FLUID EXPANSION-DISTRIBUTION ASSEMBLY

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ABSTRACT
A expansion-distribution assembly (30) for simultaneously throttling, mixing, and distributing refrigerant fluid just upstream of a heat-absorbing component (e.g., an evaporator) of a heat pump system. The expansion-distribution assembly (30) comprises a valve-nozzle adjustment device (34) which moves a piston (52) relative to a nozzle chamber (44) to vary flow-characteristics therethrough. The piston (52) is moved during operation of the heat pump system (based on, for example, pressure and temperature data) to dynamically customize the valve-nozzle for the current load of the system.
FLUID EXPANSION-DISTRIBUTION ASSEMBLY
RELATED APPLICATION

[0001] This application claims priority under 35 U.S.C. §119 (e) to U.S. Provisional Patent Application No. 60/793,813 filed on Apr. 21, 2006. The entire disclosure of this provisional application is hereby incorporated by reference.

GENERAL FIELD

[0002] A fluid expansion-distribution assembly that expands (e.g., throttles) and distributes refrigerant just upstream of a heat-absorbing component (e.g., an evaporator) in a heatpump system.

BACKGROUND

[0003] A heatpump system can be used to control the temperature of a certain medium such as, for example, the air inside of a building. A heatpump system generally comprises an evaporator, a condenser, a compressor and a series of lines (e.g., pipes, tubes, ducts) connecting these components together so that a refrigerant fluid can cycle therethrough. Typically, the evaporator is located adjacent to or within the medium (e.g., it is located inside the building) and the condenser is located remote from the medium (e.g., it is located outside of the building).

[0004] A heatpump system can operate in a first (forward) direction, wherein it cools the temperature-controlled environment, and a second (reverse) direction, wherein it heats the temperature-controlled environment. In the forward (i.e., cooling) direction, the evaporator is the heat-absorbing component (i.e., it absorbs heat from, and thus cools, the medium) and the condenser is the heat-rejecting component (i.e., it rejects the absorbed heat to the remote location). In the reverse (i.e., heating) direction, the evaporator is the heat-rejecting component and the condenser is the heat-absorbing component.

[0005] In a heatpump cycle, refrigerant fluid enters the heat-absorbing component as a low pressure and low-temperature vapor-liquid. As the vapor-liquid passes through the heat-absorbing component, it is boiled into a low pressure gas state. From the heat-absorbing component, the fluid passes through the compressor, which increases the pressure and temperature of the gas. From the compressor, the high pressure and high temperature gas passes through the heat-rejecting component where it is condensed to a liquid.

[0006] A heatpump system will often include an expansion valve immediately (or almost immediately) upstream of the heat-absorbing component. When the high pressure and high temperature liquid from heat-rejecting component passes through the expansion valve, the pressure of the fluid is reduced (e.g., the expansion valve throttles the fluid) and fluid is converted to a low pressure and low temperature vapor/liquid state. This low pressure and low temperature vapor/liquid is received by the heat-absorbing component to complete the cycle.

[0007] A heatpump cycle will often also include a distributor downstream of the expansion valve. A distributor commonly includes a mixing compartment whereat fluid is evenly distributed to a plurality of tubes which feed the multiple circuits of the heat-absorbing component. A distributor can also include a flow restriction (e.g., a nozzle) upstream of its mixing compartment which increases the velocity of the fluid just prior to its entry into the mixing compartment to promote a turbulent mixing of liquid and vapor phases.

[0008] As was indicated above, when a heatpump system is operating in a first (i.e., forward and/or cooling) direction, the evaporator is the heat-absorbing component, and when it is operating in a second (i.e., reverse and/or heating) direction, the condenser is the heat-absorbing component. Thus, an expansion-distribution assembly may be positioned at the end of the evaporator which is its inlet when fluid travels in the first direction and/or may be positioned at the end of the condenser which is its inlet when fluid travels in the second direction.

[0009] When a heatpump system is operating in a direction corresponding to the expand-then-distribute direction, liquid (at a high pressure and high temperature) will pass through the expansion-distribution assembly and will be converted into a vapor/liquid (at a lower pressure and a lower temperature) for receipt by the heat-absorbing component. When the heatpump system is operating in the opposite direction, fluid passes "backwards" through the expansion-distribution assembly. A reverse flow bypass is provided so that the fluid does not have to pass (backwards) through the throttling flow path.

