DESCRIPTION

Title of Invention

COOLING SYSTEM

Technical Field

[0001]

The present disclosure relates to a cooling system.

The present application claims priority based on Japanese Patent Application No. 2024-020310 filed in Japan on February 14, 2024, the contents of which are incorporated herein by reference.

Background Art

[0002]

In recent years, the amount of energy consumed in data centers has been increasing. In a server cooling system, it is important to reduce power consumption as much as possible. For example, PTL 1 discloses a cooling device that cools an electronic device (heat source) such as a CPU mounted on a server. The cooling device includes an evaporation section that takes heat from the heat source by using the latent heat of vaporization of a liquid.

A low-boiling-point refrigerant such as R134a or R1233zd is used as the liquid for cooling the heat source.

Citation List

Patent Literature

[0003]

[PTL 1] Japanese Patent No. 6079343

Summary of Invention

Technical Problem

[0004]

However, in consideration of recent regulations on per- and polyfluoroalkyl substances (PFASs), which are organic fluorine compounds, there is a possibility that these refrigerants become unusable in the future. For this reason, for example, development of a cooling system capable of exhibiting sufficient cooling performance even when a refrigerant that does not fall under PFAS and is not subject to use regulations is used has been regarded as a challenge.

[0005]

The present disclosure has been made to solve the above-described problem, and an object of the present disclosure is to provide a cooling system capable of improving cooling efficiency.

Solution to Problem

[0006]

In order to solve the above-described problem, a cooling system according to the present disclosure includes a circulation system through which a refrigerant for cooling a heat generating body circulates, and a pressure reduction section connected to the circulation system, in which the circulation system includes a cooling section that is attached to the heat generating body and that boils the refrigerant to take heat from the heat generating body, a heat exchange section that is provided at a position higher than the cooling section and that condenses the refrigerant in a gaseous state, a gas line that guides the refrigerant evaporated in the cooling section to the heat exchange section, and a liquid line that guides the refrigerant condensed in the heat exchange section to the cooling section, and the pressure reduction section reduces a

pressure in the circulation system by removing gas from the circulation system.

Advantageous Effects of Invention

[0007]

According to the cooling system of the present disclosure, it is possible to improve cooling efficiency.

Brief Description of Drawings

[0008]

FIG. 1 is a configuration diagram of a cooling system according to a first embodiment of the present disclosure.

FIG. 2 is a functional block diagram of a control device according to a first embodiment of the present disclosure.

FIG. 3 is a flowchart showing a procedure of a basic operation of the cooling system according to the first embodiment of the present disclosure.

FIG. 4 is a flowchart showing a procedure of an operation for removing a non-condensable gas from the circulation system according to the first embodiment of the present disclosure.

FIG. 5 is a flowchart showing a procedure of an operation for forcibly circulating the refrigerant according to the first embodiment of the present disclosure.

FIG. 6 is a flowchart showing a procedure of an operation for opening the pressure reduction section to the atmosphere according to the first embodiment of the present disclosure.

FIG. 7 is a flowchart showing a procedure of an operation for returning the refrigerant from the pressure reduction section to the circulation system according to the first embodiment of the present disclosure.

FIG. 8 is a configuration diagram of a cooling system according to a second

embodiment of the present disclosure.

FIG. 9 is a configuration diagram of a cooling system according to a third embodiment of the present disclosure.

FIG. 10 is a configuration diagram of a cooling system according to a fourth embodiment of the present disclosure.

FIG. 11 is a hardware configuration diagram according to the embodiment of the present disclosure.

Description of Embodiments

[0009]

<First Embodiment>

(Configuration of Cooling System)

Hereinafter, a cooling system 1 according to a first embodiment of the present disclosure will be described with reference to FIGS. 1 to 7.

As shown in FIG. 1, the cooling system 1 includes a server rack 2, a server 3, a circulation system 20, a pressure reduction section 30, a switching mechanism 40, a circulation system temperature sensor 4, a circulation system pressure sensor 5, a heat generation temperature sensor 6, a pressure reduction section pressure sensor 7, a level sensor 8, a refrigerant return line 9, a refrigerant return valve 9a, a refrigerant return pump 9b, a power supply section 10, a duct 11, and a control device 12.

In FIG. 1, each configuration of the cooling system 1 is schematically shown.

Hereinafter, a vertical up-down direction may be simply referred to as an “up-down direction Dv”. In addition, an upper side is denoted by a reference numeral “Dvu”, and a lower side is denoted by a reference numeral “Dvd”.

[0010]

(Server Rack)

The server rack 2 is a housing extending in the up-down direction Dv. The server rack 2 is installed in, for example, a data center. The server rack 2 accommodates a device constituting the cooling system 1 inside. For example, in addition to the server 3, a refrigerant tank 25, a forced circulation pump 28, a pressure reduction unit 33, a power supply section 10, and the like, which will be described later, are accommodated in the server rack 2.

[0011]

(Server)

A plurality of servers 3 are accommodated in the server rack 2.

The server 3 includes a casing 3a, a server board 3b, and a heat generating body 3c.

The casing 3a is a box-shaped housing extending in a horizontal direction. The casing 3a is inserted into the server rack 2 in a horizontal direction. The server board 3b and the heat generating body 3c are accommodated inside the casing 3a. The server board 3b extends in the horizontal direction.

[0012]

(Heat Generating Body)

The heat generating body 3c is an electronic component placed on the server board 3b. The heat generating body 3c is, for example, a chip such as a CPU or a GPU installed on the server board 3b. The heat generating body 3c generates heat during operation. The heat generating body 3c has a temperature range in which the heat generating body 3c can be operated most efficiently. The cooling system 1 cools each heat generating body 3c to the temperature range in which the heat generating body 3c can be operated most efficiently.

[0013]

(Circulation System)

A refrigerant R for cooling the heat generating body 3c circulates through the circulation system 20. The refrigerant R of the present embodiment is water. The circulation system 20 includes a cooling section 21, a heat exchange section 22, a gas line 23, a liquid line 24, a refrigerant tank 25, a second cooling section 26, a forced circulation line 27, and a forced circulation pump 28.

[0014]

(Cooling Section)

The cooling section 21 is attached to the heat generating body 3c. The refrigerant R is supplied to the cooling section 21. A flow path through which the refrigerant R circulates is formed inside the cooling section 21. The cooling section 21 boils the refrigerant R to take heat from the heat generating body 3c. As a result, the heat generating body 3c is cooled. The cooling section 21 of the present embodiment is a box-shaped cold plate in which the refrigerant R can circulate.

[0015]

(Heat Exchange Section)

The heat exchange section 22 is provided at a position higher than the cooling section 21. The heat exchange section 22 is supplied with the refrigerant R that is boiled and vaporized by the cooling section 21. The heat exchange section 22 condenses the refrigerant R in a gaseous state. The heat exchange section 22 of the present embodiment takes heat from the refrigerant R by performing heat exchange between the refrigerant R and air outside the heat exchange section 22, and condenses the refrigerant R.

[0016]

(Gas Line)

The gas line 23 guides the refrigerant R evaporated in the cooling section 21 to the heat exchange section 22. The gas line 23 extends upward from an upper wall of the cooling section 21 and is connected to an upper portion of the heat exchange section 22.

[0017]

(Liquid Line)

The liquid line 24 guides the refrigerant R condensed in the heat exchange section 22 to the cooling section 21. The liquid line 24 extends downward from a lower portion of the heat exchange section 22 and is connected to the cooling section 21. A connecting portion between the liquid line 24 and the cooling section 21 is located below a connecting portion between the gas line 23 and the cooling section 21.

[0018]

(Refrigerant Tank)

The refrigerant tank 25 is provided in the liquid line 24. The refrigerant tank 25 stores the liquid refrigerant R that has passed through the heat exchange section 22.

