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(54) **COOLANT TEMPERATURE CONTROL APPARATUS FOR INTERNAL COMBUSTION ENGINE**

(57) The present invention is intended to provide a technique which makes effective use of a phase transition temperature zone of cooling water by controlling a control valve for changing the temperature of the cooling water in an appropriate manner. The present invention resides in a cooling water temperature control apparatus for an internal combustion engine in which cooling water is caused to circulate, said cooling water having variable specific heat, said apparatus comprising: a received heat

amount calculation unit configured to calculate an amount of received heat which is received by said cooling water, a control valve that is controlled to open and close according to a command so as to change a circulation route or an amount of circulation of said cooling water and to change the temperature of said cooling water, and a control unit configured to control said control valve based on the amount of received heat which is calculated by said received heat amount calculation unit.

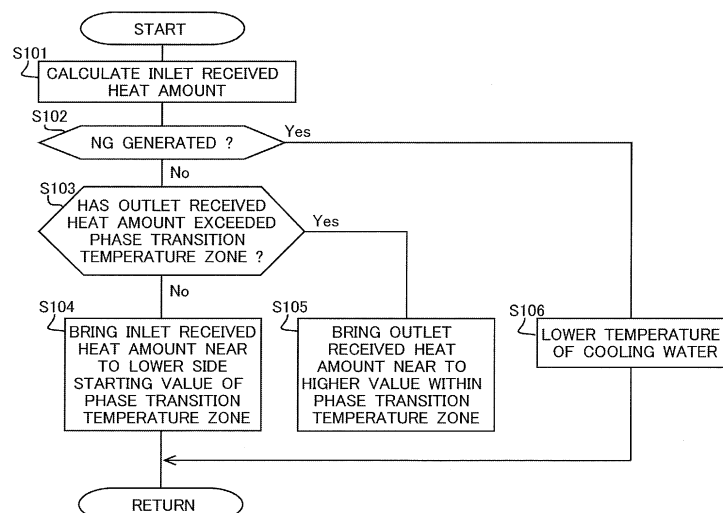


Fig.15

Description

Technical Field

[0001] The present invention relates to a cooling water temperature control apparatus for an internal combustion engine.

Background Art

[0002] There has been known a technique which controls the temperature of cooling water in an internal combustion engine by using a valve opening adjustment unit which is able to adjust electronically the degree of opening of a valve in an electronic manner, wherein an optimum value of the temperature of the cooling water is estimated based on an operating condition up to the present of the internal combustion engine, so that the degree of valve opening of the valve opening adjustment unit is adjusted based on an estimated value of a future temperature of the cooling water at an inlet port of the internal combustion engine, and said estimated optimum value (for example, refer to a first patent document). According to the technique of this first patent document, the temperature of the cooling water in the internal combustion engine can be controlled to a more suitable temperature.

[0003] On the other hand, there has been disclosed a technique which uses, as cooling water for cooling an internal combustion engine, a kind of cooling water of which the specific heat is variable due to inclusion of particles therein which change in phase from one of a solid phase state and a liquid phase state to the other thereby to change a specific heat of a medium (for example, refer to a second patent document).

Citation List

Patent Literature

[0004]

- PTL 1: Japanese patent application laid-open No. 2007-100638
- PTL 2: Japanese patent application laid-open No. 2009-044896
- PTL 3: Japanese patent application laid-open No. 2005-325790

Summary of Invention

Technical Problem

[0005] In cases where the cooling water with a variable specific heat disclosed in the second patent document is used, when control is intended to be carried out on the basis of the temperature of the cooling water using the technique disclosed in the first patent document, the con-

trol can not be performed adequately because a temperature range of the cooling water, which corresponds to a state of the cooling water in which the specific heat of the cooling water is variable (phase transition temperature zone), is narrow. Specifically, even if the temperature of the cooling water exists in the phase transition temperature zone by setting a target temperature of the cooling water to be in the phase transition temperature zone, there will be a possibility that if an amount of received heat is high or large though it is within an allowable range of the transition temperature zone, the specific heat of the cooling water may immediately become low upon receiving a further amount of heat, so that the temperature of the cooling water may rapidly go up, thus resulting in an overheat. On the other hand, if the target temperature of the cooling water is set, in order to avoid this situation, to be lower than the phase transition temperature zone, there will be a possibility that the oil in the internal combustion engine may get cold and the friction of the internal combustion engine may increase.