SUMMARY

[0010] An expansion-distribution assembly wherein a piston and a nozzle chamber interact to form a combination nozzle-valve which simultaneously throttles, mixes, and distributes refrigerant fluid. The nozzle-valve is adjustable, during use of the heatpump system, to provide variable valve-orifice and/or nozzle-passage to accommodate system load changes. Additionally or alternatively, the nozzle chamber can be oversized so that a throttle-bypass-route is not necessary for reverse flow. These and other features of the expansion-distribution assembly and/or the heatpump system are fully described and particularly pointed out in the claims. The following description and annexed drawings set forth in detail a certain illustrative embodiment, this embodiment being indicative of but one of the various ways in which the principles may be employed.

DRAWINGS

[0011] FIG. 1 is a schematic view of a heatpump system.
[0012] FIGS. 2A, 2B and 2C are a perspective view, a sectional view and an exploded view, respectively, of the expansion-distribution assembly.
[0013] FIGS. 3A-3D are schematic views showing the interaction between a nozzle chamber and a piston.

DETAILED DESCRIPTION

[0014] Referring now to the drawings, and initially to FIG. 1, a heatpump system 10 according to the present invention is schematically shown. The heatpump system 10 can be used to control the temperature of a certain medium (e.g., air inside a building) and generally comprises an evaporator 12, a condenser 14, and a compressor 16. A plurality of lines 18 (e.g., pipes, tubes, ducts) connect these components so that refrigerant fluid can cycle therethrough. The evaporator 12 can be located within the medium (i.e., it can be located
inside the building) and the compressor can be located remote from the medium (i.e., it can be located outside of the building).

[0015] The heatpump system 10 can operate in a first (forward) direction, whereat it cools the medium, and a second (reverse) direction, whereat it heats the medium. A reversing valve 20, or other flow-direction-determining means, can be used to select the direction of flow through the heatpump system 10. In the first (i.e., forward and/or cooling) direction, the evaporator 12 is the heat-absorbing component (i.e., it absorbs heat from, and thus cools, the medium) and the condenser 14 is the heat-rejecting component (i.e., it rejects the absorbed heat to a location outside of the medium). In the second (i.e., reverse and/or heating) direction, the evaporator 12 is the heat-rejecting component and the condenser 14 is the heat-absorbing component. In the forward mode of operation, fluid flows from the evaporator 12 to the intake compressor 16, from the discharge of the compressor 16 to the condenser 14, and then from the condenser 14 back to the evaporator 12 to complete the cycle. In the reverse mode of operation, fluid flows from the condenser 14 to the intake of the compressor 16, from the discharge of the compressor 16 to the evaporator 12, and then from the evaporator 12 back to the condenser 14 to complete the cycle.

[0016] The heatpump system 10 can additionally comprise temperature and pressure sensing lines 22 and 24. One set of sensing lines 22/24 is connected to the cycle lines 18 to sense the temperature and pressure of the gas exiting the evaporator 12 when fluid travels in the first direction. The other set of sensing lines 22/24 is connected to the cycle lines 18 to sense the temperature and pressure of the gas exiting the condenser 14 when fluid travels in the second direction.

[0017] The heatpump system 10 includes at least one expansion-distribution assembly 30 according to the present invention and/or the system 10 can include two expansion-distribution assemblies 30 as shown in the illustrated embodiment. An expansion-distribution assembly 30 can be located adjacent to the end of the evaporator 12 that acts as its inlet when fluid travels in the first (i.e., forward and/or cooling) direction. Additionally or alternatively, an expansion-distribution assembly 30 can be located adjacent to the end of the condenser 14 that acts as its inlet when fluid travels in the second (i.e., reverse and/or heating) direction.

[0018] For ease in explanation, the “direction” of the system 10 will be described in relation to the expansion-distribution assembly 30 positioned adjacent the evaporator 12. The description of the expansion-distribution assembly 30 positioned adjacent the condenser 14 would be essentially the same, except that the described first direction would be considered its second (reverse) direction and the described second (reverse) direction would be considered its first direction.