[0019]

(Second Cooling Section)

The second cooling section 26 is provided in the refrigerant tank 25. The second cooling section 26 cools the refrigerant R. The second cooling section 26 of the present embodiment is ice disposed in the refrigerant tank 25. The second cooling section 26 may be any section as long as the refrigerant R can be cooled. The second cooling section 26 may be, for example, a cooler driven by an external power supply (not shown).

[0020]

(Forced Circulation Line)

The forced circulation line 27 branches from the liquid line 24 and returns the refrigerant R to the cooling section 21. In the present embodiment, an upstream end of the forced circulation line 27 is connected to the refrigerant tank 25. A downstream end of the forced circulation line 27 is connected to a downstream side of the refrigerant tank 25 in the liquid line 24, that is, between the refrigerant tank 25 and the cooling section 21.

[0021]

(Forced Circulation Pump)

The forced circulation pump 28 is a pump provided in the forced circulation line 27 and capable of pumping the refrigerant R to the cooling section 21. The forced circulation pump 28 pumps the liquid refrigerant R stored in the refrigerant tank 25 to the cooling section 21. The forced circulation pump 28 is driven by power supplied from an external power source (not shown) and a power supply section 10, which will be described later.

[0022]

(Pressure Reduction Section)

The pressure reduction section 30 is connected to the circulation system 20 and reduces the pressure in the circulation system 20 by removing gas from the circulation system 20. The pressure reduction section 30 includes a gas vent line 31, a gas vent valve 32, and a pressure reduction unit 33.

[0023]

(Gas Vent Line)

The gas vent line 31 is connected to the circulation system 20 and is a line for removing gas from the circulation system 20. The gas vent line 31 is connected to the highest position in the circulation system 20. That is, the pressure reduction

section 30 is connected to the highest position in the circulation system 20. In the present embodiment, the gas vent line 31 is connected to the highest position in the heat exchange section 22.

[0024]

(Gas Vent Valve)

The gas vent valve 32 is provided in the gas vent line 31 and is a valve that can open and close the gas vent line 31.

[0025]

(Pressure Reduction Unit)

The pressure reduction unit 33 is accommodated in the server rack 2. The pressure reduction unit 33 includes an ejector 34, a drive pump 35, a drive fluid supply line 36, a drive fluid return line 37, a drive fluid tank 38, an atmosphere-release line 39, and an atmosphere-release valve 39a.

[0026]

(Ejector)

The ejector 34 is connected to a downstream end of the gas vent line 31. A drive fluid L is supplied to the ejector 34 from the outside. The ejector 34 sucks the gas in the gas vent line 31 by the flow of the drive fluid L flowing inside the ejector 34. The drive fluid L of the present embodiment is the same water as the refrigerant R. The ejector 34 includes a supply part 34a, a discharge part 34b, and a suction part 34c. The drive fluid L is supplied to the supply part 34a from the drive fluid supply line 36, which will be described later. The discharge part 34b communicates with the supply part 34a and discharges the drive fluid L that has passed through the inside of the ejector 34 to the drive fluid return line 37, which will be described later. The suction part 34c is provided at a connecting portion between the supply part 34a and the

discharge part 34b and communicates with both the supply part 34a and the discharge part 34b. A downstream end of the gas vent line 31 is connected to the suction part 34c. The gas in the gas vent line 31 is sucked into the suction part 34c by the flow of the drive fluid L flowing from the supply part 34a to the discharge part 34b. The gas sucked into the suction part 34c is discharged from the discharge part 34b together with the drive fluid L.

[0027]

(Drive Pump)

The drive pump 35 pumps the drive fluid L and supplies the drive fluid L to the ejector 34. In the present embodiment, the forced circulation pump 28 also serves as the drive pump 35. That is, one pump functions as the forced circulation pump 28 and also functions as the drive pump 35.

[0028]

(Drive Fluid Supply Line)

The drive fluid supply line 36 guides the drive fluid L from the drive pump 35 to the ejector 34. In the present embodiment, the drive fluid supply line 36 connects the downstream side of the forced circulation pump 28 (drive pump 35) in the forced circulation line 27 and the supply part 34a of the ejector 34.

[0029]

(Drive Fluid Return Line)

The drive fluid return line 37 returns the drive fluid L discharged from the ejector 34 to the drive pump 35. In the present embodiment, the drive fluid return line 37 connects the discharge part 34b of the ejector 34 and the upstream side of the forced circulation pump 28 (drive pump 35) in the forced circulation line 27.

[0030]

(Drive Fluid Tank)

The drive fluid tank 38 is provided in the drive fluid return line 37. The drive fluid tank 38 is a tank capable of storing the drive fluid L.

[0031]

(Atmosphere-Release Line)

The atmosphere-release line 39 is provided in an upper portion of the drive fluid tank 38. The atmosphere-release line 39 is a pipe that allows the inside and the outside of the drive fluid tank 38 to communicate with each other.

[0032]

(Atmosphere-Release Valve)

The atmosphere-release valve 39a is provided in the atmosphere-release line 39 and is a valve that can open and close the atmosphere-release line 39.

[0033]

(Switching Mechanism)

The switching mechanism 40 is a mechanism that can switch the flow path of the refrigerant R between a flow path in which the refrigerant R does not pass through the forced circulation line 27 and a flow path in which the refrigerant R passes through the forced circulation line 27. In addition, in the present embodiment, the switching mechanism 40 can also switch the connection between the pressure reduction unit 33 and the circulation system 20. The switching mechanism 40 includes a first valve 41, a second valve 42, a third valve 43, a fourth valve 44, and a fifth valve 45.

[0034]

The first valve 41 is provided on the downstream side of the refrigerant tank 25 in the liquid line 24 and between the refrigerant tank 25 and the cooling section 21. The first valve 41 is a valve that can open and close the liquid line 24.

The second valve 42 is provided on the downstream side of the refrigerant tank 25 in the forced circulation line 27 and on the upstream side of the connecting portion between the drive fluid return line 37 and the forced circulation line 27. The second valve 42 is a valve that can open and close the forced circulation line 27.

The third valve 43 is provided on the downstream side of the connecting portion between the drive fluid supply line 36 and the forced circulation line 27 in the forced circulation line 27. The third valve 43 is a valve that can open and close the forced circulation line 27.

[0035]

The fourth valve 44 is provided in the drive fluid supply line 36 and is a valve that can open and close the drive fluid supply line 36.

The fifth valve 45 is provided on the downstream side of the drive fluid tank 38 in the drive fluid return line 37. The fifth valve 45 is a valve that can open and close the drive fluid return line 37.

[0036]

(Circulation System Temperature Sensor)

The circulation system temperature sensor 4 measures the temperature in the circulation system 20. The circulation system temperature sensor 4 is provided in the vicinity of the connecting portion with the heat exchange section 22 in the gas vent line 31. In addition, the circulation system temperature sensor 4 is provided on the upstream side of the gas vent valve 32 in the gas vent line 31.

[0037]

(Circulation System Pressure Sensor)

The circulation system pressure sensor 5 measures the pressure in the circulation system 20. The circulation system pressure sensor 5 is provided in the

vicinity of the connecting portion with the heat exchange section 22 in the gas vent line 31. In addition, the circulation system pressure sensor 5 is provided on the upstream side of the gas vent valve 32 in the gas vent line 31.

[0038]

(Heat Generation Temperature Sensor)

The heat generation temperature sensor 6 is connected to the heat generating body 3c and measures the temperature of the heat generating body 3c.

[0039]

(Pressure Reduction Section Pressure Sensor)

The pressure reduction section pressure sensor 7 measures the pressure in the pressure reduction section 30. The pressure reduction section pressure sensor 7 is provided in the drive fluid tank 38.

