

COOLING SYSTEM AND COOLING METHOD

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a cooling system and a cooling method for cooling indoor air that is the object of air conditioning.

Description of the Related Art

10 Conventionally, there is known a cooling system which is a forced coolant circulation type that performs heat exchange between cold water in the primary cycle and coolant in the secondary cycle and circulates the coolant condensed by the heat exchange by a coolant pump.

In such a cooling system, coolant flowing into the coolant pump is desirably in a liquid state. This is because in case that the coolant flowing into the coolant pump is in a gas state, the coolant pump runs dry and may break down. This is also because in case that the coolant flowing into the coolant pump is in a state of mixed gas and liquid, the coolant pump may break down by cavitation.

20 Incidentally, cavitation is a phenomenon that, adhering to an object, a bubble in liquid divides and surrounding liquid gather toward bubbles, and a strong pressure wave thereby occurs.

Patent 1 (Translation of PCT Application JP-T-2009-512190) discloses a cooling system provided with an evaporating unit (evaporator), a condensing unit (condenser), a main pump (coolant pump), an expansion valve, and includes a line in which coolant flows and a sub-unit for receiving a part of the coolant flowing in the line and cooling the coolant to return the coolant to the line.

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SUMMARY OF THE INVENTION

However, in the technology described in Patent Document 1, it is possible that supply of coolant in a liquid state to a main pump is stopped, for example, when a condensing unit or the like has failed. In this case, as described above, there is a problem that the main pump breaks down by

running dry or cavitation, resulting in a significant drop in the cooling capacity of the entire cooling system.

Particularly, in a data center or the like where plural servers and network devices are arranged, as heat is generated accompanying processes by respective devices, it is required to always maintain the inside of an air conditioning room at a constant temperature. That is, in a data center or the like, it is necessary to surely prevent breakdown of a main pump (coolant pump).

10 In this situation, an object of the present invention is to provide a cooling system and a cooling method that enable preventing breakdown of a coolant pump.

In order to solve an object as described above, according to the present invention, a cooling system includes: a coolant liquid detection unit for individually detecting whether or not a liquid level of coolant liquid stored in a coolant liquid storage section is higher than or equal to respective plural heights including a first height and a second height higher than the first height in the coolant liquid storage section; and a control unit that changes a rotation speed of a motor of a coolant pump, corresponding to a detection result that is input from the coolant liquid detection unit.

20 According to the present invention, it is possible to provide a cooling system and a cooling method that enable preventing breakdown of a coolant pump.

Brief Description of the Drawings

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

FIG. 2 is a flowchart showing a process in controlling drive of a coolant pump, based on signal from liquid level sensors;

30 FIG. 3 is a configuration diagram of a cooling system in a second embodiment according to the present invention;

FIG. 4 is a configuration diagram of a cooling system in a third embodiment according to the present invention;

FIGS. 5A and 5B are illustrations showing other examples of liquid level sensors used in cooling systems according to the invention, wherein

FIG. 5A shows a case of using three liquid level sensors and FIG. 5B shows a case of using an ultrasonic sensor as a liquid level sensor.

Detailed Description of the Preferred Embodiments

Embodiments according to the present invention will be described below in detail with reference to the drawings, as appropriate. The same symbol will be assigned to an element common to respective drawings, and overlapping description will be omitted.

First Embodiment

10 Configuration of Cooling System

FIG. 1 is a configuration diagram of a cooling system in a first embodiment. As shown in FIG. 1, a cooling system 100 includes a primary-side system 100a and a secondary-side system 100b.

The primary-side system 100a includes a heat source device 1, a cold storage tank 2, a cold water pump 3, a three-way valve 4, and the primary-side heat-transfer tube $5h_1$ of a condenser 5. The secondary-side system 100b includes the secondary-side heat-transfer tube $5h_2$ of the condenser 5, a coolant liquid tank 6, a coolant pump 7, and an evaporator 8.

20 Incidentally, the secondary-side system 100b is not provided with a compressor or an expansion valve, and assists a natural circulation cycle by driving the coolant pump 7, wherein, in the natural circulation cycle, coolant evaporated by the evaporator 8 moves up, and coolant condensed by the condenser 5 moves down by gravity.

The heat source device 1 (chiller unit) supplies cold heat to the cold storage tank 2, using for example a heat pump cycle. In case of using a heat pump cycle, the heat source device 1 is provided with a compressor (not shown), a condenser (not shown), an expansion valve (not shown), and an evaporator (not shown).