[0006] The present invention has been made in view of the above-mentioned circumstances, and has for its object to provide a technique in which in cases where cooling water with a variable specific heat is used, a control valve for changing the temperature of the cooling water is controlled adequately, so that effective use of a phase transition temperature zone of the cooling water can be made.

Solutions to Problem

[0007] In the present invention, the following construction is adopted. That is, the present invention resides in a cooling water temperature control apparatus for an internal combustion engine in which cooling water is caused to circulate, said cooling water having variable specific heat, said apparatus comprising:

- a received heat amount calculation unit configured to calculate an amount of received heat which is received by said cooling water;
- a control valve that is controlled to open and close according to a command so as to change a circulation route or an amount of circulation of said cooling water and to change the temperature of said cooling water; and
- a control unit configured to control said control valve based on the amount of received heat which is calculated by said received heat amount calculation unit.

[0008] In the case of the cooling water with a variable specific heat, the temperature of the cooling water does not change in a phase transition temperature zone of the cooling water even if the amount of heat received by the cooling water changes to some extent. The phase transition temperature zone of the cooling water is a temperature zone corresponding to a state of the cooling water

in which the specific heat of the cooling water changes due to a phase transition of particles in the cooling water, or the like. In this phase transition temperature zone, even if a change occurs in the amount of heat given to the cooling water (i.e., the amount of received heat), a phase transition of the particles will occur, so that the specific heat thereof will change, thus changing of the temperature of the cooling water is suppressed. In other words, in the phase transition temperature zone, an allowable range of the amount of received heat is wide in which the cooling water remains unchanged in its temperature. For this reason, when it is intended to control the control valve on the basis of the temperature of the cooling water, the control of the control valve may sometimes become excessive and can not be carried out adequately because the temperature range of the phase transition temperature zone is narrow. This is because the amount of heat received by the cooling water can not be determined on the basis of the target temperature within the phase transition temperature zone. Even if the cooling water is of the target temperature, there will be a case where the amount of received heat thereof within the phase transition temperature zone may be high or low. Accordingly, even if the cooling water is of the target temperature, there will be a possibility that the state of the cooling water may immediately become out of the phase transition temperature zone when the amount of received heat thereof changes. However, if the control valve is controlled on the basis of the amount of received heat of the cooling water, the range of the amount of received heat corresponding to the phase transition temperature zone of the cooling water is wide, and hence, by setting a target amount of received heat, the control of the control valve can be finely carried out in an appropriate manner within the phase transition temperature zone.

[0009] According to this, for example, when the target amount of received heat of the cooling water is set to be a value of the receiving heat amount on a lower side of the phase transition temperature zone, even if a further amount of heat is received, the temperature of the cooling water will be maintained within the phase transition temperature zone, and hence, it is possible to avoid such a situation that the specific heat of the cooling water may immediately become low thereby to cause the temperature of the cooling water to go up rapidly, thus resulting in an overheat. In addition, it is not necessary to set the target amount of received heat of the cooling water to be an excessively low value, so it is possible to avoid such a situation that the temperature of the cooling water becomes too low, then the oil in the internal combustion engine gets cold, resulting in increasing the friction of the internal combustion engine.

[0010] According to the present invention, in cases where the cooling water with its specific heat being variable is used, it is possible to make effective use of the phase transition temperature zone of the cooling water by controlling the control valve for changing the temper-

ature of the cooling water adequately.

[0011] Said received heat amount calculation unit preferably calculates an inlet received heat amount which is received by said cooling water at an inlet port from which said cooling water flows into the internal combustion engine, and

said control unit preferably controls said control valve in such a manner that said inlet received heat amount calculated by said received heat amount calculation unit comes near to a lower side starting value of received heat amount of the phase transition temperature zone in which said cooling water is in a state in which the specific heat thereof changes due to a phase transition of particles.

[0012] According to this, it is possible to set a target inlet received heat amount of the cooling water as a value of the receiving heat amount near to the lower side starting value of the phase transition temperature zone, and hence, even if an additional amount of heat is further received by the cooling water in the internal combustion engine, the temperature of the cooling water is maintained within the phase transition temperature zone, thus making it possible to avoid such a situation that the specific heat of the cooling water may immediately become low thereby to cause the temperature of the cooling water to go up rapidly, resulting in an overheat.