[0040]

(Level Sensor)

The level sensor 8 is provided in an upper portion of the drive fluid tank 38. The level sensor 8 detects that the fluid is stored in the drive fluid tank 38 up to the height of the level sensor 8 by coming into contact with the liquid level of the fluid stored in the drive fluid tank 38. The level sensor 8 is provided below the atmosphere-release line 39.

[0041]

(Refrigerant Return Line)

The refrigerant return line 9 connects the drive fluid tank 38 and the refrigerant tank 25. The refrigerant return line 9 is a pipe that returns the refrigerant R ingressed into the drive fluid tank 38 to the inside of the refrigerant tank 25.

[0042]

(Refrigerant Return Valve)

The refrigerant return valve 9a is provided in the refrigerant return line 9 and is a valve that can open and close the refrigerant return line 9.

[0043]

(Refrigerant Return Pump)

The refrigerant return pump 9b is provided on the upstream side of the refrigerant return valve 9a in the refrigerant return line 9. The refrigerant return pump 9b pumps the refrigerant R ingressed into the drive fluid tank 38 into the refrigerant tank 25.

[0044]

(Power Supply Section)

The power supply section 10 generates power by the temperature difference between the heat generating body 3c and the cooling section 21, for example, using a Peltier element or the like. The power supply section 10 supplies power to the forced circulation pump 28.

[0045]

(Duct)

The duct 11 discharges the air around the heat exchange section 22 upward. The duct 11 has a lower opening 11a, an upper opening 11b, and a cylindrical portion 11c. The lower opening 11a is open downward, and the heat exchange section 22 is disposed inside the lower opening 11a. The upper opening 11b is located above the lower opening 11a and is open upward. The cylindrical portion 11c connects the lower opening 11a and the upper opening 11b. The cylindrical portion 11c extends in the up-down direction Dv to allow the lower opening 11a and the upper opening 11b to communicate with each other.

[0046]

(Control Device)

As shown in FIG. 2, the control device 12 includes a pressure reduction control section 50, a forced circulation control section 60, an atmosphere-release control section 70, and a refrigerant return control section 80, which are functional sections. The control device 12 can be operated by an operator.

[0047]

(Pressure Reduction Control Section)

The pressure reduction control section 50 controls the pressure reduction section 30. The pressure reduction control section 50 includes a circulation system temperature acquisition section 51, a circulation system pressure acquisition section 52, a saturation pressure calculation section 53, a circulation system pressure determination section 54, and a pressure reduction operation section 55.

[0048]

(Circulation System Temperature Acquisition Section)

The circulation system temperature acquisition section 51 acquires the temperature measured by the circulation system temperature sensor 4.

[0049]

(Circulation System Pressure Acquisition Section)

The circulation system pressure acquisition section 52 acquires the pressure measured by the circulation system pressure sensor 5.

[0050]

(Saturated Pressure Calculation Section)

The saturation pressure calculation section 53 calculates the saturation pressure in the circulation system 20 from the temperature measured by the circulation

system temperature sensor 4.

[0051]

(Circulation System Pressure Determination Section)

The circulation system pressure determination section 54 determines whether or not the pressure measured by the circulation system pressure sensor 5 is higher than the saturation pressure of the refrigerant R in the circulation system 20 calculated by the saturation pressure calculation section 53.

[0052]

(Pressure Reduction Operation Section)

The pressure reduction operation section 55 causes the pressure reduction section 30 to remove the gas from the circulation system 20 and reduce the pressure in the circulation system 20. For example, when the pressure measured by the circulation system pressure sensor 5 is higher than the saturation pressure of the refrigerant R in the circulation system 20 calculated by the saturation pressure calculation section 53, the pressure reduction operation section 55 causes the pressure reduction section 30 to reduce the pressure in the circulation system 20.

[0053]

(Forced Circulation Control Section)

The forced circulation control section 60 forcibly circulates the refrigerant R in the circulation system 20. The forced circulation control section 60 includes a heat generation temperature acquisition section 61, a heat generation temperature determination section 62, a forced circulation operation section 63, and a flow rate adjustment section 64.

[0054]

(Heat Generation Temperature Acquisition Section)

The heat generation temperature acquisition section 61 acquires the temperature measured by the heat generation temperature sensor 6.

[0055]

(Heat Generation Temperature Determination Section)

The heat generation temperature determination section 62 determines whether or not the temperature measured by the heat generation temperature sensor 6 is higher than a predetermined temperature.

[0056]

(Forced Circulation Operation Section)

The forced circulation operation section 63 operates the switching mechanism 40 and the forced circulation pump 28 to forcibly circulate the refrigerant R in the circulation system 20. For example, when the temperature measured by the heat generation temperature sensor 6 is higher than a predetermined temperature, the forced circulation operation section 63 causes the switching mechanism 40 to switch the flow path of the refrigerant R to a flow path in which at least a part of the refrigerant R passes through the forced circulation line 27, and operates the forced circulation pump 28.

[0057]

(Flow Rate Adjustment Section)

The flow rate adjustment section 64 controls the rotation speed of the forced circulation pump 28 to adjust the flow rate of the refrigerant R by the forced circulation pump 28.

[0058]

(Atmosphere-Release Control Section)

The atmosphere-release control section 70 controls the atmospheric release of

the pressure reduction section 30. The atmosphere-release control section 70 includes a pressure-in-pressure-reduction-section acquisition section 71, a pressure-in-pressure-reduction-section determination section 72, and an atmosphere-release operation section 73.

[0059]

(Pressure-In-Pressure-Reduction-Section Acquisition Section)

The pressure-in-pressure-reduction-section acquisition section 71 acquires the pressure in the pressure reduction section 30 measured by the pressure reduction section pressure sensor 7.

[0060]

(Pressure-In-Pressure-Reduction-Section Determination Section)

The pressure-in-pressure-reduction-section determination section 72 determines whether or not the pressure in the pressure reduction section 30 measured by the pressure reduction section pressure sensor 7 is higher than a predetermined pressure.

[0061]

(Atmosphere-Release Operation Section)

The atmosphere-release operation section 73 operates the atmosphere-release valve 39a to release the pressure reduction section 30 to the atmosphere. For example, when the pressure in the pressure reduction section 30 measured by the pressure reduction section pressure sensor 7 is higher than a predetermined pressure, the atmosphere-release operation section 73 operates the atmosphere-release valve 39a to open the atmosphere-release line 39.

[0062]

(Refrigerant Return Control Section)

The refrigerant return control section 80 controls an operation for returning the refrigerant R from the pressure reduction section 30 to the circulation system 20.

The refrigerant return control section 80 includes a liquid level detection information acquisition section 81 and a refrigerant return operation section 82.

[0063]

(Liquid Level Detection Information Acquisition Section)

The liquid level detection information acquisition section 81 acquires information indicating that the level sensor 8 has detected the liquid level of the fluid stored in the drive fluid tank 38.

[0064]

(Refrigerant Return Operation Section)

For example, when the liquid level detection information acquisition section 81 acquires the information indicating that the level sensor 8 has detected the liquid level, the refrigerant return operation section 82 operates the refrigerant return valve 9a to open the refrigerant return line 9, and operates the refrigerant return pump 9b to return the refrigerant R ingressed into the pressure reduction section 30 from the tank of the drive fluid L to the refrigerant tank 25.

[0065]

(Basic Operation of Cooling System)

A basic operation of the cooling system 1 according to the present embodiment will be described with reference to the flowchart of FIG. 3.

First, the pressure reduction operation section 55 operates the pressure reduction section 30 in advance (step S1). In step S1, the pressure reduction operation section 55 operates the gas vent valve 32 to open the gas vent line 31. Then, the pressure reduction operation section 55 operates the drive pump 35. As a

result, the gas is removed from the circulation system 20, and the pressure in the circulation system 20 is reduced. Thereafter, the pressure reduction operation section 55 operates the gas vent valve 32 to close the gas vent line 31. Then, the pressure reduction operation section 55 stops the drive pump 35. The time during which the pressure reduction operation section 55 operates the drive pump 35 can be changed as appropriate. The pressure reduction operation section 55 may operate the pressure reduction section 30 only for a moment, for example.