30 That is, in the heat pump cycle, a high temperature and high pressure coolant discharged from the compressor flows into the condenser and exchanges heat with external atmospheric air. Further, a medium temperature and high temperature coolant flows into the expansion valve from the condenser and is depressurized. Then, a low temperature and low pressure coolant flows through a pipe 1a (see FIG. 1) into a heat transfer tube (not shown) disposed in the cold storage tank 2 and evaporates by

exchanging heat with water. The water is cooled by discharging heat to the coolant in the above-described heat exchange.

Incidentally, the heat source device 1 is not limited to a heat pump cycle of a steam compression system. Otherwise, a heat source device as the heat source device 1, a heat source device which is, for example, an absorption type, an adhesion type, a thermoelectronic type, may be used,

Further, the heat source device 1 is preferably driven, using inexpensive power at night.

A predetermined amount of water is stored in the cold storage tank 2.

10 The above-described heat transfer tube (not shown) is arranged in the cold storage tank 2 continuously from the pipe 1a. Then, the water in the cold storage tank 2 is cooled down to a certain temperature by heat exchange with a low temperature coolant flowing from the heat source device 1 into the above-described heat transfer tube.

The cold water pump 3 includes a motor (not shown) therein and pressure-transmits cold water with a flow rate corresponding to the rotation speed of the motor, from the cold storage tank 2 through a pipe 3a toward the condenser 5. The rotation speed of the motor is controlled by a control device 10.

20 The three-way valve 4 is connected with a pipe 4a and a pipe 4b branched from the pipe 3a. Upon instruction from the control device 10, the three-way valve 4 separates a part from the cold water flowing from the pipe 4a to make the part flow in the pipe 4b in order to adjust the flow rate of cold water flowing through the pipe 3a.

The condenser 5 includes the primary-side heat-transfer tube 5h₁ whose one end communicates with the pipe 3a and whose the other end communicates with the pipe 4a, and the secondary-side heat-transfer tube 5h₂ whose one end communicates with a pipe 8a and whose the other end communicates with a pipe 5a. Herein, in order to increase the efficiency in
30 heat exchange between the cold water flowing through inside the primary-side heat-transfer tube 5h₁ and the coolant flowing through inside the secondary-side heat-transfer tube 5h₂, the primary-side heat-transfer tube 5h₁ and the secondary-side heat-transfer tube 5h₂ are disposed such as to contact each other.

That is, the condenser 5 condenses the medium temperature coolant gas flowing from the evaporator 8 through the pipe 8a into the secondary-side heat-transfer tube 5h₂, by cooling the coolant gas by the cold water flowing from the cold storage tank 2 through the pipe 3a into the primary-side heat-transfer tube 5h₁.

The secondary-side heat-transfer tube 5h₂ of the condenser 5 is connected through the pipe 5a to the top of the coolant liquid tank 6, and communicated with the inner space of the coolant liquid tank 6.

10 The coolant liquid tank 6 stores coolant in a liquid state flowing from the condenser 5 and is disposed lower than the condenser 5. That is, arrangement is made such that the coolant condensed by the condenser 5 (hereinafter, referred to as coolant liquid) moves down inside the pipe 5a by gravity and is stored in the coolant liquid tank 6.

Further, the bottom portion of the coolant liquid tank 6 is connected through a pipe 6a to a suction opening (not shown) of the coolant pump 7. That is, arrangement is made such that, accompanying the drive (suctioning and discharging of coolant liquid) of the coolant pump 7, coolant liquid in the coolant liquid tank 6 flows through inside the pipe 6a and moves toward the suction opening of the coolant pump 7.

20 Further, as shown in FIG. 1, in the coolant liquid tank 6, there are provided liquid level sensors S1, S2, as coolant liquid detection units, for detecting whether or not the liquid level of coolant liquid stored in the coolant liquid tank 6 is higher than or equal to a predetermined height.

The liquid level sensors S1, S2 are liquid level sensors of a float switch type. A liquid level sensor of a float switch type opens and closes a micro switch (not shown) by the gravity and the buoyant force of a float (not shown) that moves up and down corresponding to a change in the liquid level.

30 Incidentally, in the description below, the liquid level of coolant liquid stored in the coolant liquid tank 6 may be described as 'coolant liquid level'.

As described above, in case of using liquid level sensors of a float switch type as the liquid level sensors S1, S2, the liquid level sensor S1 outputs signal ON to the control unit 10 if the coolant liquid level is higher than or equal to a height H1. If a coolant liquid level is lower than the

height H1, the liquid level sensor S1 outputs signal OFF to the control unit 10.

The liquid level sensor S2 is arranged at a position (height H2) higher than the height H1 where the liquid level sensor S1 is disposed. The liquid level sensor S2 outputs signal ON to the control unit 10 if a coolant liquid level is higher than or equal to the height H2. If a coolant liquid level is lower than the height H2, the liquid level sensor S2 outputs signal OFF to the control unit 10.

