

COOLING SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

5 The present invention relates to a cooling system for an electronic device, and particularly to a cooling system for an electronic device which cools heat generated from a plurality of electronic devices such as a computer and a server which are installed in a server room by a cooling apparatus which includes an evaporator and a blower installed between electronic devices.

Description of the Related Art

10 In a server room, a number of electronic devices such as computers and servers are placed in a concentrated state. Electronic devices are generally installed by a rack mount method, that is, a method which stacks electronic devices in layers on racks (casings) according to functional units, and a number of racks are disposed (arranged) in line on the floor of a server room.

15 These electronic devices need a constant temperature environment for normal operation, and if the electronic devices are brought into a high-temperature state, they are likely to cause a trouble such as system stoppage. Therefore, a server room is controlled to be under a constant temperature environment by an air-conditioner.

20 In recent years, however, the heat generation amount from electronic devices has been steadily increasing with abrupt increase in processing speed and processing capacity of the electronic devices, and the running cost of an air conditioner has been sharply increasing.

25 Meanwhile, if the racks with a large heat generation quantity are randomly arranged, heat accumulation by a high-temperature exhaust gas from the racks occurs, and the racks absorb the high-temperature air of the heat accumulation, whereby the electronic devices are likely to be brought into a high-temperature state. For this reason, for the racks in ordinary server rooms, a method is adopted, which arranges air intake surfaces and air exhaust surfaces of a plurality of racks respectively side by side, zones the air in the server room into a hot isle which is at a temperature higher than an ambient

temperature due to high-temperature exhaust air from the racks, and a cold isle which is cooled by an air-conditioner and supplied to the racks and is at a temperature lower than the ambient temperature, and prevents the racks from absorbing a high-temperature air.

Against such a backdrop, various techniques of reducing the running cost for cooling electronic devices have been proposed. For example, the air-conditioning system described in Japanese Patent Application Laid-Open No. 2007-127315 is a refrigerant natural circulation type air-conditioning system which naturally circulates a refrigerant without power, and is configured by connecting an evaporator and a condenser at a place higher than the evaporator with gas piping and liquid piping. The gas of the refrigerant which is vaporized in the evaporator is fed to the condenser through the gas piping, and the gas of the refrigerant which is liquefied in the condenser is fed to the evaporator through liquid piping, whereby the refrigerant is naturally circulated, and the cooling action can be obtained in the evaporator.

By applying such a refrigerant natural circulation type air-conditioning system to local cooling of the electronic devices, the aforementioned running cost is expected to be reduced. For example, the cooling apparatus including an evaporator and a blower is installed between arranged racks, and the racks are cooled semi-locally by refrigerant natural circulation, whereby the blowing power can be reduced, and occurrence of heat accumulation can be inhibited.

Meanwhile, various techniques are proposed concerning reduction in the running cost in the method which installs the cooling apparatus between racks and performs cooling operation semi-locally. For example, the air-conditioning system described in Japanese Patent Application Laid-Open No. 2006-162248 is configured by connecting a cooling apparatus with an evaporator and a blower incorporated between racks arranged in a server room, a condenser which condenses a refrigerant, and a refrigerant pumping device which is installed between the evaporator and the condenser and pumps the refrigerant with refrigerant piping. The refrigerant pressure and the refrigerant temperature of the cooling apparatus are measured, the saturation temperature of the refrigerant is obtained from the pressure measured value, and the output power quantity of the refrigerant pumping device and the air blow quantity of the blower are controlled in accordance with the difference from the temperature measured value, whereby the running cost can be reduced.

However, in the system which has the cooling apparatus installed between the racks and performs semi-local cooling as described above, the air blow quantity by the blower incorporated in the cooling apparatus needs to be larger than the air blow quantity of the racks with respect to the racks within the range assigned to the cooling apparatus, whereas the air blow quantities of the racks individually vary in accordance with the heat generation quantities of the electronic devices mounted in the racks. For example, if the air blow quantity of the rack exceeds the air blow quantity of the cooling apparatus, the high-temperature exhaust air by the rack comes around the front surface of the rack, and is likely to cause a temperature rise of the electronic devices.

