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(54) **System and method for distributing refrigerant to a parallel flow heat exchanger using refrigerant injectors**

(57) A heat exchanger (110) is disclosed that includes a plurality of parallel refrigerant paths (112), and a refrigerant injector (118) operatively associated with an inlet to each refrigerant path for independently metering single phase refrigerant into each of the parallel refrigerant paths.

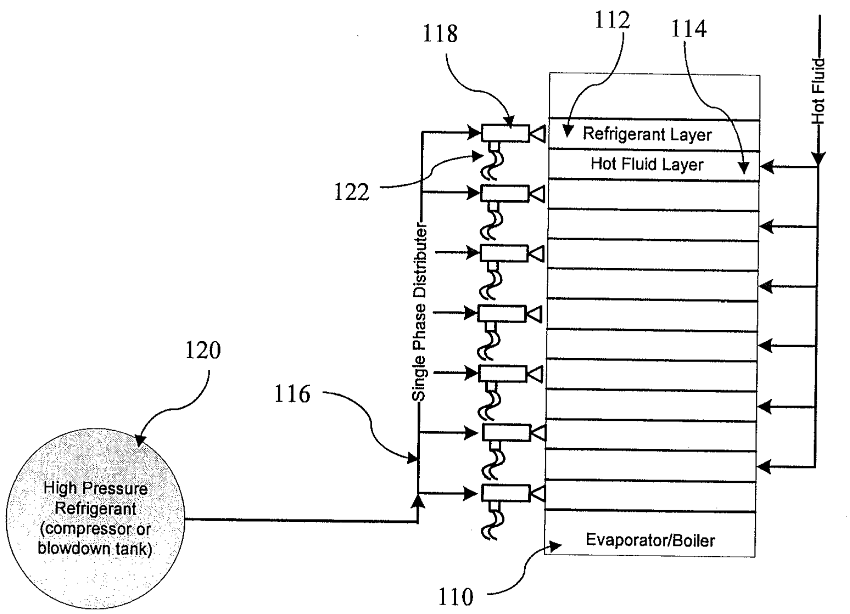

FIG. 2

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The subject invention relates to a refrigerant distribution system, and more particularly, to a refrigerant distribution system that employs refrigerant injectors for independently metering single phase refrigerant into parallel refrigerant flow paths of a heat exchanger.

2. Description of Related Art

[0002] A plate-fin heat exchanger is a type of heat exchanger design that uses plates and finned chambers to transfer heat between two fluids. It is often categorized as a compact heat exchanger to emphasize its relatively high heat transfer surface area to volume ratio. The plate-fin heat exchanger is widely used in many industries, including the aerospace industry due its compact size and lightweight properties.

[0003] A plate-fin heat exchanger is typically made of layers of corrugated sheets separated by flat metal plates, to create a series of finned chambers. Separate hot and cold fluid streams flow through alternating layers of the heat exchanger and are enclosed at the edges by side bars.

[0004] Heat is transferred from one stream through the fin interface to the separator plate and through the next set of fins into the adjacent fluid. The fins also serve to increase the structural integrity of the heat exchanger and allow it to withstand high pressures while providing an extended surface area for heat transfer.

[0005] Refrigerant mass flow is often metered to the inlet line of the heat exchanger with a thermal expansion valve. There is typically a pressure drop as the refrigerant flows through the thermal expansion valve. Often, flashing will result in the formation of a two phase flow between the thermal expansion valve and the heat exchanger. Inlet plumbing geometry and gravity often contribute to variable two phase flow patterns entering the heat exchanger.

[0006] When this situation arises, it becomes difficult to divide the two phase fluid and gas mixture so the mass flow is equally distributed to the parallel flow paths of the heat exchanger. As a result, the individual branches of the heat exchanger will not perform equal amounts of heat transfer. Consequently, the maximum capacity of the heat exchanger will be determined when one branch reaches its maximum refrigerant flow and the other branches are at less than their maximum capacity. So the capacity of the heat exchanger is sacrificed because all the layers were not used to their maximum capacity.

[0007] Furthermore, uneven mass flow between the parallel flow paths often results in uneven heat transfer, which can exacerbate poor flow distribution. It would be beneficial therefore, to provide a refrigerant distribution system that is adapted and configured to preclude the distribution of two phase flow into parallel refrigerant flow paths of a compact heat exchanger.