[0013] Said received heat amount calculation unit preferably calculates an outlet received heat amount which is received by said cooling water at an outlet port from which said cooling water flows out of the internal combustion engine, and

in cases where said outlet received heat amount calculated by said received heat amount calculation unit becomes a high amount of received heat in excess of an amount of received heat of said phase transition temperature zone, said control unit preferably controls said control valve so that said outlet received heat amount is included in the range of the amount of received heat of said phase transition temperature zone.

[0014] According to this, it is possible to set a target outlet received heat amount of the cooling water as a value included in the range of the amount of received heat of the phase transition temperature zone, as a result the temperature of the cooling water flowing out of the internal combustion engine is maintained within the range of the temperature of the phase transition temperature zone, thus making it possible to avoid such a situation that the specific heat of the cooling water may immediately become low thereby to cause the temperature of the cooling water to go up rapidly, resulting in an overheat.

[0015] In cases where said received heat amount calculation unit can not calculate the amount of received heat, it is preferable to control said control valve in such a manner as to lower the temperature of said cooling water.

[0016] According to this, in cases where the amount of received heat can not be calculated, it is possible to

lower the temperature of the cooling water, thus making it possible to avoid the temperature of the cooling water from going up to cause an overheat.

Advantageous Effects of Invention

[0017] According to the present invention, in cases where cooling water with its specific heat being variable is used, by controlling the control valve for changing the temperature of the cooling water adequately, it is possible to make effective use of the phase transition temperature zone of the cooling water.

Brief Description of Drawings

[0018]

Fig. 1 is a view showing the schematic configuration of an internal combustion engine in a first embodiment of the present invention.

Fig. 2 is a view showing a model of cooling water in the first embodiment.

Fig. 3 is a view showing the relation between a temperature and a specific heat of the cooling water in the first embodiment.

Fig. 4 is a view showing a characteristic curve of the relation between an amount of received heat per unit amount of cooling water at a reference temperature of 25 degrees C, and a temperature of the cooling water in which a specific heat thereof changes, in the first embodiment.

Fig. 5 is a view showing a model for amounts of received heat in the internal combustion engine and various kinds of equipment in the first embodiment.

Fig. 6 is a view showing a map for calculating a flow rate of cooling water flowing through a radiator or a flow rate of cooling water flowing through a bypass passage, in the first embodiment.

Fig. 7 is a view showing a map for calculating a flow rate of cooling water flowing through a heater core, a flow rate of cooling water flowing through a reservoir tank, a flow rate of cooling water flowing through an oil cooler, a flow rate of cooling water flowing through a throttle valve and an EGR valve, or a flow rate of cooling water flowing through an EGR cooler, in the first embodiment.

Fig. 8 is a view showing a map for calculating an amount of heat dissipation in the radiator or an amount of heat dissipation in the reservoir tank, in the first embodiment.

Fig. 9 is a view showing a map for calculating an amount of heat dissipation in the heater core in the first embodiment.

Fig. 10 is a view showing a map for calculating an amount of heat dissipation in the oil cooler, an amount of heat dissipation in the throttle valve and the EGR valve, or an amount of heat dissipation in the EGR cooler, in the first embodiment.

Fig. 11 is a view showing the control of an electronic thermostat based on an inlet received heat amount in the first embodiment.

Fig. 12 is a view showing a problem in the control of the electronic thermostat based on the inlet received heat amount in the first embodiment.

Fig. 13 is a view showing the control of the electronic thermostat based on an outlet received heat amount in the first embodiment.

Fig. 14 is a view showing the control of the electronic thermostat in cases where the inlet received heat amount or the outlet received heat amount can not be calculated, in the first embodiment.

Fig. 15 is a flow chart showing a cooling water temperature control routine in the first embodiment.

Description of Embodiments

[0019] In the following, a specific embodiment of the present invention will be described.

<First Embodiment>

[0020] Fig. 1 is a view showing the schematic configuration of an internal combustion engine to which a cooling water temperature control apparatus for an internal combustion engine in a first embodiment of the present invention is applied. In the internal combustion engine 1 shown in Fig. 1, cooling water is caused to circulate through a cooling water passage 2 so as to cool a cylinder block and a cylinder head. As the cooling water passage 2, there are provided a passage 2a by way of which the cooling water flows through the radiator 3, a passage 2b by way of which the cooling water flows through an oil cooler 4, a passage 2c by way of which the cooling water flows through a throttle valve 5a and an EGR valve 5b, a passage 2d by way of which the cooling water flows through a reservoir tank 6, a passage 2e by way of which the cooling water flows through a heater core 7, a passage 2f by way of which the cooling water flows through an EGR cooler 8, and a bypass passage 2g through which the cooling water flows as it is.