That is, if the liquid level of coolant liquid stored in the coolant liquid tank 6 is lower than the height H1, the liquid level sensors S1 and S2 respectively output signal OFF to the control unit 10.

Further, if the liquid level of coolant liquid stored in the coolant liquid tank 6 is higher than or equal to the height H1 and lower than the height H2, the liquid level sensor S1 outputs signal ON to the control unit 10, and the liquid level sensor S2 outputs signal OFF to the control unit 10.

Still further, if the liquid level of coolant liquid stored in the coolant liquid tank 6 is higher than or equal to the height H2, the liquid level sensors S1 and S2 respectively output signal ON to the control unit 10.

More details will be described later. In brief, the control unit 10 stops the coolant pump 7 when a signal from the liquid level sensor S1 has turned to OFF, and thereafter resumes driving of the coolant pump 7 when a signal from the liquid level sensor S2 has turned to ON.

The liquid level sensors S1 and S2 (coolant liquid detection units) are arranged, as described above, at different heights H1 and H2 in the coolant liquid tank by the following reason. For example, in case that the liquid level sensor S1 is arranged at the height H1, and the liquid level sensor S2 is not arranged, signals ON/OFF, which are input from the liquid level sensor S1, are frequently switched from each other, accompanying moving up and moving down of liquid level. In this case, corresponding to ON/OFF signals input from the liquid level sensor S1, if driving and stopping of the coolant pump 7 are frequently repeated, wasteful power consumption is caused and the coolant pump 7 may break down. This is the reason for arranging the liquid level S2 at a different height in addition to the liquid level sensor S1.

Setting of the heights H1 and H2 will be described later.

The coolant pump 7 pressure-transmits coolant liquid flowing in from the coolant liquid tank 6 toward the evaporator 8, and is arranged lower than the coolant liquid tank 6. Further, the discharge opening (not shown) of the coolant pump 7 communicates through the pipe 7a with a heat transfer tube 8h of the evaporator 8. That is, accompanying the drive (suction and discharge of coolant liquid) of the coolant pump 7, coolant liquid is pressure-transmitted through the pipe 7a toward the evaporator 8.

10 The evaporator 8 evaporates coolant by heat exchange with indoor air, which is the object of air conditioning, and is arranged higher than the coolant pump 7. The evaporator 8 is provided with a fan 9. The fan 9 rotates, upon an instruction from the control device 10, to take in high temperature air, which is in the room, and blows out the air toward the heat transfer tube 8h. Then, the high temperature air, which has been blown out toward the heat transfer tube 8h, exchanges heat (discharge heat) with low temperature coolant liquid flowing through inside the heat transfer tube 8h, and is blown out in the room as low temperature air.

20 On the other hand, the low temperature coolant liquid flowing through inside the heat transfer tube 8h evaporates by heat exchange with (heat absorption from) the high temperature air and moves through the pipe 8a toward the condenser 5. The pipe 8a communicates with the secondary-side heat-transfer tube 5h₂ of the condenser 5.

The control device 10 is configured with an electronic circuit including a CPU, a RAM, a ROM, and various interfaces, and integrally controls the cooling system 100. Further, the control device 10 controls the cooling system 100 such that air with a certain temperature corresponding to a set temperature is blown out from the evaporator 8.

30 The control device 10 controls the rotation speed of the motor (not shown) incorporated in the cold water pump 3, the opening degree of the three-way valve 4, the rotation speed of the fan 9, and the like so that air with a certain temperature is blown out from the evaporator 8. The control device 10 controls the rotation speed of the motor (not shown) incorporated in the coolant pump 7, corresponding to inputs from the above-described liquid level sensors S1 and S2.

Circulation of Coolant

In the initial state of driving the cooling system 100, coolant liquid is stored at least up to the height H2 in the coolant liquid tank 6, and the inside of the pipe 6a, which communicates with the bottom portion of the coolant liquid tank 6, and the pipe 7a are filled with coolant liquid. Water in the cold storage tank 2 is sufficiently cooled by the heat source device 1.

In operating the cooling system 100, the control device 10 adjusts the opening degree of the three-way valve 4 such that cold water flows with a flow rate corresponding to a set temperature into the primary-side heat-transfer tube 5h₁ of the condenser 5, and drives the cold water pump 3.

10 Further, the control device 10 rotates the motor (not shown) incorporated in the coolant pump 7 at a predetermined rotation speed. In this case, the coolant pump 7 sucks coolant in the pipe 6a with a pressure corresponding to the above-described rotation speed, and pressure-transmits coolant in the pipe 7a toward the evaporator 8.