Meanwhile, in the capacity control of the refrigerant natural circulation system, the piping pressure loss becomes small at a time of partial load, and therefore, the set value of the condenser refrigerant temperature can be reduced, but a method for controlling the condenser refrigerant temperature to be constant is adopted.

Accordingly, in order to suppress the running cost of the cooling system, it is important to change the set value of the condenser refrigerant temperature as well as to control the air blow quantity of the cooling apparatus in accordance with load while preventing a temperature rise of the electronic devices.

SUMMARY OF THE INVENTION

The present invention is made in view of the above circumstances, and has an object to provide a cooling system with high energy-saving performance, which reduces running cost by controlling an air blow quantity of the cooling apparatus in accordance with load while preventing a temperature rise of electronic devices, in a cooling system including a cooling apparatus which is installed between racks and performs semi-local cooling operation in a refrigerant natural circulation cycle.

In order to attain the above-described object, the present invention provides, in a cooling system comprising a plurality of racks which are loaded with a plurality of electronic devices, have structures capable of passing air in front surfaces and rear surfaces, and are arranged so that respective air intake surfaces are aligned with one another and respective air exhaust surfaces are aligned with one another, an evaporator which is installed between the racks, vaporizes a refrigerant by heat exchange with high-temperature exhaust air from the racks, and cools the high-temperature exhaust air, a

blower which supplies the high-temperature exhaust air from the racks to the evaporator, a cooling apparatus with the evaporator and the blower incorporated therein, a condenser which is installed at a place higher than the evaporator and liquefies the vaporized refrigerant, gas piping which feeds a refrigerant gas vaporized in the evaporator to the condenser, liquid piping which feeds a refrigerant liquid liquefied in the condenser to the evaporator, a cold water pump which supplies cold water to the condenser, cold water piping which connects the condenser and the cold water pump, and a natural circulation mechanism which naturally circulates the refrigerant between the evaporator and the condenser, characterized by comprising: an intake air temperature sensor which measures an intake air temperature to the evaporator by the blower; a return air temperature sensor which measures a return air temperature which is cooled in the evaporator; and a blower frequency switching device which switches a frequency of the blower, wherein the blower frequency switching device controls the frequency of the blower to a frequency of the blower corresponding to a difference between the intake air temperature which is measured by the intake air temperature sensor and the return air temperature which is measured by the return air temperature sensor.

Further according to the present invention, it is preferable that the blower frequency switching device includes a required air blow quantity calculating device which calculates a required air blow quantity of the blower, and the required air blow quantity calculating device calculates thermal load from detected values of the intake air temperature sensor and the return air temperature sensor, and controls the frequency of the blower to a frequency necessary for thermal load processing.

Further, according to the present invention, it is preferable that the cooling system includes a rack intake air temperature sensor which measures a rack intake air temperature within a range assigned to the cooling apparatus, wherein the blower frequency switching device increases the air blow quantity of the blower when the detected value of the rack intake air temperature sensor is a predetermined value or above.

Further, according to the present invention, it is preferable that the cooling system includes a refrigerant temperature sensor which measures a refrigerant temperature at an outlet port of the condenser, and a required refrigerant temperature calculating device which calculates a required condenser refrigerant temperature from

the frequency of the blower and a cooling performance table, wherein the required refrigerant temperature calculating device calculates a required condenser refrigerant temperature from the frequency of the blower and the cooling performance table, and sets a set value of a refrigerant temperature of the condenser at a calculated value.

5 Further, according to the present invention, it is preferable that the cooling system includes a computer room in which the plurality of racks are arranged so that respective air intake surfaces are aligned with one another and respective air exhaust surfaces are aligned with one another and a device which detects an indoor dew point temperature of the computer room, wherein the required refrigerant temperature
10 calculating device calculates a required condenser refrigerant temperature from the frequency of the blower and the cooling performance table, and changes a set value of the condenser refrigerant temperature to a calculated value when the calculated value is the indoor dew point temperature or above, and changes the set value of the condenser refrigerant temperature to the indoor dew point temperature when the calculated value is
15 the indoor dew point temperature or below.

