ACTIVE/PASSIVE COOLING SYSTEM WITH PUMPED REFRIGERANT

FIELD OF THE INVENTION

[0001] This invention relates to cooling systems and systems and methods to control them. In particular, this invention relates to a cooling system having both active and passive modes. A particularly suitable application, for example, is in data center cooling systems.

BACKGROUND OF THE INVENTION

[0002] Data centers often require large amounts of energy to operate. The servers in these data centers generate a large amount of heat, requiring cooling. To reduce the energy use of data centers, more efficient cooling systems are desired.

SUMMARY

[0003] In one aspect, the disclosure relates to a cooling system including an evaporator, a passive condenser, a heat exchanger, a liquid line, and a pump. The evaporator contains a primary cooling medium. The evaporator is configured to receive a process fluid and, when receiving the process fluid, extract heat from the process fluid to cool the process fluid and to change the phase of the primary cooling medium from liquid to gas. The passive condenser includes an outer surface and is fluidly coupled to the evaporator. The passive condenser is configured to have an airstream directed over the outer surface thereof, and when the airstream is directed over the outer surface of the passive condenser, the passive condenser is configured (i) to receive the primary cooling medium in the gas phase from the evaporator, (ii) to transfer heat from the primary cooling medium, (iii) to change the phase of the primary cooling medium from gas to liquid, and (iv) to supply the primary cooling medium in the liquid phase to the evaporator. The heat exchanger is fluidly coupled to the evaporator and configured to have a secondary cooling medium selectively provided thereto. When the secondary cooling medium is provided to the heat exchanger, at least some of the primary cooling medium in the gas phase switches from being received by the passive condenser to the heat exchanger without operating any valves located between the evaporator and the passive condenser and between the evaporator and the heat exchanger, and the heat exchanger is configured (i) to receive the primary cooling medium in the gas phase from the evaporator, (ii) to transfer heat from the primary cooling medium, (iii) to change the phase of the primary cooling medium from gas to liquid, and (iv) to supply the primary cooling medium in the liquid phase to the evaporator. When the secondary cooling medium is not provided to the heat exchanger, the heat exchanger does not supply the primary cooling

medium in the liquid phase to the evaporator. The liquid line fluidly connects the evaporator to each of the passive condenser and the heat exchanger to supply the primary cooling medium in the liquid phase to the evaporator from at least one of the passive condenser and the heat exchanger. The pump is located in the liquid line and configured to pump the primary cooling medium in the liquid phase to the evaporator. The passive condenser is arranged in parallel with the heat exchanger relative to the fluid flow of the primary cooling medium.

[0004] In another aspect, the disclosure relates to a cooling system including an evaporator, a plurality of passive condensers, at least one heat exchanger, a liquid line, and a pump. The evaporator contains a primary cooling medium. The evaporator is configured to receive a process fluid and, when receiving the process fluid, extract heat from the process fluid to cool the process fluid and to change the phase of the primary cooling medium from liquid to gas. Each passive condenser has an outer surface and is fluidly coupled to the evaporator. Each passive condenser being configured to have an airstream directed over the outer surface thereof, and, when the airstream is directed over the outer surface of the passive condenser, the passive condenser is configured (i) to receive the primary cooling medium in the gas phase from the evaporator, (ii) to transfer heat from the primary cooling medium, (iii) to change the phase of the primary cooling medium from gas to liquid, and (iv) to supply the primary cooling medium in the liquid phase to the evaporator. The at least one heat exchanger is fluidly coupled to the evaporator and configured to have a secondary cooling medium selectively provided thereto. When the secondary cooling medium is provided to the at least one heat exchanger, at least some of the primary cooling medium in the gas phase switches from being received by the passive condenser to the at least one heat exchanger without operating any valves located between the evaporator and the passive condenser and between the evaporator, and the heat exchanger and the at least one heat exchanger is configured (i) to receive the primary cooling medium in the gas phase from the evaporator, (ii) to transfer heat from the primary cooling medium, (iii) to change the phase of the primary cooling medium from gas to liquid, and (iv) to supply the primary cooling medium in the liquid phase to the evaporator. When the secondary cooling medium is not provided to the at least one heat exchanger, the heat exchanger does not supply the primary cooling medium in the liquid phase to the evaporator. The liquid line fluidly connects the evaporator to each passive condenser of the plurality of passive condensers and the at least one heat exchanger

to supply the primary cooling medium in the liquid phase to the evaporator from at least one of the plurality of passive condensers and the at least one heat exchanger. The pump located in the liquid line and configured to pump the primary cooling medium in the liquid phase to the evaporator. At least one passive condenser of the plurality of passive condensers is arranged in parallel with the at least one heat exchanger relative to the fluid flow of the primary cooling medium.

[0004a] In an aspect, the present disclosure refers to a multi-level data center, comprising:

a plurality of floors including a first floor and a second floor, the second floor being higher than the first floor;

a plurality of racks holding electronic components positioned on the second floor; and

the cooling system according to claim 28, wherein the return air opening is connected to the return air duct to receive air from the plurality of racks positioned on the second floor and the supply air opening is connected to the supply air duct to supply air to the plurality of racks positioned on the second floor.

[0004b] In an aspect, the present disclosure refers to a multi-level data center, comprising:

a plurality of floors including a first floor and a second floor, the second floor being higher than the first floor;

a plurality of racks holding electronic components positioned on the second floor; and the cooling system according to claim 1, wherein the evaporator is positioned on the second floor and the passive condenser and the heat exchanger are positioned lower than the second floor.

[0005] These and other examples of the disclosure will become apparent from the following disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Figure 1 is an elevation view of a multi-story data center using a cooling system according to a preferred embodiment of the invention.

[0007] Figure 2 is a schematic of the cooling system according to a preferred embodiment of the invention operating in a passive mode.

[0008] Figure 3 is a schematic of the cooling system shown in Figure 3 operating in an active mode.

[0009] Figure 4 is a schematic of an air handling unit of a cooling assembly according to a preferred embodiment of the invention.

[0010] Figure 5 is a schematic of a condensing unit used with the air handling unit shown in Figure 4.

[0011] Figure 6 elevation view of a cooling system according to a preferred embodiment of the invention.

[0012] Figures 7A and 7B are examples of server racks cooled by an immersion cooling system used in conjunction with the cooling assembly shown in Figure 1. Figure 7A shows a single-phase immersion cooling system, and Figure 7B shows a two-phase immersion cooling system.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0013] Figure 1 shows a data center 100 having at least one cooling system 200 according to a preferred embodiment of the invention. Although the cooling system 200 is shown and described in reference to a data center 100, the cooling system 200 is not limited to this application and may be used in other suitable cooling applications, including those used to cool airstreams with air heated from other sources. Electronic components such as servers may be mounted on racks 112. These racks 112 may be arranged in rows forming aisles