SUMMARY OF THE INVENTION

[0008] The subject invention is directed to a new and useful heat exchanger that is adapted and configured to prevent flow maldistribution of two phase flow of refrigerant into the parallel flow paths of the heat exchanger. It is envisioned that the compact heat exchanger of the subject invention could be configured as an evaporator or a boiler.

[0009] The compact heat exchanger of the subject invention includes a plurality of parallel refrigerant paths and a refrigerant injector operatively associated with an inlet to each refrigerant path of the heat exchanger for independently metering single phase refrigerant into each of the parallel refrigerant paths.

[0010] Preferably, the refrigerant injectors are adapted and configured to meter equal amounts of refrigerant into the refrigerant paths of the heat exchanger. This ensures even parallel refrigerant mass flow distribution throughout the branches of the heat exchanger. In the case of a compact boiler, uneven distribution is less susceptible to amplification from boiling heat transfer and viscosity variation of the hot side fluid. Furthermore, all refrigerant paths will be equally utilized and essentially reach the full boiling limit simultaneously.

[0011] Each of the refrigerant injectors is in fluid communication with a source of pressurized refrigerant. More particularly, a distribution manifold delivers single phase refrigerant to each of the refrigerant injectors from a source of pressurized refrigerant. The source of pressurized refrigerant could be a compressor or a blow down tank depending upon the application or operating environment. The heat exchanger further includes means for controlling the flow of single phase refrigerant through the refrigerant injectors..

[0012] The step of independently injecting single phase refrigerant into each of the refrigerant flow paths of the heat exchanger involves metering equal amounts of refrigerant into each refrigerant flow path. The method further includes the steps of distributing single phase refrigerant to each of the refrigerant injectors, and controlling the flow of single phase refrigerant through each of the refrigerant injectors.

[0013] These and other features of the subject invention and the manner in which it is employed will become more readily apparent to those having ordinary skill in the art from the following enabling description of the preferred embodiments of the subject invention taken in conjunction with the several drawings described below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] So that those skilled in the art to which the subject invention appertains will readily understand how to make and use the subject invention without undue experimentation, preferred embodiments thereof will be described in detail herein below, by way of example only and with reference to certain figures, wherein:

Fig. 1 is a schematic rendering of a prior art compact heat exchanger which includes a distribution manifold that enables the delivery of two phase refrigerant into the refrigerant flow paths of the heat exchanger; and

Fig. 2 is a schematic rendering of a compact heat exchanger constructed in accordance with a preferred embodiment of the subject invention, which includes injectors for independently metering single phase refrigerant to each of the refrigerant flow paths of the heat exchanger.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0015] Referring now to the drawings wherein like reference numerals identify similar structural features or aspects of the subject invention, there is illustrated in Fig. 1 a prior art compact heat exchanger designated generally by reference numeral 10.

[0016] Compact heat exchanger 10 is preferably a plate and fin type heat exchanger that includes a plurality of alternating refrigerant and hot fluid layers 12, 14 arranged in a parallel configuration. Plate and fin type heat exchangers are often made of aluminum alloys, which provide high heat transfer efficiency, while reducing the weight of the equipment.

[0017] There are several basic types of fins that are used in compact heat exchangers. These include: plain fins, which refer to simple straight-finned triangular or rectangular designs; herringbone fins, where the fins are placed sideways to provide a zigzag path; and serrated and perforated fins which refer to cuts and perforations in the fins to augment flow distribution and improve heat transfer.

[0018] With continuing reference to Fig. 1, a distribution manifold 16 is operatively associated with the compact heat exchanger 10 for delivering refrigerant to the plurality of parallel refrigerant layers 12 of the heat exchanger 10. A thermal expansion valve 18 is located upstream from the distribution manifold 16 for metering refrigerant flow to the distribution manifold 16. More particularly, the thermal expansion valve 18 controls the amount of superheating that occurs at the outlet of the heat exchanger 10.

[0019] A source of high pressure refrigerant 20 is located upstream from the expansion valve 18. The source of pressurized refrigerant 20 could be a compressor or a blow down tank depending upon the application with which the heat exchanger is employed.

