third conduit passing through an upper portion of said housing for passing a two phase fluid into the space above said upper tube sheet and within said wall member; and a fourth conduit communicating with a lower portion of said housing for the withdrawal of the two phase fluid after it has been passed in contact with said plurality of tubes.

2. Heat exchanging apparatus comprising a housing having a substantially cylindrical casing, an upper closure member and a lower closure member; a core member positioned inside of and substantially coaxial with said casing; an upper tube sheet, a liquid distribution plate and a lower tube sheet positioned inside of said casing and substantially perpendicular to the axis of said casing and connected to said core member; said liquid distribution plate being between said upper tube sheet and said lower tube sheet and having a diameter equal to the inside diameter of said casing, the diameter of said upper and lower tube sheets being substantially less than said inside diameter of said casing; said liquid distribution plate having a plurality of openings therethrough; a first head connected to the lower side of said lower tube sheet to form a first chamber; a second head connected to the upper side of said upper tube sheet to form a second chamber; a plurality of tubes helically wound around said core member and connected between said upper and lower tube sheets through said liquid distribution plate and in fluid communication with said first and second chambers; a first conduit passing through said housing and connected to said second head to provide fluid communication between said second chamber and said first conduit; a second conduit passing through said housing and said first head to provide fluid communication with said first chamber; a phase separator; a third conduit connected to the inlet of said phase separator for introducing a two phase fluid therein; a fourth conduit connected between a lower portion of said phase separator and said housing at a point above said liquid distribution plate for passing liquid into the space above said liquid distribution plate and within said housing; a fifth conduit connected between an upper portion of said phase separator and said housing at a point below and adjacent to said liquid distribution plate; and a sixth conduit communicating with a lower portion of said housing for the withdrawal of the two phase fluid after it has been passed in contact with said plurality of tubes.

3. Apparatus for utilizing a high pressure liquid stream as a cooling fluid in a heat exchanger having a plurality of flow paths therethrough and wherein it is desirable that substantially all of the cooling fluid be vaporized in passing through said heat exchanger although said liquid steam is at a pressure higher than the pressure at which substantially all of said liquid stream would be vaporized by being passed through said heat exchanger, and wherein said liquid stream would have a liquid phase and a gas phase upon the pressure of said liquid stream being reduced to said pressure at which substantially all of said liquid stream would be vaporized by being passed through said heat exchanger, comprising means for reducing the pressure on said liquid stream to said pressure at which substantially all of said liquid stream would be vaporized by being passed through said heat exchanger, thereby producing a two phase fluid; a heat exchanger housing having a substantially cylindrical casing, an upper closure member and a lower closure member; a core member positioned inside of and substantially coaxial with said casing; an upper tube sheet and a lower tube sheet positioned inside of said casing and substantially perpendicular to the axis of said casing and connected to said core member, said core member passing through the center of each of said upper and lower tube sheets; said upper tube sheet having a first inner portion and a second outer portion; a first head connected to the lower side of said lower tube sheet to form a first chamber; a second head connected to the upper side of said first portion of said upper tube sheet to form a second chamber; a plurality of tubes connected between said upper and lower tube sheets and in fluid communication with said first and second chambers; a first conduit passing through said housing and connected

in fluid communication with said second chamber; a second conduit passing through said housing and connected in fluid communication with said first chamber; a vertical wall member positioned above said upper tube sheet and connected to the periphery of said upper tube sheet; said wall member being spaced from said housing to form an annular passageway therebetween; said upper tube sheet having a plurality of openings therethrough in said outer portion; a third conduit passing through an upper portion of said housing for passing said two phase fluid into the space above said upper tube sheet and within said wall member; and a fourth conduit communicating with a lower portion of said housing for the withdrawal of the two phase fluid after it has been passed in contact with said plurality of tubes.

4. Apparatus for utilizing a high pressure liquid stream as a cooling fluid in a heat exchanger having a plurality of flow paths therethrough and wherein it is desirable that substantially all of the cooling fluid be vaporized in passing through said heat exchanger although said liquid stream is at a pressure higher than the pressure at which substantially all of said liquid stream would be vaporized by being passed through said heat exchanger, and wherein said liquid stream would have a liquid phase and a gas phase upon the pressure of said liquid stream being reduced to said pressure at which substantially all of said liquid stream would be vaporized by being passed through said heat exchanger, comprising means for reducing the pressure on said liquid stream to said pressure at which substantially all of said liquid stream would be vaporized by being passed through said heat exchanger, thereby producing a two phase fluid; a heat exchanger housing having a substantially cylindrical casing, an upper closure member and a lower closure member; a core member positioned inside of and substantially coaxial with said casing; an upper tube sheet, a liquid distribution plate and a lower tube sheet positioned inside of said casing and substantially perpendicular to the axis of said casing and connected to said core member; said liquid distribution plate being between said upper tube sheet and said lower tube sheet and having a diameter equal to the inside diameter of said casing; the diameter of said upper and lower tube sheets being substantially less than said inside diameter of said casing; a first head connected to the lower side of said lower tube sheet to form a first chamber; a second head connected to the upper side of said upper tube sheet to form a second chamber; a plurality of tubes connected between said upper and lower tube sheets through said liquid distribution plate and in fluid communication with said first and second chambers; a first conduit passing through said housing and connected to said second head to provide fluid communication between said second chamber and said first conduit; a second conduit passing through said housing and said first head to provide fluid communication with said first chamber; said liquid distribution plate having a plurality of openings therethrough; a phase separator; a third conduit connected to the inlet of said phase separator for introducing said two phase fluid therein; a fourth conduit connected between a lower portion of said phase separator and said housing at a point above said liquid distribution plate for passing liquid into the space above said liquid distribution plate and within said housing; a fifth conduit connected between an upper portion of said phase separator and said housing at a point below and adjacent to said liquid distribution plate; and a sixth conduit communicating with a lower portion of said housing for the withdrawal of the two phase fluid after it has been passed in contact with said plurality of tubes.

5. Heat exchanging apparatus comprising a housing having a substantially cylindrical casing, an upper closure member and a lower closure member; an upper tube sheet and a lower tube sheet positioned inside of said casing and substantially perpendicular to the axis of said casing; a first head connected to the lower side of said lower tube sheet to form a first chamber; a second head connected to the upper side of said upper tube sheet to form a second chamber; a plurality of tubes connected between said upper and lower tube sheets and in fluid communication with said first and second chambers; a first conduit means passing through said housing to provide fluid communication between said second chamber and said first conduit means; a second conduit means passing through said housing to provide fluid communication between said first chamber and said second conduit means; means for separating a two phase fluid into a liquid portion and a vapor portion; means for passing said vapor portion downwardly in said housing and in substantially equal heat exchanging relationship with each of said plurality of tubes, means adjacent said upper tube sheet for spraying said liquid portion against said plurality of tubes in substantially equal heat exchanging relationship with each of said plurality of tubes, and third conduit means connected to a lower portion of said housing for withdrawing therefrom the two phase fluid after it has been passed in contact with said plurality of tubes.

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