Still further, the control device 10 rotates the fan 9 at a certain rotation speed.

When the coolant pump 7 is driven, coolant liquid in the pipe 7a is pressure-transmitted toward the heat transfer tube 8h in the evaporator 8. Herein, high temperature air (indoor air) is taken in by the rotation of the
20 fan 9 into the evaporator 8, discharges heat by heat exchange with low temperature coolant flowing through the heat transfer tube 8h, and is blown out in the room to be low temperature air. Thus, indoor air, which is the object of air conditioning, is cooled.

On the other hand, coolant in the heat transfer tube 8h absorbs heat by heat exchange with high temperature air, and evaporates to become medium temperature coolant gas. This coolant gas flows through inside the pipe 8a, flows into the secondary-side heat-transfer tube 5h₂ of the condenser 5, discharges heat by heat exchange with cold water flowing through in the primary-side heat-transfer tube 5h₁, and thereby condenses
30 to become low temperature coolant liquid.

Then, the above-described coolant liquid moves down in the pipe 5a by gravity and is stored in the coolant liquid tank 6. In such a manner, a cycle is obtained wherein coolant evaporated by the evaporator 8 is condensed by the condenser 5, temporarily stored in the coolant liquid tank

6, and further pressure-transmitted by the coolant pump 7 toward the evaporator 8.

Accordingly, as long as the cooling system 100 is free from failure, the coolant liquid level in the coolant liquid tank 6 is maintained substantially at a constant height.

However, when a failure has occurred on the cooling system 100, the coolant liquid level in the coolant liquid tank 6 may drop. As an example of such a failure, there is a case that a crack is generated at a welding portion of a pipe and coolant leaks out, causing the coolant liquid level in the
10 coolant liquid tank 6 to drop.

As another example, there is also a case that, if temperature control by the control device 10 is not appropriate, a part of coolant liquid does not evaporate in the evaporator 8 to remain in a liquid state, and the partial remaining coolant liquid does not return to the coolant liquid tank 6, resulting in a drop in the coolant liquid level in the coolant liquid tank 6.

If the coolant pump 7 continues to drive with the above-described state continued, the coolant pump 7 breaks down by the above-described running dry or cavitation, which causes a drop in the cooling capacity of the cooling system 100.

20 In order to avoid such an event, the cooling system 100 in the present embodiment performs the following process.

Process by Cooling System

FIG. 2 is a flowchart showing a process in controlling drive of a coolant pump, based on signals from liquid level sensors.

In step S101, the control device 10 determines whether or not a signal from the liquid level sensor S1 is OFF. If the signal from the liquid level sensor S1 is OFF (step S101 → Yes), in other words, if the coolant liquid level in the coolant liquid tank 6 is lower than the height H1, the process by the control device 10 proceeds to step S102.

30 If the signal from the liquid level sensor S1 is ON (step S101 → No), in other words, if the coolant liquid level in the coolant liquid tank 6 is higher than or equal to the height H1, the process by the control device 10 proceeds to step S104.

In step S102, the control device 10 stops the coolant pump 7. That is, the control device 10 outputs a signal that makes the rotation speed of the

motor zero to the above-described motor (not shown) incorporated in the coolant pump 7.

Incidentally, a certain time is required from the time when the signal is input to the coolant pump 7 to the time when pressure-transmission of coolant by the coolant pump 7 completely stops. This is because a flow of coolant liquid is generated before and after the coolant pump 7 at the time when the above-described signal is output from the control device 10 and impellers (not shown) incorporated in the coolant pump 7 continue to rotate for a while by inertia.

10 Accordingly, the height H1 shown in FIG. 1 is set to a height that ensures, at the minimum, the amount in which the coolant pump 7 transmits coolant during the time from when the liquid level sensor S1, which is arranged lower, has stopped detection of coolant liquid until pressure-transmission of coolant liquid by the coolant pump 7 completely stops.

Incidentally, the height H1 may be set higher than the above-described height to make a larger allowance.

In step S103, the control device 10 determines whether or not a signal from the liquid level sensor S2 is ON. If the signal from the liquid
20 level sensor S2 is ON (step S103 → Yes), in other words, the coolant liquid level in the coolant liquid tank 6 is higher than or equal to the height H2, the process by the control device 10 proceeds to step S104.

If the signal from the liquid level sensor S2 is OFF (step S103 → No), in other words, the coolant liquid level in the coolant liquid tank 6 is lower than the height H2, the process by the control device 10 returns to step S102.

Herein, the height H2 is set sufficiently higher than the above-described height H1. This is because, if the difference between the height H1 and the height H2 is set small, drive and stop of the coolant pump 7 are frequently repeated, which is not desirable in a point of view of maintenance
30 and power consumption of the coolant pump 7.