[0021] The radiator 3 serves to cool the cooling water by carrying out heat exchange between the cooling water and outside air. The oil cooler 4 is a water cooled oil cooler, and carries out heat exchange between oil supplied to the internal combustion engine 1 and the cooling water thereby to cool the oil. The throttle valve 5a is a valve which serves to control an amount of intake air of the internal combustion engine 1, and it is cooled by the cooling water. The EGR valve 5b is a valve which serves to control an amount of EGR gas which is a part of an exhaust gas which is caused to flow back or return to the internal combustion engine 1, and it is cooled by the cooling water. The reservoir tank 6 temporarily stores the cooling water. The heater core 7 serves to warm the cooling water. The EGR cooler 8 is a water cooling type EGR cooler, and carries out heat exchange between the EGR

gas returned to the internal combustion engine 1 and the cooling water thereby to cool the EGR gas.

[0022] The passage 2b, through which the cooling water coming from a cylinder block flows through the oil cooler 4, is connected to the passage 2a, through which the cooling water flows through the radiator 3. In addition, the passage 2a, through which the cooling water flows through the radiator 3, branches into the passage 2c, through which the cooling water flows through the throttle valve 5a and the EGR valve 5b, and the passage 2d, through which the cooling water flows through the reservoir tank 6. The passage 2f, through which the cooling water coming from the cylinder block flows through the EGR cooler 8, is connected to the passage 2e, through which the cooling water flows through the heater core 7.

[0023] An electronic thermostat 9 is arranged at a location at which the passage 2a, through which the cooling water flows through the radiator 3, and the bypass passage 2g are connected to each other. The electronic thermostat 9 is a control valve which is controlled to open and close in accordance with a command, and when opened, it can change the flow path and the flow amount of the cooling water so that the cooling water flows through the radiator 3, thereby making it possible to lower the temperature of the cooling water. At this time, the amount of flow of the cooling water in the bypass passage 2g is throttled or reduced. On the contrary, by closing the electronic thermostat 9, the circulation route (flow path) and the flow amount of the cooling water can be changed, so that it becomes difficult for the cooling water to flow through the radiator 3, thereby making it difficult for the temperature of the cooling water to fall. At this time, the amount of flow of the cooling water in the bypass passage 2g is increased. The cooling water is sent into a water pump 10 at the downstream side of the electronic thermostat 9. The water pump 10 pumps up the cooling water, and supplies it into the cylinder block of the internal combustion engine 1. In addition, a water temperature sensor 11 is arranged at a location at which the cooling water passage 2 is connected to an outlet port of the internal combustion engine 1, so that the temperature of the cooling water flowing out of the internal combustion engine 1 is detected by means of the water temperature sensor 11.

[0024] Here, the cooling water flowing through the cooling water passage 2 is cooling water of which the specific heat is variable. That is, the cooling water is kind of cooling water of which the specific heat is variable due to containing particles that make a phase transition from one of a solid phase state and a liquid phase state to the other thereby change the specific heat of a medium. Here, note that as such particles, there can also be used those which make a phase transition from one of a liquid phase state and a gas phase state to the other, in addition to the particles which make a phase transition from one of the solid phase state and the liquid phase state to the other. The cooling water is one in which particles formed by wrapping some substances in capsules are mixed into