[0066]

After step S1, the heat generating body 3c is operated (step S2). In step S2, the refrigerant R in the cooling section 21 boils due to the heat of the heat generating body 3c. Since the pressure in the circulation system 20 is reduced, the boiling point of the refrigerant R is lower than that before the pressure reduction. Therefore, the refrigerant R boils faster than before the pressure reduction. The refrigerant R boils, so that the refrigerant R in a gaseous state is generated. At this time, the latent heat of vaporization of the refrigerant R is taken away from the heat generating body 3c. As a result, the heat generating body 3c is cooled. The refrigerant R in a gaseous state is supplied to the heat exchange section 22 through the gas line 23 provided in the upper portion of the cooling section 21. In the heat exchange section 22, heat exchange is performed between the outside air and the refrigerant R. As a result, the refrigerant R is cooled and condensed. The condensed refrigerant R is stored in the refrigerant tank 25 through the liquid line 24. The refrigerant R stored in the refrigerant tank 25 is supplied to the cooling section 21 again through the liquid line 24. In this way, the refrigerant R naturally circulates in the circulation system 20 only by natural convection caused by the heat of the heat generating body 3c. In step S2, the first valve 41 opens the liquid line 24, and the second valve 42 and the third

valve 43 close the forced circulation line 27.

The basic operation of the cooling system 1 is completed by the above procedure.

[0067]

The order of step S1 and step S2 can be appropriately adjusted. For example, the pressure reduction operation section 55 may operate the pressure reduction section 30 while the refrigerant R is circulating in the circulation system 20.

[0068]

The cooling system 1 can execute an operation other than the above-described basic operation. Hereinafter, an operation other than the basic operation will be described.

[0069]

(Operation for Removing Non-Condensable Gas)

A non-condensable gas may be ingressed into the circulation system 20. The non-condensable gas increases the pressure in the circulation system 20. When the pressure in the circulation system 20 increases, the boiling point of the refrigerant R rises, and the refrigerant R is less likely to evaporate. Therefore, it is preferable that the non-condensable gas is removed from the circulation system 20.

Hereinafter, a procedure of removing the non-condensable gas from the circulation system 20 will be described with reference to the flowchart of FIG. 4.

[0070]

First, the circulation system temperature acquisition section 51 acquires the temperature measured by the circulation system temperature sensor 4 (step S10). After step S10, the circulation system pressure acquisition section 52 acquires the pressure measured by the circulation system pressure sensor 5 (step S11). The timing

at which step S11 is started can be changed as appropriate. For example, step S10 and step S11 may be performed at the same time. After step S11, the saturation pressure calculation section 53 calculates the saturation pressure in the circulation system 20 from the temperature measured by the circulation system temperature sensor 4 (step S12).

[0071]

After step S12, the circulation system pressure determination section 54 determines whether or not the pressure measured by the circulation system pressure sensor 5 is higher than the saturation pressure of the refrigerant R in the circulation system 20 calculated by the saturation pressure calculation section 53 (step S13).

[0072]

When the pressure measured by the circulation system pressure sensor 5 is higher than the saturation pressure of the refrigerant R in the circulation system 20 calculated by the saturation pressure calculation section 53 (step S13; YES), the non-condensable gas has ingressed into the circulation system 20 to such an extent as to interfere with the boiling of the refrigerant R. In this case (step S13; YES), the pressure reduction operation section 55 operates the pressure reduction section 30 (step S14). In step S14, the pressure reduction section 30 removes the gas from the circulation system 20. As a result, the non-condensable gas is removed from the circulation system 20, and the pressure in the circulation system 20 is reduced. Thereafter, the pressure reduction operation section 55 stops the operation of the pressure reduction section 30, and the flow ends.

[0073]

On the other hand, when the pressure measured by the circulation system pressure sensor 5 is not higher than the saturation pressure of the refrigerant R in the

circulation system 20 calculated by the saturation pressure calculation section 53 (step S13; NO), the possibility that the non-condensable gas has ingressed into the circulation system 20 to such an extent as to interfere with the boiling of the refrigerant R is low. In this case (step S13; NO), the flow ends without going through step S14.

The operation for removing the non-condensable gas is completed by the above procedure.

[0074]

The series of flows of step S10 to step S14 may be started at any timing by the operator, or may be automatically performed at regular intervals.

In addition, the operator may omit the procedures of steps S10 to S13 in the series of flows of steps S10 to S14 and execute step S14 at any timing.

[0075]

(Forced Circulation Operation)

In addition, when the temperature of the heat generating body 3c exceeds the criteria (for example, 70 degrees or higher and 120 degrees or lower), dryout occurs in the cooling section 21. Then, the supply amount of the refrigerant R to the cooling section 21 is insufficient, and the cooling system 1 cannot sufficiently cool the heat generating body 3c. In preparation for such a case, the cooling system 1 has a function of forcibly circulating the refrigerant R.

Hereinafter, a procedure of forcibly circulating the refrigerant R will be described with reference to the flow of FIG. 5.

[0076]

First, the heat generation temperature acquisition section 61 acquires the temperature measured by the heat generation temperature sensor 6 (step S20). After

step S20, the heat generation temperature determination section 62 determines whether or not the temperature measured by the heat generation temperature sensor 6 is higher than a predetermined temperature (step S21). The predetermined temperature can be set as appropriate. The predetermined temperature is set to, for example, a criteria. When the temperature measured by the heat generation temperature sensor 6 is higher than the predetermined temperature (step S21; YES), the forced circulation operation section 63 causes the switching mechanism 40 to switch the flow path of the refrigerant R to a flow path in which at least a part of the refrigerant R passes through the forced circulation line 27, and operates the forced circulation pump 28 (step S22). In step S22, for example, the first valve 41 closes the liquid line 24, and the second valve 42 and the third valve 43 open the forced circulation line 27. Therefore, all the refrigerant R circulating in the circulation system 20 passes through the forced circulation line 27. The refrigerant R passing through the forced circulation line 27 is pumped by the forced circulation pump 28. The refrigerant R is forcibly circulated in the circulation system 20 by the pressure feed force of the forced circulation pump 28 in addition to the natural convection caused by the heat of the heat generating body 3c. As a result, a larger amount of the refrigerant R is supplied to the cooling section 21 per unit time, the insufficient supply amount of the refrigerant R to the cooling section 21 is eliminated, and the flow ends.

In step S22, it is assumed that the fourth valve 44 closes the drive fluid supply line 36 and the fifth valve 45 closes the drive fluid return line 37.

[0077]

On the other hand, when the temperature measured by the heat generation temperature sensor 6 is not higher than the predetermined temperature (step S21; NO), step S22 is omitted, and the flow ends.

The forced circulation operation is completed by the above procedure.

[0078]

In addition, among the flow paths of the refrigerant R, a flow path in which the refrigerant R passes through the forced circulation line 27 is referred to as a forced circulation flow path, and a flow path in which the refrigerant R does not pass through the forced circulation line 27 is referred to as a natural circulation flow path. In step S22, the first valve 41 opens the liquid line 24, and the cooling system 1 may use the forced circulation flow path and the natural circulation flow path in combination. In this case, the flow rate adjustment section 64 may adjust the rotation speed of the forced circulation pump 28 such that the power consumption of the forced circulation pump 28 is minimized.

[0079]

In addition, the operator may omit the procedures of steps S20 and S21 in the series of flows of steps S20 to S22 and execute step S22 at any timing.