In step S104, the control device 10 drives the coolant pump 7. That is, the control device 10 rotates the motor (not shown) incorporated in the coolant pump 7 at a predetermined speed.

Advantage 1

In the cooling system 100 in the present embodiment, the control device 10 stops the coolant pump 7 or resumes driving of the coolant pump 7, based on signals from the liquid level sensors S1 and S2.

That is, when the liquid level of coolant stored in the coolant liquid tank 6 becomes lower than the height H1, signal OFF is output from the liquid level sensor S1, which is arranged lower, to the control device 10, and the control device 10 stops the coolant pump 7.

As described above, the height H1 is set to a height that ensures, at the minimum, the amount in which the coolant pump 7 transmits coolant during the time from when the liquid level sensor S1, which is arranged lower, has stopped detection of coolant liquid until pressure-transmission of coolant liquid by the coolant pump 7 completely stops.

Thus, even when a failure has occurred on the cooling system 100, it is possible to surely supply coolant liquid from the coolant liquid tank 6 toward the coolant pump 7 until pressure-transmission of coolant liquid by the coolant pump 7 stops, regardless of the cause of the failure.

Further, as described above, the height H2 where the liquid level sensor S2 is set sufficiently higher than the height H1 where the lower liquid level sensor S1 is arranged. Accordingly, by avoiding frequent repeat of drive and stop of the coolant pump 7, it is possible to prevent the coolant pump 7 from breaking down and reduce wasteful power consumption by the coolant pump 7.

That is, in resuming drive of the coolant pump 7, as coolant liquid is stored in the coolant liquid tank 6 at least up to the height H2, it is possible to ensure a sufficient time from driving to stopping of the coolant pump 7.

In such a manner, in the cooling system 100 in the present embodiment, it is possible to surely prevent the coolant pump 7 from breaking down due to running dry or cavitation. Thus, for example, in a data center or the like, it is possible to stably operate the cooling system 100, and improve the reliability of equipment.

Second Embodiment

FIG. 3 is a configuration diagram of a cooling system in a second embodiment according to the present invention. In the cooling system 100 in the first embodiment, the evaporator 8 is arranged at a position higher than the coolant pump 7 (see FIG. 1). A cooling system 100A in a second

embodiment is different in that, in the cooling system 100A, an evaporator 8 is arranged lower than a coolant pump 7, and a pipe connecting the coolant pump 7 and the evaporator 8 includes a standing coolant tube 7b.

As the second embodiment is similar to the first embodiment in other points, only differences from the first embodiment will be described, omitting description of overlapping parts.

The coolant pump 7 pressure-transmits coolant liquid toward the evaporator 8, the coolant pump 7 is accordingly, in general, disposed lower than the evaporator 8. However, depending on the conditions of the installation environment, there is a case that the coolant pump 7 is
10 arranged higher than the evaporator 8.

In order to handle such a case, the cooling system 100A in the present embodiment is configured such that the pipe connecting the coolant pump 7 and the evaporator 8 includes a standing coolant tube 7b, wherein the standing coolant tube 7b is extended up to a height higher than or equal to the height H2.

In the cooling system 100A, when coolant circulation is appropriately performed, a pipe 6a, the standing coolant tube 7b, and a pipe 7c are filled with coolant liquid. Coolant having evaporated by heat
20 exchange with high temperature air in the evaporator 8 moves up in a pipe 8a as coolant gas toward a condenser 5.

Herein, if a failure has occurred on the 100A and the coolant liquid level in the coolant liquid tank 6 drops to become lower than the height H1, a control device 10 stops driving of the coolant pump 7 similarly to the case described above (see FIG, 2).

At this moment, as described above, the pipe 6a, the standing coolant tube 7b, and the pipe 7c are filled with coolant liquid.

Thereafter, coolant liquid in the pipe 7c moves down by gravity toward the evaporator 8. On the other hand, the end portion of the coolant liquid column in the standing coolant tube 7b is coolant whose inner liquid
30 changes in phase, depending on the pressure state, and turns into a gas phase due to pressure distribution formed by a disposition structure including the standing coolant tube 7b and the pipe 7c. Accordingly, the end portion of the coolant liquid column gradually moves down from the position A shown in FIG. 3. Consequently, coolant liquid in a certain amount moves

to the coolant liquid tank 6 side such that the pressure applied to the coolant liquid column in the standing coolant tube 7b and the pressure applied to the coolant liquid in the coolant liquid tank 6 balance with each other.

Further, coolant liquid in a secondary-side heat-transfer tube 5h₂ of the condenser 5 flows by gravity through the pipe 5a into the coolant liquid tank 6.