According to the cooling system, in a semi-local cooling system by natural circulation of the refrigerant, at the time of a partial load, the air blow quantity of the cooling apparatus can be controlled while the rack is prevented from absorbing high-temperature air, and the set value of the condenser refrigerant temperature can be
20 changed in accordance with load while occurrence of dew formation is prevented, whereby air-conditioning equipment with high energy conservation can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing a configuration of a cooling system of a first embodiment;

25 Fig. 2 is a block diagram showing a configuration of a cooling system of a second embodiment;

Fig. 3 is a block diagram showing a configuration of a cooling system of a third embodiment;

30 Fig. 4 is a block diagram showing a configuration of a cooling system of a fourth embodiment;

Fig. 5 is a block diagram showing a configuration of a cooling system of a fifth embodiment;

Fig. 6 is a block diagram showing a configuration of a cooling system of a sixth embodiment;

5 Fig. 7 is an explanatory diagram of a blower operation control example of the cooling system shown in Fig. 1;

Fig. 8 is an explanatory diagram of a blower operation control example of the cooling system shown in Fig. 2; and

10 Fig. 9 is an explanatory diagram of a blower operation control example of the cooling system shown in Fig. 4.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, preferred embodiments of a cooling system according to the present invention will be described in accordance with the accompanying drawings.

15 Fig. 1 is a block diagram showing a configuration of a cooling system of a first embodiment.

In Fig. 1, in a server room (computer room) 1, a plurality of racks 10 loaded with respective electronic devices which generate heat are arranged so that air intake surfaces and air exhaust surfaces are respectively aligned, and between the racks, a cooling apparatus 20a with an evaporator 21a and a blower 22a incorporated, and a
20 cooling apparatus 20b with an evaporator 21b and a blower 22b incorporated are installed. A refrigerant liquid is supplied inside the evaporators 21a and 21b, and the refrigerant liquid is evaporated with a high-temperature exhaust air 11 from the rack 10, and thereby, deprives a periphery of heat of vaporization to be gasified. Thereby, the high-temperature exhaust air 11 from the rack 10 is cooled. Reference numerals and
25 characters 23a and 23b designate cooling air exhausted from the cooling apparatuses 20a and 20b.

Meanwhile, a condenser 50 is provided at a position higher than the evaporators 21a and 21b, and between the condenser 50 and the aforementioned respective evaporators 21a and 21b, a refrigerant circulation line in which the refrigerant naturally
30 circulates is provided. The refrigerant circulation line is configured by gas piping 40 and liquid piping 42. In the condenser 50, the refrigerant which is gasified in the

evaporators 21a and 21b exchanges heat with cold water and is liquefied. The liquefied refrigerant flows by gravitational force through the inside of the liquid piping 42 which connects the evaporators 21a and 21b and the condenser 50, and naturally circulates to the evaporators 21a and 21b. Reference numeral 53 designates a low temperature heat source which cools cold water to be supplied to the condenser 50, and the cold water which is cooled by the low temperature heat source 53 is circulated and supplied to the condenser 50 through cold water piping by a cold water pump 52.

In the cooling system, the blowers 22a and 22b in the cooling apparatuses 20a and 20b are operated at a constant air flow rate even when the load of the rack 10 reduces. Thus, an intake air temperature sensors 80 are installed at the air intake surfaces, and return air temperature sensors 82 are installed at the air exhaust surfaces in the cooling apparatuses 20a and 20b, and from the measured values of the intake air temperature sensors 80 and the return air temperature sensors 82, the temperature difference of the intake air temperature and the return air temperature is calculated by a blower frequency switching device 70. The frequencies of the blowers 22a and 22b are controlled to the frequencies corresponding to the temperature difference by the blower frequency switching device 70.