[0080]

In addition, in the present embodiment, both the refrigerant R and the drive fluid L are water. Therefore, for example, the pressure reduction section 30 may be operated while the refrigerant R is being forcibly circulated in the circulation system 20 (step S22). In this case, the fourth valve 44 opens the drive fluid supply line 36, and the fifth valve 45 opens the drive fluid return line 37. Then, the forced circulation pump 28 also functions as the drive pump 35 and circulates the drive fluid L in the pressure reduction unit 33.

[0081]

(Atmosphere-Release Operation of Pressure Reduction Section)

Each time the pressure reduction section 30 is operated, the gas is removed

from the circulation system 20, and the internal pressure increases. Therefore, the cooling system 1 has a function for opening the pressure reduction section 30 to the atmosphere.

Hereinafter, a procedure of releasing the pressure reduction section 30 to the atmosphere will be described with reference to the flow of FIG. 6.

[0082]

First, the pressure-in-pressure-reduction-section acquisition section 71 acquires the pressure in the pressure reduction section 30 measured by the pressure reduction section pressure sensor 7 (step S30). After step S30, the pressure-in-pressure-reduction-section determination section 72 determines whether or not the pressure in the pressure reduction section 30 measured by the pressure reduction section pressure sensor 7 is higher than a predetermined pressure (step S31). The predetermined pressure can be appropriately set. The predetermined pressure may be, for example, a design pressure of the pressure reduction section 30. When the pressure in the pressure reduction section 30 measured by the pressure reduction section pressure sensor 7 is higher than the predetermined pressure (step S31; YES), the atmosphere-release operation section 73 operates the atmosphere-release valve 39a to open the atmosphere-release line 39 (step S32). As a result, the pressure in the pressure reduction section 30 is reduced, and the flow ends.

[0083]

On the other hand, when the pressure in the pressure reduction section 30 measured by the pressure reduction section pressure sensor 7 is not higher than the predetermined pressure (step S31; NO), step S32 is omitted, and the flow ends.

The atmosphere-release operation of the pressure reduction section 30 is completed by the above procedure.

[0084]

In addition, the operator may omit the procedure of steps S30 and S31 in the series of flows of steps S30 to S32 and execute step S32 at any timing.

[0085]

(Refrigerant Return Operation)

In addition, when the pressure reduction section 30 removes the gas from the circulation system 20, the refrigerant R may be sucked into the pressure reduction section 30. The refrigerant R sucked into the pressure reduction section 30 is stored in the drive fluid tank 38. On the other hand, the refrigerant R is reduced in the circulation system 20. Therefore, the cooling system 1 is provided with a function for returning the refrigerant R from the pressure reduction section 30 to the circulation system 20.

Hereinafter, an operation for returning the refrigerant R from the pressure reduction section 30 to the circulation system 20 will be described with reference to the flow of FIG. 7.

[0086]

First, the liquid level detection information acquisition section 81 acquires information indicating that the level sensor 8 has detected the liquid level of the fluid stored in the drive fluid tank 38 (step S40). After step S40, the refrigerant return operation section 82 operates the refrigerant return valve 9a to open the refrigerant return line 9, and operates the refrigerant return pump 9b. (Step S41) As a result, the refrigerant R ingressed into the pressure reduction section 30 is returned from the drive fluid tank 38 to the refrigerant tank 25.

The refrigerant return operation is completed by the above procedure.

[0087]

In addition, the operator may omit the procedure of step S40 in the series of flows of steps S40 and S41 and execute step S41 at any timing.

[0088]

(Operation and Effect)

According to the cooling system 1 of the present embodiment, the following actions and effects can be achieved.

[0089]

In the present embodiment, the cooling system 1 includes the circulation system 20 and the pressure reduction section 30. The refrigerant R for cooling the heat generating body 3c circulates through the circulation system 20. The circulation system 20 includes the cooling section 21, the heat exchange section 22, the gas line 23, and the liquid line 24. The cooling section 21 is attached to the heat generating body 3c and boils the refrigerant R to take heat from the heat generating body 3c. The heat exchange section 22 is provided at a position higher than the cooling section 21 and condenses the refrigerant R in a gaseous state. The gas line 23 guides the refrigerant R evaporated in the cooling section 21 to the heat exchange section 22. The pressure reduction section 30 is connected to the circulation system 20. The pressure reduction section 30 reduces the pressure in the circulation system 20 by removing gas from the circulation system 20.

[0090]

According to the above configuration, the cooling system 1 can reduce the pressure in the circulation system 20 and set the inside of the circulation system 20 to a low-pressure state of atmospheric pressure or lower. As a result, the boiling point of the refrigerant R is lowered. Therefore, the cooling system 1 can boil the refrigerant R at a lower temperature than before the pressure reduction in the cooling

section 21. Therefore, the cooling system 1 can efficiently cool the heat generating body 3c. Therefore, even when a liquid having a high boiling point at atmospheric pressure, such as water that does not correspond to PFAS, is used as the refrigerant R as in the present embodiment, the cooling system 1 can efficiently cool the heat generating body 3c.

In addition, since the inside of the circulation system 20 is under negative pressure, for example, even when the circulation system 20 is damaged, air is sucked into the circulation system 20. The flow of the sucked air suppresses the leakage of the refrigerant R to the outside. Therefore, the cooling system 1 can suppress the leaked refrigerant R from flowing to the server 3 side.

In addition, even when a non-condensable gas has ingressed into the circulation system 20, the pressure reduction section 30 can remove the non-condensable gas.

[0091]

In the present embodiment, the pressure reduction section 30 is connected to the highest position in the circulation system 20.

[0092]

When a non-condensable gas has ingressed into the circulation system 20, the non-condensable gas is likely to accumulate in the upper portion in the circulation system 20. According to the above configuration, the pressure reduction section 30 can efficiently remove the non-condensable gas accumulated in the upper portion in the circulation system 20.

[0093]

In the present embodiment, the pressure reduction section 30 includes the gas vent line 31, the ejector 34, the drive pump 35, the drive fluid supply line 36, the drive

fluid return line 37, and the drive fluid tank 38. The gas vent line 31 is a pipe connected to the circulation system 20 and configured to remove gas in the circulation system 20. The ejector 34 is connected to the gas vent line 31 and sucks the gas in the gas vent line 31 by a flow of the drive fluid L flowing inside the ejector 34. The drive pump 35 supplies the drive fluid L to the ejector 34. The drive fluid supply line 36 guides the drive fluid L from the drive pump 35 to the ejector 34. The drive fluid return line 37 returns the drive fluid L discharged from the ejector 34 to the drive pump 35. The drive fluid tank 38 is provided in the drive fluid return line 37 and can store the drive fluid L.

[0094]

According to the above configuration, the configuration of the pressure reduction section 30 can be simplified.

[0095]

In the present embodiment, the cooling system 1 further includes the circulation system temperature sensor 4, the circulation system pressure sensor 5, and the pressure reduction control section 50. The circulation system temperature sensor 4 measures the temperature in the circulation system 20. The circulation system pressure sensor 5 measures the pressure in the circulation system 20. The pressure reduction control section 50 controls the pressure reduction section 30. The pressure reduction control section 50 includes the circulation system temperature acquisition section 51, the circulation system pressure acquisition section 52, the saturation pressure calculation section 53, and the pressure reduction operation section 55. The circulation system temperature acquisition section 51 acquires the temperature measured by the circulation system temperature sensor 4. The circulation system pressure acquisition section 52 acquires the pressure measured by the circulation

system pressure sensor 5. The saturation pressure calculation section 53 calculates the saturation pressure in the circulation system 20 from the temperature measured by the circulation system temperature sensor 4. When the pressure measured by the circulation system pressure sensor 5 is higher than the saturation pressure of the refrigerant R in the circulation system 20 calculated by the saturation pressure calculation section 53, the pressure reduction operation section 55 causes the pressure reduction section 30 to reduce the pressure in the circulation system 20.