Accordingly, in case of stopping the coolant pump 7, the coolant liquid level in the coolant liquid tank 6 is raised by coolant liquid flowing in from the standing coolant tube 7b and the condenser 5.

In such a manner, the coolant liquid level in the coolant liquid tank 6 gradually rises, and when the coolant liquid level has reached the height H₂, the liquid level sensor S2 outputs signal ON to the control device 10 so that the control device 10 resumes driving of the coolant pump 7 (see FIG. 2).
Advantage 2

In the cooling system 100A in the present embodiment, even in case that the evaporator 8 is arranged lower than the coolant pump 7, it is possible to quickly raise the coolant liquid level in the coolant liquid tank 6 upon stopping the coolant pump 7.

Incidentally, in case that the standing coolant tube 7b were not provided and a pipe 7a (not shown) connecting the coolant pump 7 and the evaporator 8 is arranged such as to be directed downward toward the evaporator 8, the following event occurs. That is, if the operation of the coolant pump 7 is stopped and this state is left as it is, coolant liquid in the coolant liquid tank 6 flows down toward the evaporator 8, which is disposed lower, and a state that coolant liquid is not stored in the coolant liquid tank 6 occurs. In this case, as the coolant pump 7 becomes into a state of running dry at the time of start of the next operation, a failure is thereby caused.

Different from this case, the cooling system 100A in the present embodiment is configured such that the pipe connecting the coolant pump 7 and the evaporator 8 includes the standing coolant tube 7b. Accordingly, even in case that the evaporator 8 is arranged lower than the coolant pump 7, it is possible to avoid an event that the coolant liquid level in the coolant liquid tank 6 drops after pressure-transmission of coolant liquid by the coolant pump 7 is stopped.

Thus, it is possible to prevent the coolant pump 7 from breaking down due to running dry or cavitation. Further, by quickly raising the coolant liquid level in the coolant liquid tank 6 upon stopping the coolant pump 7, it is possible to shorten the time from the stoppage of the coolant pump 7 to a resume of operation, and reduce a drop in the cooling capacity of the cooling system 100A.

Third Embodiment

FIG. 4 is a configuration diagram of a cooling system in a third embodiment according to the present invention. In the cooling system 100 in the first embodiment, driving of the coolant pump 7 is controlled, corresponding to signals from the liquid level sensors S1 and S2 (see FIG. 1). A cooling system 100B in the third embodiment is different in that a control device 10 controls driving of a coolant pump 7, corresponding to signals from a differential pressure sensor 11.

As the third embodiment is similar to the first embodiment in other points, only differences from the first embodiment will be described, omitting description of overlapping parts.

As shown in FIG. 4, a coolant liquid tank 6 is provided with the differential pressure sensor 11. The differential pressure sensor 11 is provided with, for example, piezoelectric elements Q1, Q2 on the both sides of a diaphragm to output a difference (differential pressure) between pressures applied to the respective piezoelectric elements Q1, Q2, as a detection value.

As shown in FIG. 4, in the coolant liquid tank 6, the piezoelectric element Q1 is disposed at a height lower than or equal to a height H1, and the piezoelectric element Q2 is disposed at a height higher than or equal to a height H2. As the heights H1 and H2 are similar to those described in the first embodiment, description will be omitted.

The reason for disposing the piezoelectric elements Q1 and Q2 at positions as above-described is to make it possible to detect a state that the coolant liquid level in the coolant liquid tank 6 is the height H1 and a state that the coolant liquid level is the height H2, distinguishing these states from other states.

Incidentally, if the piezoelectric element Q1 were disposed at a position (referred to as a height H3) higher than the height H1 shown in

FIG. 1, a detection value by the differential pressure sensor 11 detected when the coolant liquid level has become the height H3 and a detection value detected when the coolant liquid level has become height H1 substantially agree with each other. In this case, it is impossible for the control device 10 to distinguish a state that the coolant liquid level has become the height H1 from a state that the coolant liquid level has become the height H2.

10 A process by the cooling system 100B will be described below. When a detection value that is input from the differential pressure sensor 11 has become lower than or equal to a pressure P1 which corresponds to a state that coolant liquid is stored up to the height H1, the control device 10 stops the rotation of a motor (not shown) incorporated in the coolant pump 7.

Thereafter, when a detection value that is input from the differential pressure sensor 11 has become higher than or equal to a pressure P2 which corresponds to a state that coolant liquid is stored up to the height H2, the control device 10 resumes the rotation of the motor.

Incidentally, the above-described pressure P1, P2 are obtained by testing or the like, and are stored in advance in the storage section (not shown) of the control device 10.