For example, when the aforesaid temperature difference is large with respect to a predetermined reference value, the cooling capacities of the cooling apparatuses 20a and 20b are determined to be excessive, and the frequencies of the blowers 22a and 22b are decreased to decrease the rotational speeds of the blowers 22a and 22b. In contrast with this, when the aforesaid temperature difference is small with respect to the predetermined reference value, the cooling capacities of the cooling apparatuses 20a and 20b are determined to be insufficient, and the frequencies of the blowers 22a and 22b are increased to increase the rotational speeds of the blowers 22a and 22b. Thereby, operation corresponding to the thermal load of the rack 10 is enabled, and energy saving operation control is enabled.

Fig. 2 is a block diagram showing a configuration of a cooling system of a second embodiment, and the same or similar members as those of the cooling system shown in Fig. 1 will be described by being assigned with the same reference numerals and characters.

The cooling system of Fig. 2 is a system which calculates thermal load by a required air blow quantity calculating device 71 of the blower frequency switching device 70 based on the measured values of the intake air temperature sensor 80 and the return air temperature sensor 82, and controls the frequencies of the blowers 22a and 22b to the frequencies required for processing the aforesaid thermal load by the required air blow quantity calculating device 71, in contrast with the cooling system shown in Fig. 1.

Fig. 3 is a block diagram showing a configuration of a cooling system of a third embodiment, and the same or similar members as those of the cooling system shown in Fig. 1 will be described by being assigned with the same reference numerals and characters.

In the cooling system of Fig. 3, a rack intake air temperature sensor 83 which measures an intake air temperature of one or more racks 10 which the cooling apparatuses 20a and 20b are in charge of is installed in the cooling system shown in Fig. 1. When the measured value of the rack intake air temperature sensor 83 is a predetermined value or above, the blower frequency switching device 70 forcefully increases an air blow quantity of the blower 22, and prevents a temperature rise of the electronic devices as a result of the rack 10 absorbing high-temperature air.

Fig. 4 is a block diagram showing a configuration of a cooling system of a fourth embodiment, and the same or similar members as those of the cooling system shown in Fig. 1 will be described by being assigned with the same reference numerals and characters.

The cooling system of Fig. 4 includes a temperature sensor 84 which measures a refrigerant temperature of the condenser 50, and a required refrigerant temperature calculating device 86 which calculates the required refrigerant temperature of the condenser 50 from the frequencies of the blowers 22a and 22b and a cooling performance table in the cooling system shown in Fig. 1, and sets a set value of the refrigerant temperature of the condenser 50 at the calculated value. Thereby, the refrigerant temperature of the condenser 50 can be set to be high at the time of partial load.

Fig. 5 is a block diagram showing a configuration of a cooling system of a fifth embodiment, and the same or similar members as those of the cooling system shown in Fig. 1 will be described by being assigned with the same reference numerals and characters.

In the cooling system of Fig. 5, in the cooling system shown in Fig. 1, an indoor dew point temperature detecting device 85 which detects an indoor dew point temperature is installed in the server room 1. If the calculated value by the required refrigerant temperature calculating device 86 which calculates a necessary condenser refrigerant temperature from the frequency of the blower 22 and the cooling performance table is an indoor dew point temperature or above which is detected by the indoor dew point temperature detecting device 85, the set value of the refrigerant temperature of the condenser 50 is changed to the calculated value, and if the calculated value is the indoor dew point temperature or below, the set value of the refrigerant temperature of the condenser 50 is changed to the dew point temperature. Thereby, occurrence of dew formation can be prevented.

[Modified example]

In each of the cooling systems shown in Figs. 1 to 5, the condenser 50 which performs heat exchange of cold water and the refrigerant is installed, but a refrigerant cooling tower 55 which condenses the refrigerant by using external air cold heat may be provided instead of the condenser 50 as in Fig. 6.

[Air blow operation control example of the cooling system of the first embodiment]

For example, as shown in Fig. 7, a difference ΔT ($\Delta T = T_{in} - T_{out}$) between a measured value T_{in} of the intake air temperature sensor 80 (see Fig. 1) and a measured value T_{out} of the return air temperature sensor 82 is calculated, and when the aforesaid temperature difference ΔT is within a range of $\Delta T_1 \leq \Delta T \leq \Delta T_2$ where a design maximum temperature difference of the cooling apparatus is set as ΔT_1 °C, and a design minimum temperature difference is set as ΔT_2 °C with respect to the value of the temperature difference ΔT , a blower frequency f corresponding to ΔT is set in advance.