[0096]

When the pressure in the circulation system 20 is higher than the saturation pressure of the refrigerant R, the non-condensable gas has ingressed into the circulation system 20. According to the above configuration, when the pressure in the circulation system 20 is higher than the saturation pressure of the refrigerant R, the pressure reduction section 30 reduces the pressure in the circulation system 20. Therefore, the pressure reduction section 30 can immediately remove the non-condensable gas ingressed into the circulation system 20.

[0097]

In the present embodiment, the circulation system 20 includes a forced circulation line 27 and a forced circulation pump 28. The forced circulation line 27 branches from the liquid line 24 and returns the refrigerant R to the cooling section 21. The forced circulation pump 28 is provided in the forced circulation line 27 and can pump the refrigerant R to the cooling section 21. The cooling system 1 further includes a switching mechanism 40. The switching mechanism 40 can switch the flow path of the refrigerant R between a flow path in which the refrigerant R does not pass through the forced circulation line 27 and a flow path in which the refrigerant R passes through the forced circulation line 27.

[0098]

As a result, the cooling system 1 can appropriately select a method of naturally circulating the refrigerant R in the circulation system 20 by only the heat of the heat generating body 3c and a method of forcibly circulating the refrigerant R in the circulation system 20 by the pressure feed force of the forced circulation pump 28.

[0099]

In the present embodiment, the cooling system 1 further includes a heat generation temperature sensor 6 and a forced circulation control section 60. The heat generation temperature sensor 6 measures the temperature of the heat generating body 3c. The forced circulation control section 60 forcibly circulates the refrigerant R in the circulation system 20. The forced circulation control section 60 includes a heat generation temperature acquisition section 61 and a forced circulation operation section 63. The heat generation temperature acquisition section 61 acquires the temperature measured by the heat generation temperature sensor 6. When the temperature measured by the heat generation temperature sensor 6 is higher than a predetermined temperature, the forced circulation operation section 63 causes the switching mechanism 40 to switch the flow path of the refrigerant R to a flow path in which at least a part of the refrigerant R passes through the forced circulation line 27, and operates the forced circulation pump 28.

[0100]

Accordingly, when the heat generating body 3c is at a high temperature, the cooling system 1 can increase the supply amount of the refrigerant R to the cooling section 21 by the forced circulation pump 28.

[0101]

In the present embodiment, the cooling system 1 further includes the power

supply section 10. The power supply section 10 generates power by the temperature difference between the heat generating body 3c and the cooling section 21 to supply power to the forced circulation pump 28.

[0102]

Accordingly, the cooling system 1 can cover a part of the power required for driving the forced circulation pump 28 with the energy obtained from the temperature difference between the heat generating body 3c and the cooling section 21. Therefore, the energy required for the operation of the cooling system 1 can be reduced.

[0103]

In the present embodiment, the heat exchange section 22 takes heat from the refrigerant R by performing heat exchange between the refrigerant R and the air outside the heat exchange section 22. The cooling system 1 further includes the duct 11. The duct 11 has a lower opening 11a that is open downward and an upper opening 11b that is open upward. The heat exchange section 22 is disposed inside the lower opening 11a. The duct 11 discharges the air around the heat exchange section 22 upward.

[0104]

Accordingly, the air around the heat exchange section 22 is heated by the heat exchange section 22. Accordingly, an ascending flow is generated in the duct 11. The ascending flow supplies the air to the heat exchange section 22. Therefore, the heat exchange section 22 can efficiently air-cool the refrigerant R.

[0105]

In the present embodiment, the cooling system 1 includes the second cooling section 26 disposed in the refrigerant tank 25. The second cooling section 26 cools the refrigerant R.

[0106]

Accordingly, for example, when a non-condensable gas has ingressed into the refrigerant R, the non-condensable gas is easily separated from the refrigerant R by cooling the refrigerant R with the second cooling section 26. Therefore, the cooling system 1 can efficiently remove the non-condensable gas from the circulation system 20.

[0107]

In the present embodiment, the forced circulation pump 28 also functions as the drive pump 35 and circulates the drive fluid L in the pressure reduction unit 33.

[0108]

Accordingly, since one pump functions as the forced circulation pump 28 and also functions as the drive pump 35, the installation space of the cooling system 1 can be narrowed.

[0109]

<Second Embodiment>

Hereinafter, a cooling system 201 according to a second embodiment of the present disclosure will be described with reference to FIG. 8. The same configurations as those in the above-described embodiment will be denoted by the same names and the same reference numerals, and the description thereof will be appropriately omitted.

As shown in FIG. 8, the server rack 2 can accommodate a plurality of servers 3 inside. A plurality of servers 3 are accommodated in the server rack 2 in the up-down direction Dv. A plurality of heat generating bodies 3c are provided on the server board 3b to extend in the horizontal direction. In FIG. 8, for the sake of simplification, a case where one heat generating body 3c is installed for each server

board 3b is shown. The number of heat generating bodies 3c installed on one server board 3b can be changed as appropriate.

[0110]

A plurality of cooling sections 21 are provided. The cooling section 21 is attached to each of the plurality of heat generating bodies 3c.

[0111]

In addition, the gas line 23 has one gas main line 23a extending from the heat exchange section 22 and a gas branch line 23b branching from the gas main line 23a. The gas branch lines 23b are provided in the same number as the cooling sections 21. The gas branch line 23b is connected to the corresponding cooling section 21.

[0112]

In addition, the liquid line 24 has one liquid main line 24a extending from the heat exchange section 22 and a liquid branch line 24b branching from the liquid main line 24a. The liquid branch lines 24b are provided in the same number as the cooling sections 21. The liquid branch line 24b is connected to the corresponding cooling section 21. In the present embodiment, the first valve 41 is provided in the liquid main line 24a.

[0113]

In addition, a plurality of power supply sections 10 are provided in the same number as the cooling section 21. The plurality of power supply sections 10 can supply power to the forced circulation pump 28 (drive pump 35).

[0114]

(Operation and Effect)

According to the cooling system 201 of the present embodiment, in addition to the same operations and effects as those of the first embodiment, the following

operations and effects can be exhibited.

[0115]

In the present embodiment, the circulation system 20 includes a plurality of cooling sections 21.

[0116]

As a result, the cooling efficiency of the circulation system 20 can be improved. For example, by attaching one heat generating body 3c to each of the plurality of cooling sections 21, the cooling system 201 can cool the plurality of heat generating bodies 3c with one circulation system 20.

[0117]

<Third Embodiment>

Hereinafter, a cooling system 301 according to a third embodiment of the present disclosure will be described with reference to FIG. 9. The same configurations as those in the above-described embodiment will be denoted by the same names and the same reference numerals, and the description thereof will be appropriately omitted.

As shown in FIG. 9, in the present embodiment, a plurality of circulation systems 20 are provided. Only one pressure reduction section 30 is provided for the plurality of circulation systems 20. The one pressure reduction section 30 reduces the pressure in each of the plurality of circulation systems 20 by removing gas from each of the plurality of circulation systems 20.

[0118]

The gas vent line 31 includes one gas vent main line 31a extending from the pressure reduction unit 33 and a gas vent branch line 31b branching from the gas vent main line 31a. The gas vent branch lines 31b are provided in the same number as the

number of the circulation systems 20. The gas vent branch line 31b is connected to the corresponding circulation system 20.

[0119]

In the present embodiment, the pressure reduction unit 33 is installed outside the server rack 2. In addition, the drive pump 35 of the present embodiment is a pump different from the forced circulation pump 28. The drive fluid supply line 36 and the drive fluid return line 37 are directly connected to the drive pump 35.

[0120]

(Operation and Effect)

According to the cooling system 301 of the present embodiment, in addition to the same operations and effects as those of the first embodiment, the following operations and effects can be obtained.