a solvent of the cooling water, so that the internal substances of the particles make a phase transition from a solid state to a liquid state when the temperature thereof becomes equal to or higher than a fixed level, as shown in Fig. 2. Fig. 2 is a view showing a model of the cooling water in this embodiment. Fig. 3 is a view showing the relation between the temperature and the specific heat of the cooling water in this embodiment. As shown in Fig. 2, a plurality of particles in the cooling water make a phase transition from one of a solid phase state and a liquid phase state to the other, resulting in a variable specific heat region in which the specific heat of the cooling water is changed due to the phase transition of the plurality of particles, as shown in Fig. 3. This variable specific heat region corresponds to a state of a phase transition temperature zone in which even if an amount of heat is applied to the cooling water, particles make a phase transition thereby to change the specific heat of the cooling water (refer to Fig. 4). Fig. 4 is a view showing a characteristic curve of the relation between an amount of received heat per unit amount of cooling water at a reference temperature of 25 degrees C, and the temperature of the cooling water in which the specific heat thereof changes, according to this embodiment. The phase transition temperature zone shown in Fig. 4 is a temperature zone corresponding to a state of the cooling water in which the specific heat of the cooling water changes due to a phase transition of particles in the cooling water from one of the solid phase state and the liquid phase state to the other, and in this phase transition temperature zone, even if a change occurs in the amount of received heat applied to the cooling water, a phase transition of particles will occur, so that the specific heat of the cooling water will change, thus making it difficult for the temperature of the cooling water to change. With the use of such cooling water, in the warming up process of the internal combustion engine 1, by making the specific heat of the cooling water lower than that in the conventional art, the warming up characteristics of the internal combustion engine 1 can be enhanced thereby to improve fuel consumption or mileage, whereas after the warming up of the engine, the specific heat of the cooling water becomes high in a certain specific temperature range (i.e., the phase transition temperature zone), so an allowable range of the amount of received heat becomes larger, thus making it possible to avoid an overheat, etc.

[0025] An ECU (electronic control unit) 12 is provided in combination with this internal combustion engine 1. A variety of kinds of sensors such as the water temperature sensor 11 and so on are connected to the ECU 12 through electrical wiring, so that output signals of these various sensors are inputted to the ECU 12. On the other hand, the throttle valve 5a, the EGR valve 5b, the heater core 7, the electronic thermostat 9, the water pump 10, and so on are connected to the ECU 12 through electrical wiring, so that these component parts are controlled by means of the ECU 12.

(Cooling Water Temperature Control)

[0026] In the past, an electronic thermostat has been controlled on the basis of the temperature of cooling water has been carried out. For example, a future optimal temperature of the cooling water is estimated, and the electronic thermostat is controlled in such a manner that the temperature of the cooling water is adjusted to become the optimal temperature thus estimated. However, in cases where a cooling water with its specific heat being variable as in this embodiment is used as cooling water, there has been a problem that the advantage of such a cooling water could not be exploited effectively.

[0027] That is, in the case of the cooling water with a variable specific heat, the temperature of the cooling water does not change in the phase transition temperature zone of the cooling water even if the amount of heat received by the cooling water changes to some extent. In other words, in the phase transition temperature zone of the cooling water, the allowable range of the amount of received heat is wide in which the cooling water remains unchanged in its temperature. For this reason, when it is intended to control the electronic thermostat on the basis of the temperature of the cooling water as in the past, the control of the electronic thermostat may sometimes become excessive and can not be carried out in an appropriate manner because the temperature range of the phase transition temperature zone of the cooling water is narrow. This is because with a target temperature in the phase transition temperature zone of the cooling water, the amount of heat received by the cooling water can not be determined, so there will be a case where even if the cooling water is at the target temperature, the amount of received heat thereof lying within the phase transition temperature zone may be high (at point A in Fig. 4) or low. The point A shown in Fig. 4 corresponds to a state of the cooling water in which the cooling water at the outlet port of the internal combustion engine is of a target temperature within the phase transition temperature zone, and the amount of received heat of the cooling water is high within the phase transition temperature zone. Accordingly, there will be a possibility that even if the cooling water is of the target temperature within the phase transition temperature zone, when the amount of received heat thereof changes, the state of the cooling water may immediately become out of the phase transition temperature zone. For example, in the case of the point A in Fig. 4, when the amount of received heat increases, such as when a high load is rapidly applied, the temperature of the cooling water will exceed the phase transition temperature zone, and the specific heat of the cooling water will immediately become low, so that the temperature of the cooling water will go up rapidly, thus resulting in an overheat.

[0028] In order to avoid such an overheat, it is considered that the target temperature of the cooling water may be set lower than the phase transition temperature zone. A point B shown in Fig. 4 represents a state of the cooling

water in the case where the cooling water at the outlet port of the internal combustion engine is of a target temperature lower than the phase transition temperature zone. However, in the case of the point B in Fig. 4, the temperature of the cooling water at the inlet port of the internal combustion engine, which has become low after having circulated through the cooling water passage, becomes excessively lower than the phase transition temperature zone, so that the oil in the internal combustion engine gets cold, thereby increasing the friction of the internal combustion engine.

[0029] As described above, in the case of using the cooling water of which the specific heat is variable, when the electronic thermostat was controlled based on the temperature of the cooling water, the advantage of the cooling water of which the specific heat is variable could not be utilized efficiently, so that the electronic thermostat was not able to be controlled in an appropriate manner. For this reason, it is possible to make effective use of the phase transition temperature zone of the cooling water.