20 Although an example using the differential pressure sensor 11 has been described above, arrangement may be made as follows. That is, piezoelectric elements Q1, Q2 are arranged at the respective positions shown in FIG. 4, electric signals are output from the respective piezoelectric elements directly to the control device 10, and the control device 10 computes a differential pressure from these electrical signals.

Advantage 3

By the cooling system 100B in the present embodiment, the control device 10 can control driving of the coolant pump 7, corresponding to a detection value that is input from the differential pressure sensor 11.

30 Further, the piezoelectric elements Q1, Q2 are disposed at positions that make it possible to detect a state that the coolant liquid level in the coolant liquid tank 6 is the height H1 and a state that the coolant liquid level is the height H2, distinguishing these states from other states. Thus, the control device 10 can accurately detect whether or not the coolant liquid level in the coolant liquid tank 6 is lower than or equal to the height H1,

and whether or not the coolant liquid level is higher than or equal to the height H2.

Thus, when the coolant liquid level in the coolant liquid tank 6 has become lower than the height H1, the control device 10 can stop driving of the coolant pump coolant pump 7, and when the coolant liquid level thereafter has become higher than or equal to the height H2, the control device 10 can resume driving of the coolant pump 7.

That is, the cooling system 100B in the present embodiment can surely prevent the coolant pump 7 from breaking down, by making coolant in a liquid state flow from the coolant liquid tank 6 into the coolant pump 7.

Modified Example

Cooling systems according to the present invention have been described above in respective embodiments, embodiments according to the invention are not limited to the above description, and various changes and modification can be made.

For example, in the above-described first embodiment and the second embodiment, two liquid level sensors are arranged in a coolant liquid tank 6, however, without being limited thereto, three or more liquid level sensors may be arranged.

For example, as shown in FIG. 5A, a liquid level sensor S3 may be arranged between the liquid level sensor S1 and the liquid level sensor S2 described in the first embodiment.

In this case, the liquid level sensors S1 to S3 respectively output a detection signal of coolant liquid to the control device 10. In case that the liquid level sensor S1 does not detect coolant liquid and the liquid level sensor S3 does not detect coolant liquid either, the control device 10 determines that the coolant liquid level is lower than the height H1 and stops driving of the coolant pump 7.

In case that the liquid level sensor S2 has detected coolant liquid or the liquid level sensor S3 has detected coolant liquid, the control device 10 determines that the coolant liquid level is higher than or equal to the height H2, and resumes driving of the coolant pump 7.

In such a manner, by arranging the liquid level sensor S3 between the liquid level sensor S1 and the liquid level sensor S2 so that the control device 10 performs control as described above, even in an event that one of

the three liquid level sensors has a failure, the control device 10 can control driving of the coolant pump 7, based on signals from the other two liquid level sensors. Accordingly, the coolant pump 7 can be further surely prevented from breaking down.

Further, although, in the above-described first to third embodiments, driving of the coolant pump 7 is stopped when the coolant liquid level in the coolant liquid tank 6 becomes lower than the height H1, the invention is not limited thereto.

10 For example, in case of using the three liquid level sensors, shown in FIG. 5A, the following control may be performed. That is, when the coolant liquid level has become lower than the height H2 (S2: signal OFF) in the coolant liquid tank 6, the control device 10 drives the motor (not shown) of the coolant pump 7 at a rotation speed v_2 that is lower than a rotation speed v_1 of normal operation.

When, the coolant liquid level in the coolant liquid tank 6 has become lower than the height H3 (S2, S3: signal OFF), the control device 10 rotates the motor at a rotation speed v_3 that is lower than the rotation speed v_2 , and when the coolant liquid level becomes lower than the height H1 (S2, S3, S1: signal OFF) thereafter, the control device 10 stops driving of
20 the coolant pump 7.

In such a manner, the control device 10 decreases the rotation speed of the motor of the coolant pump 7 step by step as the coolant liquid level in the coolant liquid tank 6 drops.

Further, in a state of rotating the motor at the rotation speed V_3 , when a detection signal of coolant liquid is input from the liquid level sensor S3, the control device 10 may control the motor to rotate at the rotation speed v_2 ($v_2 > v_3$).

In such a manner, the control device 10 increases the rotation speed of the motor of the coolant pump 7 step by step as the coolant liquid level in
30 the coolant liquid tank 6 rises.

Still further, arrangement may also be made as follows. That is, the time length from when the control device 10 has stopped driving of the coolant pump 7 until the control device 10 resumes operation of the coolant pump 7, in other words, the time length taken by a rise in the coolant liquid level in the coolant liquid tank 6 from the height H1 to the height H2 is

measured for plural times (for example, three times), then, based on the measured plural time lengths, the average rising speed of the coolant liquid level is obtained, and based on the average rising speed, the coolant pump 7 is continuously driven.