[0019] Referring now to FIGS. 2A-2C, the expansion-distribution assembly 30 is shown isolated from the rest of the heatpump system 10. The expansion-distribution assembly 30 comprises a distributor body 32 and a valve-nozzle adjustment device 34. The distributor body 32 defines an inlet/outlet chamber 40, a distribution chamber 42, a nozzle chamber 44 between the inlet/outlet chamber 40 and the distribution chamber 42, and a plurality (e.g., at least five, at least ten, at least fifteen, at least twenty, etc.) of distributor tubes 46 in direct fluid communication with the distribution chamber 42. The inlet/outlet chamber 40 is adapted for connection to line 18F (e.g., it is a fitting) and functions as an inlet chamber in the first direction and an outlet chamber in the second direction. The nozzle chamber 44 represents a restricted flow path relative to the inlet/outlet chamber 40 and it converges towards the distribution chamber 42 (this is perhaps better seen by referring briefly to FIGS. 3A-3D). The inlet/outlet of the distributor tubes 46 (which feeds/ drain the multiple circuits of the heat-absorbing component) surround the circumference of the distribution chamber 42. The distributor body 32 can also comprises an internally threaded opening 48 for removable (or non-removable) mounting of the valve-dispersion device 34.

[0020] The valve-dispersion device 34 comprises a casing 50, a piston 52, and a drive mechanism 54. The casing 50 has an externally threaded portion which mates with the opening 48 for attachment to the distributor body 32. The piston 52 is movable in the inlet-outlet direction (i.e., up-down in the illustrated orientation) within the casing 50, the distribution chamber 42 and/or the nozzle chamber 44. Piston movement is motivated by the drive mechanism 54 which can comprise a linear actuator (e.g., a digital linear actuator) and controlled based on, for example, information conveyed by the temperature and pressure sensing lines 22 and 24. Appropriate seals (shown but not specifically numbered) can be provided between the distributor body 32, the casing 50, and/or the piston 52.

[0021] Referring now to FIGS. 3A-3D, the interaction between the nozzle chamber 44 and the piston 52 is schematically shown. The piston 52 comprises a conical nose portion 60 which tapers towards the nozzle chamber 44 and a stem portion 62 which extends from the nose portion 60 (and through an opening in the distribution chamber 42) for connection to the drive mechanism 54. During operation of the heatpump system 10, the piston 52 is driven to move among a minimum-flow-area position (FIG. 3A), a maximum-flow-area position (FIGS. 3B and 3C) and positions therebetween (FIG. 3D).

[0022] In the minimum-flow-area position (FIG. 3A), the piston 52 is in its most extended position and its nose portion 60 is situated well within the nozzle chamber 44. The ability to move the piston 52 to this position (and/or positions close thereto), allows the refrigerant velocity to remain high at even low loads. With conventional expansion-distribution assemblies, the nozzle geometry remains the same at low loads and the distributor may not be provided with the velocity needed to mix and distribute the refrigerant.

[0023] In the maximum-flow-area position (FIGS. 3B and 3C), the piston 52 is in its most retracted position and its nose portion 60 is situated almost entirely within the distribution chamber 42. If, when the heatpump system is operating in the first direction (FIG. 3B), the nozzle chamber 44 sufficiently provides the desired velocity for throttling, mixing, and distribution, the piston nose portion 60 can simply function as a dispersion cone within the distribution chamber 42. In a dual-direction heatpump system, it may be desirable to oversize the nozzle chamber 44 so that, when the heatpump is operating in the second direction (FIG. 3C), a throttle-bypass-route is not necessary for reverse flow. That being said, the use of a bypass with the expansion-distribution assembly 30 is certainly possible.
The piston 52 can be moved into a plurality of positions between its minimum-flow-area position and its maximum-flow-area position (FIG. 3B). Piston strokes in the range of 10-40 millimeters and/or 20-30 millimeters may be appropriate, but this will vary depending upon the heatpump system characteristics, evaporator size, chamber/piston geometries and/or other factors. In any event, when the piston 52 is in its non-maximum-area positions, the piston 52 and the nozzle chamber 44 interact to form a combination nozzle-valve which simultaneously throttles, mixes, and distribute refrigerant fluid. Moreover, this nozzle-valve is adjustable, during use of the heatpump system 10, to dynamically provide a customized valve-orifice and/or nozzle-passage for the current system load.