Subsequently, at the time of $\Delta T > \Delta T_1$, the blower frequency is changed to a maximum frequency f_{max} . At the time of $\Delta T < \Delta T_2$, the blower frequency is changed to a minimum frequency f_{min} . At the time of $\Delta T_1 \leq \Delta T \leq \Delta T_2$, the blower frequency corresponding to the temperature difference ΔT is changed to the value f which is set in advance. Thereby, when the thermal load of the rack 10 reduces, operation is enabled by reducing the blower frequency, and energy-saving operation is enabled. Further, when the cooling performance is reduced due to abnormality or the like of the cooling

apparatus, the measured value T_{out} of the return air temperature sensor 82 increases and is close to the value of the measured value T_{in} of the intake air temperature sensor 80, and therefore, the temperature difference ΔT becomes small. Thus, the air blow quantity is decreased by decreasing the blower frequency. Therefore, the high-temperature exhaust air from the rack 10 can be prevented from being supplied to the air intake surface of the rack 10 without being cooled.

[Air blow operation control example of the cooling system of the second embodiment]

For example, as shown in Fig. 8, when a design maximum thermal load of the cooling apparatus is set as Q_1 kw, and a design minimum thermal load is set as Q_2 kw, a blower frequency f for ensuring an air blow quantity required for cooling a heat quantity Q is set in advance. An air blow quantity is obtained from a present blower operation frequency, and the heat quantity Q is calculated from the measured values of the intake air temperature sensor 80 (see Fig. 2) and the return air temperature sensor 82 and the blower air blow quantity. At the time of $Q \geq Q_1$, the blower frequency is changed to the maximum frequency f_{max} , and at the time of $Q \leq Q_2$, the blower frequency is changed to the minimum frequency f_{min} . At the time of $Q_1 < Q < Q_2$, the blower frequency is changed to the blower frequency f corresponding to the heat quantity Q which is set in advance. Thereby, when the thermal load of the rack 10 reduces, operation is enabled by reducing the blower frequency, and energy-saving operation is enabled. Further, when the cooling performance reduces due to abnormality or the like of the cooling apparatus, the measured value T_{out} of the return air temperature sensor 82 increases and is close to the value of the measured value T_{in} of the intake air temperature sensor 80, and therefore, the heat quantity Q becomes small. Thus, the air blow quantity is decreased by decreasing the blower frequency, and therefore, the high-temperature exhaust air from the rack 10 can be prevented from being supplied to the air intake surface of the rack 10 without being cooled.

For example, when the value of an air blow quantity Q of the cooling apparatus satisfies $Q < Q_3$ with respect to a high-temperature exhaust air quantity Q_3 of the rack 10, high-temperature exhaust air which is equal to or more than the air blow quantity of the cooling apparatus is supplied, and the high-temperature exhaust air in the quantity exceeding the air blow quantity of the cooling apparatus comes around the air intake

surface of the rack 10. This causes the fear of increasing the intake air temperature of the rack 10 and causing a temperature rise of the electronic devices mounted on the rack 10. Accordingly, when the measured value of the rack intake air temperature sensor 83 which measures the intake air temperature of the rack 10 becomes the design indoor
5 temperature or higher, it is determined that the high-temperature exhaust air of the rack 10 comes around the air intake surface, and the operation frequency of the blower 22 is forcefully increased. Thereby, the high-temperature exhaust air from the rack 10 can be prevented from coming around the air intake surface.