[0020] In prior art compact heat exchangers of this type, as the pressure drops across the thermal expansion valve 18, some of the refrigerant flashes from a liquid phase to a vapor phase. This results in two phase flow from the valve 18 through the distribution manifold 16 and into the refrigerant flow paths 12, which is not an ideal mode of operation. Indeed, two phase flow with concurrent heat transfer and fluid viscosity variations can lead to instabilities that limit its performance.

[0021] Referring now to Fig. 2, there is illustrated a compact plate and fin type heat exchanger constructed in accordance with a preferred embodiment of subject invention and designated generally by reference numeral 110. Preferably, the compact heat exchanger 110 of the subject invention is configured as a boiler or evaporator. Heat exchanger 110 includes a plurality of alternating refrigerant and hot fluid layers 112, 114 that are arranged in a parallel configuration. A refrigerant injector 118 is operatively associated with an inlet opening of each refrigerant layer 112 of the heat exchanger 110. The refrigerant injectors 118 are configured to meter equal amounts of refrigerant into each parallel refrigerant layer 112 of heat exchanger 110. By distributing refrigerant mass flow evenly throughout the branches of the heat exchanger, performance is maximized and operational instability is reduced.

[0022] An electronic controller 122 associated with the refrigerant injectors 118 controls the flow of single phase refrigerant to each of the refrigerant injectors 118. Two phase flow will result downstream of the injectors With individual flow control through the refrigerant injectors 118, single paths can be turned off in cases of less than maximum heat load and for fault accommodation. Furthermore, those skilled in the art will readily appreciate that individual flow path control provides the capability for superheat control for each path, with appropriate feedback sensors.

[0023] A distribution manifold 116 delivers single phase refrigerant to each of the refrigerant injectors 118 from a source of pressurized refrigerant 120. The source of pressurized refrigerant 120 could be a compressor or a blow down tank depending upon the application or operating environment. Those skilled in the art will readily appreciate that by using independent refrigerant injection in heat exchanger 110, there is no need to place a thermal expansion valve between the distribution manifold 116 and the source of pressurized refrigerant 120. Instead, the injectors 118 control the hot fluid outlet temperature and if desired, the amount of superheating at the refrigerant outlet of the heat exchanger 110.

[0024] With each refrigerant flow path 112 of the heat exchanger 110 receiving an even share of the total flow through the heat exchanger, the maximum capacity of the heat exchanger can be realized. Moreover, balanced refrigerant flow to the parallel refrigerant flow paths 112 results maximum useable capacity for the heat exchanger 110, minimizing the need to oversize the heat exchanger in the design phase, which is often the preferred design choice. Consistent even flow distribution provides a more robust design that is insensitive to effects of gravity or other body accelerations.

[0025] The subject invention is further directed to a method of distributing refrigerant in a heat exchanger 110 having a plurality of parallel refrigerant flow paths 112. The method includes the steps of associating a refrigerant injector 118 with each refrigerant flow path 112 of the heat exchanger 110, and independently injecting single phase refrigerant into each of the refrigerant flow paths 112 of the heat exchanger 110 to maximize the capacity of the heat exchanger 110.

[0026] The step of independently injecting single phase refrigerant into each of the refrigerant flow paths 112 of the heat exchanger 110 involves metering equal amounts of refrigerant into each refrigerant flow path 112. The method further includes the steps of distributing single phase refrigerant to each of the refrigerant injectors 118, and controlling the flow of single phase refrigerant through each of the refrigerant injectors 118.

[0027] While the subject invention has been shown and described with reference to preferred embodiments, those skilled in the art will readily appreciate that various changes and/or modifications may be made thereto without departing from the scope of the subject invention as defined by the appended claims.

Claims

1. A heat exchanger (110) comprising:

a) a plurality of parallel refrigerant paths (112); and
b) a refrigerant injector (118) operatively associated with an inlet to each refrigerant path for independently metering single phase refrigerant into each of the parallel refrigerant paths.

2. A heat exchanger as recited in Claim 1, wherein the refrigerant injectors are adapted and configured to meter equal amounts of refrigerant into the refrigerant paths of the heat exchanger.

3. A heat exchanger as recited in Claim 1 or 2, wherein each of the refrigerant injectors is in fluid communication with a source of pressurized refrigerant.

4. A heat exchanger as recited in any preceding Claim, wherein a distribution manifold (116) delivers single phase refrigerant to each of the refrigerant injectors.