[0121]

In the present embodiment, a plurality of circulation systems 20 are provided. The pressure reduction section 30 reduces the pressure in each of the plurality of circulation systems 20 by removing gas from each of the plurality of circulation systems 20.

[0122]

Accordingly, the cooling system 301 can reduce the pressure in the plurality of circulation systems 20 with one pressure reduction section 30.

[0123]

<Fourth Embodiment>

Hereinafter, a cooling system 401 according to a fourth embodiment of the present disclosure will be described with reference to FIG. 10. The same configurations as those in the above-described embodiment will be denoted by the

same names and the same reference numerals, and the description thereof will be appropriately omitted.

As shown in FIG. 10, in the present embodiment, as in the third embodiment, the plurality of circulation systems 20 are provided, and only one pressure reduction section 30 is provided for the plurality of circulation systems 20. Further, as in the second embodiment, each circulation system 20 includes a plurality of cooling sections 21. In addition, a plurality of power supply sections 10 are provided in the same number as the cooling section 21.

[0124]

(Operation and Effect)

According to the cooling system 401 of the present embodiment, the same operations and effects as those of the first to third embodiments can be obtained.

[0125]

(Hardware Configuration)

The control device 12 according to the above-described embodiment is mounted in a computer as shown in FIG. 11. FIG. 11 is an example of a schematic block diagram showing a configuration of a computer in which the control device 12 according to each embodiment is mounted. The computer 1100 includes a processor 1110, a main memory 1120, a storage 1130, and an interface 1140.

[0126]

Then, the operations of the respective functional sections of the control device 12 are stored in the storage 1130 in the form of a program. The processor 1110 reads the program from the storage 1130, develops the read program in the main memory 1120, and executes the above-described processing in accordance with the program. In addition, the processor 1110 allocates a storage area in the main memory 1120

according to the program.

[0127]

The program may be intended to realize some of functions fulfilled by the computer 1100. For example, the program may fulfill a function in combination with another program previously stored in the storage 1130, or in combination with another program installed in another device. In addition, the computer 1100 may include a custom large-scale integrated circuit (LSI) such as a programmable logic device (PLD) in addition to or in place of the above configuration. Examples of the PLD include a programmable array logic (PAL), a generic array logic (GAL), a complex programmable logic device (CPLD), and a field programmable gate array (FPGA). In this case, functions that are realized by the processor 1110 may be partially or entirely realized by the integrated circuit.

[0128]

As an example of the storage 1130, a magnetic disk, a magneto-optical disk, or a semiconductor memory can be used. The storage 1130 may be an internal medium directly connected to a bus of the computer 1100, or may be an external medium connected to the computer 1100 via the interface 1140 or a communication line. In addition, when this program is distributed to the computer 1100 via the communication line, the computer 1100 receiving the distributed program may deploy the program in the main memory 1120 to execute the above-described process. The storage 1130 may be a non-transitory tangible storage medium.

[0129]

In addition, the program may be used to partially realize the above-described functions. In addition, the program may be a so-called difference file (difference program) that realizes the above-described functions in combination with another

program previously stored in the storage 1130.

[0130]

(Other Embodiments)

Although the embodiments of the present disclosure have been described in detail with reference to the drawings, the specific configuration is not limited to the embodiments and includes design changes and the like within a scope not departing from the gist of the present disclosure.

In the above-described embodiment, the refrigerant R is water, but the present disclosure is not limited thereto.

[0131]

In addition, in the above-described embodiment, the cooling section 21 is a box-shaped cold plate in which the refrigerant R can circulate, but the present disclosure is not limited thereto. The cooling section 21 may be a container that can be attached to the heat generating body 3c and can boil the refrigerant R by the heat of the heat generating body 3c.

[0132]

In addition, in the above-described embodiment, the case where the pressure reduction section 30 includes the gas vent line 31, the gas vent valve 32, and the pressure reduction unit 33 has been described, but the present disclosure is not limited thereto. The pressure reduction section 30 may be able to remove the gas from the circulation system 20 and reduce the pressure in the circulation system 20. For example, the pressure reduction section 30 may be configured with the gas vent line 31 and a pump that sucks the gas in the circulation system 20 via the gas vent line 31.

[0133]

In addition, in the above-described embodiment, the drive fluid L is the same

water as the refrigerant R, but the present disclosure is not limited thereto. The drive fluid L may be, for example, a fluid other than water, such as air.

[0134]

In addition, in the above-described embodiment, the pressure reduction section 30 is connected to the highest position in the circulation system 20, but the present disclosure is not limited thereto. The pressure reduction section 30 may be connected to the gas line 23 or the liquid line 24 in the circulation system 20.

[0135]

<Supplementary Note>

The cooling systems 1, 201, 301, 401 described in each embodiment are understood as follows, for example.

[0136]

(1) A cooling system 1, 201, 301, 401 according to a first aspect includes a circulation system 20 through which a refrigerant R for cooling a heat generating body 3c circulates, and a pressure reduction section 30 connected to the circulation system 20, in which the circulation system 20 includes a cooling section 21 that is attached to the heat generating body 3c and that boils the refrigerant R to take heat from the heat generating body 3c, a heat exchange section 22 that is provided at a position higher than the cooling section 21 and that condenses the refrigerant R in a gaseous state, a gas line 23 that guides the refrigerant R evaporated in the cooling section 21 to the heat exchange section 22, and a liquid line 24 that guides the refrigerant R condensed in the heat exchange section 22 to the cooling section 21, and the pressure reduction section 30 reduces a pressure in the circulation system 20 by removing gas from the circulation system 20.

Examples of the refrigerant R include a refrigerant that does not correspond to

PFAS, such as water.

[0137]

According to the above configuration, the cooling systems 1, 201, 301, 401 can reduce the pressure in the circulation system 20 and set the inside of the circulation system 20 to a low-pressure state of atmospheric pressure or lower. As a result, the boiling point of the refrigerant R is lowered. Therefore, the cooling system 1 can boil the refrigerant R at a lower temperature than before the pressure reduction in the cooling section 21. Therefore, the cooling system 1 can efficiently cool the heat generating body 3c. In addition, since the inside of the circulation system 20 is under negative pressure, for example, even when the circulation system 20 is damaged, air is sucked into the circulation system 20. The flow of the sucked air suppresses the leakage of the refrigerant R to the outside. In addition, even when a non-condensable gas has ingressed into the circulation system 20, the pressure reduction section 30 can remove the non-condensable gas.

[0138]

(2) The cooling systems 1, 201, 301, 401 according to a second aspect are the cooling systems 1, 201, 301, 401 according to (1), in which the pressure reduction section 30 may be connected to the highest position in the circulation system 20.

[0139]

When a non-condensable gas has ingressed into the circulation system 20, the non-condensable gas is likely to accumulate in the upper portion in the circulation system 20. According to the above configuration, the pressure reduction section 30 can efficiently remove the non-condensable gas accumulated in the upper portion in the circulation system 20.

[0140]

(3) The cooling systems 1, 201, 301, 401 according to a third aspect is the cooling systems 1, 201, 301, 401 according to (1) or (2), in which the pressure reduction section 30 may include a gas vent line 31 that is connected to the circulation system 20 and that removes gas in the circulation system 20, an ejector 34 that is connected to the gas vent line 31 and that sucks the gas in the gas vent line 31 by a flow of a drive fluid L flowing inside the ejector 34, a drive pump 35 that supplies the drive fluid L to the ejector 34, a drive fluid supply line 36 that guides the drive fluid L from the drive pump 35 to the ejector 34, a drive fluid return line 37 that returns the drive fluid L discharged from the ejector 34 to the drive pump 35, and a drive fluid tank 38 that is provided in the drive fluid return line 37 and that is able to store the drive fluid L.

Examples of the drive fluid L include water and air.

[0141]

According to the above configuration, the configuration of the pressure reduction section 30 can be simplified.