[0030] Accordingly in this embodiment, the amount of heat received by the cooling water is calculated, and the electronic thermostat 9 is controlled based on the amount of received heat thus calculated. In this case, the range of the amount of received heat of the phase transition temperature zone of the cooling water is wide, and hence, by setting a target amount of received heat, the control of the control valve can be finely carried out in an appropriate manner in a range including the phase transition temperature zone.

[0031] As specific control in this embodiment, an inlet received heat amount, which is received by the cooling water at the inlet port from which said cooling water flows into the internal combustion engine, is calculated. Then, the electronic thermostat 9 is controlled in such a manner that the inlet received heat amount thus calculated comes near to a lower side starting value of the received heat amount of the phase transition temperature zone in which the cooling water is in a state in which the particles make a phase transition thereby the specific heat of the cooling water changes.

[0032] Fig. 5 is a view showing a model for amounts of received heat in the internal combustion engine and various kinds of equipment according to this embodiment. As shown in Fig. 5, the inlet received heat amount of the internal combustion engine 1 is calculated from an outlet received heat amount which is received at an output port from which the cooling water flows out of the internal combustion engine, amounts of transfer heat of various kinds of equipment, and flow rates of the cooling water in the various kinds of equipment. The ECU 12, which calculates the inlet received heat amount, corresponds to a received heat amount calculation unit in the present invention. The amounts of transfer heat of the various kinds of equipment are transfer amounts of heat of the cooling water flowing through the radiator 3, the bypass passage 2g, the heater core 7, the reservoir tank 6, the oil cooler 4, the throttle valve 5a, the EGR valve

5b, and the EGR cooler 8, respectively. The flow rates in the various kinds of equipment are flow rates of the cooling water flowing through the radiator 3, the bypass passage 2g, the heater core 7, the reservoir tank 6, the oil cooler 4, the throttle valve 5a, the EGR valve 5b, and the EGR cooler 8, respectively.

[0033] The calculation method of the inlet received heat amount of the internal combustion engine 1 is explained hereinafter. First, an outlet received heat amount is calculated which is received by the cooling water at the outlet port from which the cooling water flows out of the internal combustion engine 1. As shown in Fig. 4, an outlet received heat amount Q_{engout} can be derived by looking up in the characteristic curve of the cooling water a temperature T_{engout} of the cooling water detected by the water temperature sensor 11 at the outlet port of the internal combustion engine 1. The ECU 12, which calculates the outlet received heat amount, corresponds to a received heat amount calculation unit in the present invention.

[0034] Next, the flow rates in the various kinds of equipment will be calculated. Fig. 6 is a view showing a map for calculating a flow rate $Grad$ of cooling water flowing through the radiator 3 or a flow rate G_{by} of cooling water flowing through the bypass passage 2g according to this embodiment. $Grad$ or G_{by} depends on the degree of valve opening of the electronic thermostat 9 and the number of revolutions per unit time of the water pump 10, and hence, can be calculated by looking up these values in the map shown in Fig. 6. Here, as the degree of valve opening of the electronic thermostat 9, there can be appropriated or used the degree of opening thereof for control. As the number of revolutions per unit time of the water pump 10, there can be used a value proportional to engine rpm in the case of a mechanically operated water pump, whereas in the case of an electrically operated (motorized) water pump, there can be used the number of revolutions per unit time of a drive motor. Fig. 7 is a view showing a map for calculating a flow rate G_{heat} of cooling water flowing through the heater core 7, a flow rate G_{res} of cooling water flowing through the reservoir tank 6, a flow rate G_{oil} of cooling water flowing through the oil cooler 4, a flow rate G_{thr} of cooling water flowing through the throttle valve 5a and the EGR valve 5b, or a flow rate G_{egr} of cooling water flowing through the EGR cooler 8, according to this embodiment. G_{heat} , G_{res} , G_{oil} , G_{thr} , or G_{egr} depends on the number of revolutions per unit time of the water pump 10, and hence, can be calculated by looking up these values in the map shown in Fig. 7.