5. A heat exchanger as recited in any preceding Claim, further comprising means for controlling the flow of single phase refrigerant through each of the refrigerant injectors.

6. A heat exchanger as recited in any preceding Claim, wherein the heat exchanger is configured as an evaporator.

7. A heat exchanger as recited in any preceding Claim, wherein the heat exchanger is configured as a boiler.

8. A heat exchanger (110) comprising:

a) a plurality of alternating refrigerant (112) and hot fluid layers (114) arranged in a parallel configuration;
b) a refrigerant injector (118) operatively associated with an inlet to each refrigerant layer for metering single phase refrigerant into each of the refrigerant layers; and
c) a distribution manifold (116) for delivering single phase refrigerant to each of the refrigerant injectors.

9. A heat exchanger as recited in Claim 8, wherein each of the refrigerant injectors are adapted and configured to meter equal amounts of refrigerant into the refrigerant layers of the heat exchanger.

10. A heat exchanger as recited in Claims 8 or 9, further comprising means (122) for controlling the flow of single phase refrigerant through the refrigerant injectors.

11. A heat exchanger as recited in any one of Claims 8 to 10, wherein the heat exchanger is configured as an evaporator.

12. A heat exchanger as recited in any one of Claims 8 to 11, wherein the heat exchanger is configured as a boiler.

13. A method of distributing refrigerant in a heat exchanger (110) having a plurality of parallel refrigerant flow paths (112), comprising the steps of:

a) associating a refrigerant injector (118) with each refrigerant flow path of the heat exchanger; and
b) independently injecting single phase refrigerant into each of the refrigerant flow paths of the heat exchanger to maximize the performance of the heat exchanger.

14. A method according to Claim 13, wherein the step of independently injecting single phase refrigerant into each of the refrigerant flow paths of the heat exchanger involves metering equal amounts of refrigerant into each refrigerant flow path.

15. A method according to Claim 13 or 14, further comprising the steps of distributing single phase refrigerant to each of the refrigerant injectors, and controlling the flow of single phase refrigerant through each of the refrigerant injectors.

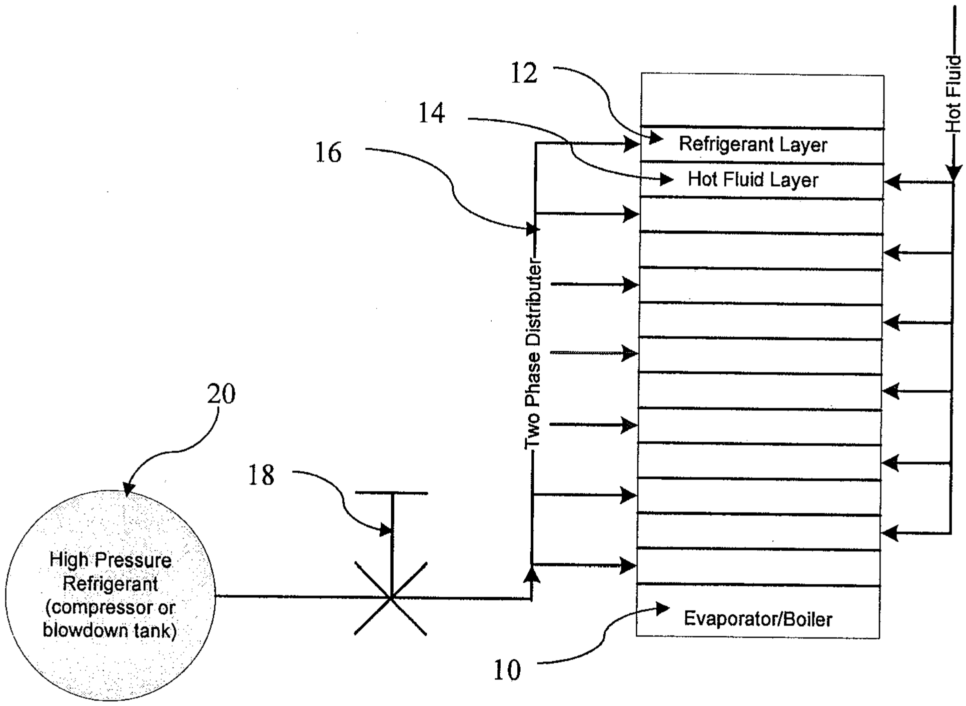

FIG. 1

(PRIOR ART)