[Blower operation control example of the cooling system of the fourth
10 embodiment]

For example, as shown in Fig. 9, a cooling performance table is created in advance from the relationship of a processing heat quantity of the cooling apparatus and the blower frequency and the condenser refrigerant temperature, the heat quantity Q is calculated from the value of the present blower frequency and the temperature difference
15 between the intake air temperature and the return air temperature of the cooling apparatus, and the condenser refrigerant temperature is changed to a condenser refrigerant temperature T_r corresponding to the heat quantity Q from the aforesaid cooling performance table. Thereby, if the heat quantity Q becomes large, the condenser refrigerant temperature is raised, whereas if the heat quantity Q becomes small, the
20 condenser refrigerant temperature is lowered, and therefore, energy-saving operation at the time of partial load is enabled.

It will be apparent to those skilled in the art that various modifications and variations, such as a cooling system comprising three or more cooling apparatuses, can be made in the present invention without departing from the spirit or scope of the
25 invention. Thus, it is intended that the present invention covers the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

WHAT IS CLAIMED IS:

1. A cooling system comprising a plurality of racks which are loaded with a plurality of electronic devices, have structures capable of passing air in front surfaces and rear surfaces, and are arranged so that respective air intake surfaces are aligned with one another and respective air exhaust surfaces are aligned with one another, an evaporator which is installed between the racks, vaporizes a refrigerant by heat exchange with high-temperature exhaust air from the racks, and cools the high-temperature exhaust air, a blower which supplies the high-temperature exhaust air from the racks to the evaporator, a cooling apparatus with the evaporator and the blower incorporated therein, a condenser which is installed at a place higher than the evaporator and liquefies the vaporized refrigerant, gas piping which feeds a refrigerant gas vaporized in the evaporator to the condenser, liquid piping which feeds a refrigerant liquid liquefied in the condenser to the evaporator, a cold water pump which supplies cold water to the condenser, cold water piping which connects the condenser and the cold water pump, and a natural circulation mechanism which naturally circulates the refrigerant between the evaporator and the condenser, characterized by comprising:
 - an intake air temperature sensor which measures an intake air temperature to the evaporator by the blower;
 - a return air temperature sensor which measures a return air temperature which is cooled in the evaporator; and
 - a blower frequency switching device which switches a frequency of the blower, wherein the blower frequency switching device controls the frequency of the blower to a frequency of the blower corresponding to a difference between the intake air temperature which is measured by the intake air temperature sensor and the return air temperature which is measured by the return air temperature sensor.
2. The cooling system according to claim 1,
 - wherein the blower frequency switching device comprises a required air blow quantity calculating device which calculates a required air blow quantity of the blower, and
 - the required air blow quantity calculating device calculates a thermal load from detected values of the intake air temperature sensor and the return air temperature sensor,

and controls the frequency of the blower to a frequency necessary for thermal load processing.

3. The cooling system according to claim 1 or 2, further comprising:

a rack intake air temperature sensor which measures a rack intake air

5 temperature within a range assigned to the cooling apparatus,

wherein the blower frequency switching device increases the air blow quantity of the blower when the detected value of the rack intake air temperature sensor is a predetermined value or above.

4. The cooling system according to any one of claims 1 to 3, further comprising:

10 a refrigerant temperature sensor which measures a refrigerant temperature at an outlet port of the condenser; and

a required refrigerant temperature calculating device which calculates a required condenser refrigerant temperature from the frequency of the blower and a cooling performance table,

15 wherein the required refrigerant temperature calculating device calculates a required condenser refrigerant temperature from the frequency of the blower and the cooling performance table, and sets a set value of a refrigerant temperature of the condenser at a calculated value.

5. The cooling system according to any one of claims 1 to 4, further comprising:

20 a computer room in which the plurality of racks are arranged so that respective air intake surfaces are aligned with one another and respective air exhaust surfaces are aligned with one another;

a device which detects an indoor dew point temperature of the computer room,

25 wherein the required refrigerant temperature calculating device calculates a required condenser refrigerant temperature from the frequency of the blower and the cooling performance table, and changes a set value of the condenser refrigerant temperature to a calculated value when the calculated value is the indoor dew point temperature or above, and changes the set value of the condenser refrigerant temperature

to the indoor dew point temperature when the calculated value is the indoor dew point temperature or below.