[0142]

(4) The cooling system 1, 201, 301, 401 according to a fourth aspect is the cooling system 1, 201, 301, 401 according to any one of (1) to (3), and further includes a circulation system temperature sensor 4 that measures a temperature in the circulation system 20; a circulation system pressure sensor 5 that measures a pressure in the circulation system 20; and a pressure reduction control section 50 that controls the pressure reduction section 30, in which the pressure reduction control section 50 may include a circulation system temperature acquisition section 51 that acquires the temperature measured by the circulation system temperature sensor 4, a circulation system pressure acquisition section 52 that acquires the pressure measured by the

circulation system pressure sensor 5, a saturation pressure calculation section 53 that calculates a saturation pressure in the circulation system 20 from the temperature measured by the circulation system temperature sensor 4, and a pressure reduction operation section 55 that, when the pressure measured by the circulation system pressure sensor 5 is higher than the saturation pressure of the refrigerant R in the circulation system 20 calculated by the saturation pressure calculation section 53, causes the pressure reduction section 30 to reduce the pressure in the circulation system 20.

[0143]

When the pressure in the circulation system 20 is higher than the saturation pressure of the refrigerant R, the non-condensable gas has ingressed into the circulation system 20. According to the above configuration, when the pressure in the circulation system 20 is higher than the saturation pressure of the refrigerant R, the pressure reduction section 30 reduces the pressure in the circulation system 20. Therefore, the pressure reduction section 30 can immediately remove the non-condensable gas ingressed into the circulation system 20.

[0144]

(5) The cooling system 1, 201, 301, 401 of a fifth aspect is the cooling system 1, 201, 301, 401 of any one of (1) to (4), in which the circulation system 20 may include a forced circulation line 27 that branches from the liquid line 24 and that returns the refrigerant R to the cooling section 21, and a forced circulation pump 28 that is provided in the forced circulation line 27 and that is able to pump the refrigerant R to the cooling section 21, and the cooling system 1, 201, 301, 401 may further include a switching mechanism 40 that is able to switch a flow path of the refrigerant R between a flow path in which the refrigerant R does not pass through the forced

circulation line 27 and a flow path in which the refrigerant R passes through the forced circulation line 27.

[0145]

Accordingly, the cooling system 1, 201, 301, 401 can appropriately select a method of naturally circulating the refrigerant R in the circulation system 20 by only the heat of the heat generating body 3c and a method of forcibly circulating the refrigerant R in the circulation system 20 by a pressure feed force of the forced circulation pump 28.

[0146]

(6) The cooling system 1, 201, 301, 401 of the fifth aspect is the cooling system 1, 201, 301, 401 of (5), and further includes a heat generation temperature sensor 6 that measures a temperature of the heat generating body 3c, and a forced circulation control section 60 that forcibly circulates the refrigerant R in the circulation system 20, in which the forced circulation control section 60 may include a heat generation temperature acquisition section 61 that acquires the temperature measured by the heat generation temperature sensor 6, and a forced circulation operation section 63 that, when the temperature measured by the heat generation temperature sensor 6 is higher than a predetermined temperature, causes the switching mechanism 40 to switch the flow path of the refrigerant R to a flow path in which at least a part of the refrigerant R passes through the forced circulation line 27, and operates the forced circulation pump 28.

[0147]

Accordingly, when the heat generating body 3c is at a high temperature, the cooling system 1, 201, 301, 401 can increase the supply amount of the refrigerant R to the cooling section 21 by the forced circulation pump 28.

[0148]

(7) The cooling system 1, 201, 301, 401 of a seventh aspect is the cooling system 1, 201, 301, 401 of (5) or (6), and may further include a power supply section 10 that generates power by a temperature difference between the heat generating body 3c and the cooling section 21 to supply power to the forced circulation pump 28.

[0149]

Accordingly, the cooling system 1, 201, 301, 401 can cover a part of the power required for driving the forced circulation pump 28 with the energy obtained from the temperature difference between the heat generating body 3c and the cooling section 21.

[0150]

(8) The cooling system 1, 201, 301, 401 of an eighth aspect is the cooling system 1, 201, 301, 401 of any one of (1) to (7), in which the heat exchange section 22 may take heat from the refrigerant R by performing heat exchange between the refrigerant R and the air outside the heat exchange section 22, and the cooling system 1, 201, 301, 401 may further include a duct 11 that includes the lower opening 11a including the heat exchange section 22 therein, and being open downward and the upper opening 11b being open upward, and that discharges air around the heat exchange section 22 upward.

[0151]

Accordingly, the air around the heat exchange section 22 is heated by the heat exchange section 22. Accordingly, an ascending flow is generated in the duct 11. Air is supplied to the heat exchange section 22 by the ascending flow. Therefore, the heat exchange section 22 can efficiently air-cool the refrigerant R.

[0152]

(9) The cooling system 201, 401 of a ninth aspect is the cooling system 201,

401 of any one of (1) to (8), in which the circulation system 20 may include a plurality of the cooling sections 21.

[0153]

As a result, the cooling efficiency of the circulation system 20 can be improved. For example, by attaching one heat generating body 3c to each of the plurality of cooling sections 21, the cooling system 201, 401 can cool the plurality of heat generating bodies 3c with one circulation system 20.

[0154]

(10) The cooling system 301, 401 of a tenth aspect is the cooling system 301, 401 of any one of (1) to (9), in which a plurality of the circulation systems 20 may be provided, and the pressure reduction section 30 may reduce a pressure in each of the circulation systems 20 by removing gas from each of the circulation systems 20.

[0155]

As a result, the cooling system 301, 401 can reduce the pressure in the plurality of circulation systems 20 with one pressure reduction section 30.

Industrial Applicability

[0156]

According to the cooling system of the present disclosure, it is possible to improve cooling efficiency.

Reference Signs List

[0157]

1: cooling system

2: server rack

3: server

3a: casing

3b: server board

3c: heat generating body

4: circulation system temperature sensor

5: circulation system pressure sensor

6: heat generation temperature sensor

7: pressure reduction section pressure sensor

8: level sensor

9: refrigerant return line

9a: refrigerant return valve

9b: refrigerant return pump

10: power supply section

11: duct

11a: lower opening

11b: upper opening

11c: cylindrical portion

12: control device

20: circulation system

21: cooling section

22: heat exchange section

23: gas line

23a: gas main line

23b: gas branch line

24: liquid line

24a: liquid main line

24b: liquid branch line

25: refrigerant tank

26: second cooling section

27: forced circulation line

28: forced circulation pump

30: pressure reduction section

31: gas vent line

31a: gas vent main line

31b: gas vent branch line

32: gas vent valve

33: pressure reduction unit

34: ejector

34a: supply part

34b: discharge part

34c: suction part

35: drive pump

36: drive fluid supply line

37: drive fluid return line

38: drive fluid tank

39: atmosphere-release line

39a: atmosphere-release valve

40: switching mechanism

41: first valve

42: second valve

43: third valve

44: fourth valve

45: fifth valve

50: pressure reduction control section

51: circulation system temperature acquisition section

52: circulation system pressure acquisition section

53: saturation pressure calculation section

54: circulation system pressure determination section

55: pressure reduction operation section

60: forced circulation control section

61: heat generation temperature acquisition section

62: heat generation temperature determination section

63: forced circulation operation section

64: flow rate adjustment section

70: atmosphere-release control section

71: pressure-in-pressure-reduction-section acquisition section

72: pressure-in-pressure-reduction-section determination section

73: atmosphere-release operation section

80: refrigerant return control section

81: liquid level detection information acquisition section

82: refrigerant return operation section

Dv: up-down direction

R: refrigerant

L: drive fluid

201: cooling system

301: cooling system

401: cooling system

1100: computer

1110: processor

1120: main memory

1130: storage

1140: interface