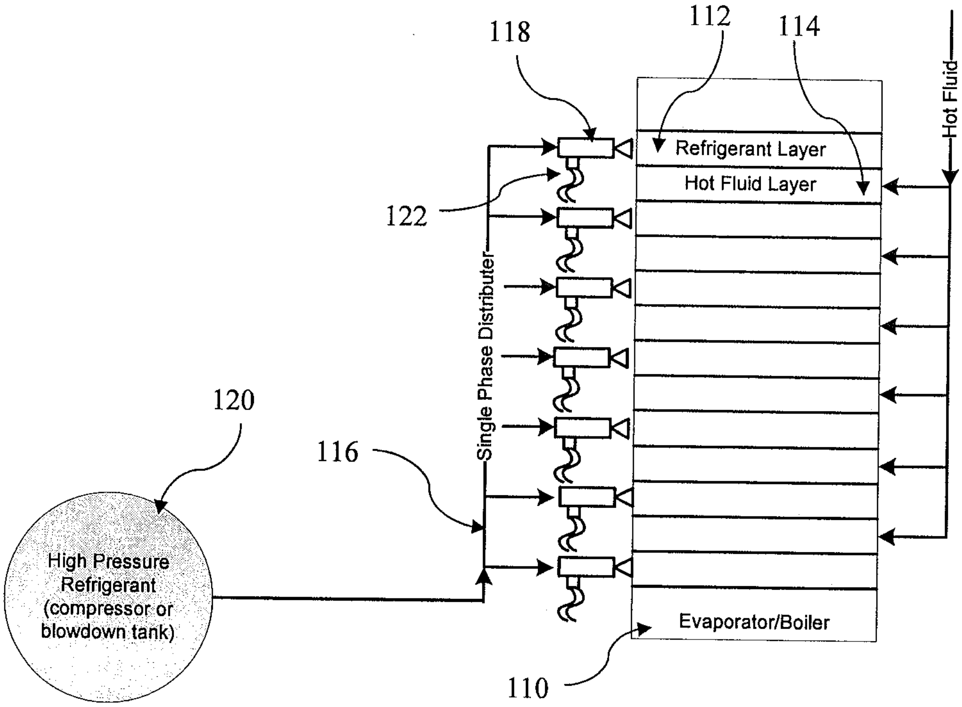
118
112
114
Hot Fluid
Refrigerant Layer
Hot Fluid Layer
122
Single Phase Distributer
120
116
High Pressure Refrigerant (compressor or blowdown tank)
Evaporator/Boiler
110

FIG. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 14 18 4530

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X,P	EP 2 674 697 A1 (ALFA LAVAL CORP AB [SE]) 18 December 2013 (2013-12-18) * paragraph [0001]; figures 5,6 * * paragraph [0044] * -----	1-15	INV. F28F9/02 F25B39/02 F28F27/02 F28D9/00
X,P	EP 2 674 714 A1 (ALFA LAVAL CORP AB [SE]) 18 December 2013 (2013-12-18) * figures 6,7 * -----	1-15	
A	US 5 704 221 A (LEGO FRANCOIS [FR]) 6 January 1998 (1998-01-06) * the whole document * -----	1-15	

TECHNICAL FIELDS SEARCHED (IPC)
F28F
F25B
F28D

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	28 January 2015	Bain, David

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 14 18 4530

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2674697 A1	18-12-2013	EP 2674697 A1	18-12-2013
		TW 201405083 A	01-02-2014
		WO 2013186195 A1	19-12-2013
EP 2674714 A1	18-12-2013	EP 2674714 A1	18-12-2013
		TW 201408982 A	01-03-2014
		WO 2013186192 A1	19-12-2013
US 5704221 A	06-01-1998	AT 166958 T	15-06-1998
		CA 2178080 A1	08-06-1995
		DE 69410823 D1	09-07-1998
		DE 69410823 T2	14-01-1999
		EP 0730719 A1	11-09-1996
		ES 2118541 T3	16-09-1998
		FR 2713320 A1	09-06-1995
		JP H09505879 A	10-06-1997
		US 5704221 A	06-01-1998
		WO 9515467 A1	08-06-1995

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