In this case, the control device 10 controls the rotation speed of the motor (not shown) of the coolant pump 7 such that the dropping speed of the coolant liquid level caused by transmission of coolant by the coolant pump 7 becomes lower than the above-described average rising speed.

10 That is, the control device 10 newly sets the rotation speed of the motor so that the amount of coolant per unit time, the coolant being pressure-transmitted by the coolant pump 7, becomes lower than the amount of coolant liquid per unit time, the coolant liquid moving down from the condenser 5 to the coolant liquid tank 6.

Thus, without stopping driving of the coolant pump 7 (except during the stoppage periods of the above described plural times), it is possible to continue to send low temperature air in the room.

Further, although, in the first embodiment and the second embodiment, the liquid level sensors S1 and S2 are arranged on the side surface of the coolant liquid tank 6, the invention is not limited thereto.

20 That is, as shown in FIG. 5B, arrangement may made as follows. That is, an ultrasonic liquid level sensor S4 is arranged on the ceiling surface of the coolant liquid tank 6, a time length from when an ultrasonic wave is discharged from the liquid level sensor S4 until the ultrasonic wave returns back after being reflected by the liquid surface is measured, and the coolant liquid level is detected, based on the time length.

In this case, the control device 10 compares the heights of the coolant liquid surface detected by the S4 and the above-described heights H1, H2 (, and H3), and controls driving of the coolant pump 7, based a result of the comparison.

What is claimed is:

1. A cooling system, comprising:

an evaporator for evaporating a coolant by heat exchange with indoor air that is an object of air conditioning;

a condenser for cooling and thereby condensing the coolant evaporated by the evaporator;

a coolant liquid storage section that communicates with the condenser and stores the coolant liquid flowing in from the condenser;

10 a coolant pump that communicates with the coolant liquid storage section and pressure-transmits the coolant liquid toward the evaporator, the coolant liquid flowing in from the coolant liquid storage section;

a coolant liquid detection unit for individually detecting whether or not a liquid level of the coolant liquid stored in the coolant liquid storage section is higher than or equal to respective plural heights including a first height and a second height higher than the first height in the coolant liquid storage section; and

a control unit that changes a rotation speed of a motor of the coolant pump, corresponding to a detection result that is input from the coolant liquid detection unit.

20

2. The cooling system according to claim 1,

wherein the coolant liquid detection unit comprises plural liquid level sensors including a first liquid level sensor that detects whether or not coolant liquid with a liquid level higher than or equal to the first height is stored in the coolant liquid storage section and a second liquid level sensor that detects whether or not coolant liquid with a liquid level higher than or equal to the second height is stored in the coolant liquid storage section,

and wherein the control unit:

30 stops rotation of the motor when coolant liquid is not detected by the first liquid level sensor; and

resumes rotation of the motor when coolant liquid is detected by the second liquid level sensor.

3. The cooling system according to claim 1,

wherein the coolant liquid detection unit comprises a pressure difference sensor arranged at the coolant liquid storage section,
and wherein the control unit:

stops rotation of the motor when a detection value by the pressure difference sensor has become lower than or equal to a first pressure that is a pressure at a time when coolant liquid is stored up to the first height; and

thereafter resumes rotation of the motor when a detection value by the pressure difference sensor has become higher than or equal to a second pressure that is a pressure at a time when coolant liquid is stored up to the
10 second height.

4. The cooling system of any one of claims 1 to 3,
wherein a pipe connecting the coolant pump and the evaporator includes a standing tube that is standing up to a height higher than or equal to the second height.

5. A cooling method for a cooling system,
wherein the cooling system includes:
an evaporator for evaporating a coolant by heat exchange with

20 indoor air that is an object of air conditioning;

a condenser for cooling and thereby condensing the coolant evaporated by the evaporator;

a coolant liquid storage section that communicates with the condenser and stores the liquid flowing in from the condenser;

a coolant pump that communicates with the coolant liquid storage section and pressure-transmits the coolant liquid toward the evaporator, the coolant liquid flowing in from the coolant liquid storage section;

a coolant liquid detection unit for detecting whether or not a liquid level of the coolant liquid stored in the coolant liquid storage section is

30 higher than or equal to a predetermined height; and

a control unit,

the cooling method comprising the steps of:

individually detecting whether or not the liquid level of the coolant liquid stored in the coolant liquid storage section is higher than or equal to

respective plural heights including a first height and a second height higher than the first height in the coolant liquid storage section; and

changing, by the control unit, a rotation speed of a motor of the coolant pump, corresponding to a detection result that is input from the coolant liquid detection unit.