Although the expansion-distribution assembly 30 has been shown and described with respect to a certain embodiment or embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of this specification and the annexed drawings. In regard to the various functions performed by the above described elements (e.g., components, assemblies, systems, devices, compositions, etc.), the terms (including a reference to a “means”) used to describe such elements are intended to correspond, unless otherwise indicated, to any element which performs the specified function of the described element (i.e., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function. In addition, while a particular feature of the invention may have been described above with respect to only one or more of several illustrated embodiments, such feature may be combined with one or more other features of the other embodiments, as may be desired and advantageous for any given or particular application.

1. A expansion-distribution assembly comprising a distributor body and a valve-nozzle adjustment device;

the distributor body defining an inlet/outlet chamber, a distribution chamber, a nozzle chamber between the inlet/outlet chamber and the distribution chamber, and a plurality of tubes in direct fluid communication with the distribution chamber;

the valve-nozzle adjustment device including a piston and a drive mechanism for moving the piston is driven to move in the inlet-outlet direction relative to the nozzle chamber; and

wherein the piston is moveable among a minimum-flow-area position whereat flow area through the nozzle chamber is minimized, a maximum flow-area position whereat flow area through the nozzle chamber is at a maximum, and at least one position therebetween.

2. An expansion-distribution assembly as set forth in claim 1, wherein the nozzle chamber diverges towards the distribution chamber.

3. An expansion-distribution assembly as set forth in claim 1, wherein the drive mechanism comprises a linear actuator.

4. An expansion-distribution assembly as set forth in claim 1, wherein the drive mechanism is controlled based on system pressure-temperature conditions.

5. An expansion-distribution assembly as set forth in claim 1, wherein the piston is in its most extended position when it is in its minimum-flow-area position and in its most retracted position when it is in its maximum-area-position.

6. An expansion-distribution assembly as set forth in claim 1, wherein the piston comprises a conical nose which tapers towards the nozzle chamber.

7. An expansion-distribution assembly as set forth in claim 6, wherein, the nose portion of the piston is situated within the nozzle chamber when the piston is in its minimum-flow-area position.

8. An expansion-distribution assembly as set forth in claim 6, wherein the nose portion of the piston is situated within the distribution chamber when the piston is in its maximum-flow-area position.

9. An expansion-distribution assembly as set forth in claim 1, wherein the nozzle chamber diverges towards the distribution chamber and wherein the piston comprises a conical nose which tapers towards the nozzle chamber;

wherein the nose portion of the piston is situated well within the nozzle chamber when the piston is in its minimum-flow-area position; and

wherein the nose portion of the piston is situated almost entirely within the distribution chamber when the piston is in its maximum-flow-area position.

10. A heatpump system comprising a first component which acts as a heat-absorbing component when fluid is flowing in a first direction and the expansion-distribution assembly set forth in claim 1 upstream of the inlet of the first component.

11. In combination, an evaporator, a refrigerant fluid, and the expansion-distribution assembly set forth in claim 1 with its tubes connected to the evaporator, the refrigerant fluid flowing in a first direction from the expansion-distribution assembly to the evaporator.

12. The combination set forth in claim 11, wherein the piston is in its minimum-flow-area position whereat flow area through the nozzle chamber is minimized.

13. The combination set forth in claim 12, wherein the piston is in one the positions between its minimum flow-area position and its maximum flow-area position.

14. The combination set forth in claim 12, wherein the piston is at its maximum flow-area position whereat flow area through the nozzle chamber is at a maximum.

15. In combination, an evaporator, a refrigerant fluid, and the expansion-distribution assembly set forth in claim 1, wherein:

the tubes of the expansion-distribution assembly are connected to the evaporator;

the refrigerant fluid flows in a second direction from the evaporator to the expansion-distribution assembly; and

the piston is at its maximum flow-area position whereat flow area through the nozzle chamber is at a maximum.

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