[0035] Then, the amounts of transfer heat in the various kinds of equipment will be calculated. Fig. 8 is a view showing a map for calculating an amount of heat dissipation ΔQ_{rad} in the radiator 3 or an amount of heat dissipation ΔQ_{res} in the reservoir tank 6 according to this embodiment. ΔQ_{rad} or ΔQ_{res} depends on the speed of wind or air which is received by each equipment, and the flow rate of cooling water flowing through each of the

various kinds of equipment, and hence, can be calculated by looking up these values in the map shown in Fig. 8. Here, as the wind speed, there can be used a value which is obtained by adding the speed of a vehicle and the wind speed of a cooling fan of the vehicle, or the like. Fig. 9 is a view showing a map for calculating an amount of heat dissipation ΔQ_{heat} in the heater core 7 according to this embodiment. ΔQ_{heat} depends on an air volume of a heater and the flow rate of cooling water flowing through the heater core 7, and hence, can be calculated by looking up these values in the map shown in Fig. 9. Fig. 10 is a view showing a map for calculating an amount of heat dissipation ΔQ_{oil} in the oil cooler 4, an amount of heat dissipation ΔQ_{thr} in the throttle valve 5a and the EGR valve 5b, or an amount of heat dissipation ΔQ_{egr} in the EGR cooler 8 according to this embodiment. ΔQ_{oil} , ΔQ_{thr} , or ΔQ_{egr} depends on the temperature of cooling water at the outlet port of the internal combustion engine 1 detected by the water temperature sensor 11 and the flow rate of cooling water flowing through each of the various kinds of equipment, and hence, can be calculated by looking up these values in the map shown in Fig. 10. Then, the amounts of received heat of the various kinds of equipment are calculated by deducting the respective amounts of heat dissipation of the various kinds of equipment from the outlet received heat amount. That is, the amount of received heat Q_{rad} in the radiator 3 is equal to $Q_{engout} - \Delta Q_{rad}$. The amount of received heat Q_{res} in the reservoir tank 6 is equal to $Q_{engout} - \Delta Q_{res}$. Here, note that there is almost no transfer of heat in the bypass passage 2g, and hence, the amount of received heat Q_{by} in the bypass passage 2g is equal to Q_{engout} . The amount of received heat Q_{heat} in the heater core 7 is equal to $Q_{engout} - \Delta Q_{heat}$. The amount of received heat Q_{oil} in the oil cooler 4 is equal to $Q_{engout} - \Delta Q_{oil}$. The amount of received heat Q_{thr} in the throttle valve 5a and the EGR valve 5b is equal to $Q_{engout} - \Delta Q_{thr}$. The amount of received heat Q_{egr} in the EGR cooler 8 is equal to $Q_{engout} - \Delta Q_{egr}$.

[0036] Thereafter, an inlet received heat amount is calculated which is received by the cooling water at the inlet port from which the cooling water flows into the internal combustion engine 1. An inlet received heat amount Q_{engin} is obtained by dividing a total sum of products of the amounts of received heat of the various kinds of equipment and the respective flow rates in the various kinds of equipment by the amounts of received heat of the various kinds of equipment. That is, the inlet received heat amount Q_{engin} is equal to $(Q_{rad} \times Grad + Q_{res} \times Gres + Q_{by} \times G_{by} + Q_{heat} \times G_{heat} + Q_{oil} \times G_{oil} + Q_{thr} \times G_{thr} + Q_{egr} \times G_{egr}) / (Q_{rad} + Q_{res} + Q_{by} + Q_{heat} + Q_{oil} + Q_{thr} + Q_{egr})$.

[0037] Fig. 11 is a view showing the control of the electronic thermostat 9 based on the inlet received heat amount according to this embodiment. As shown in Fig. 11, the electronic thermostat 9 is controlled in such a manner that the inlet received heat amount calculated in the above-mentioned manner comes near to a lower side

starting value of received heat amount of the phase transition temperature zone. Stated in another way, the electronic thermostat 9 is controlled in such a manner that the inlet received heat amount thus calculated comes near to a target received heat amount which is the lower side starting value of received heat amount of the phase transition temperature zone. The lower side starting value of received heat amount of the phase transition temperature zone has been able to be set in advance by experiments, verifications, etc. The ECU 12, which controls the electronic thermostat 9, corresponds to a control unit of the present invention. As a result of this, when the inlet received heat amount is lower than the lower side starting value of received heat amount of the phase transition temperature zone, the electronic thermostat 9 is controlled to a closed side so as to reduce the amount of the cooling water flowing into the radiator 3. On the other hand, when the inlet received heat amount is higher than the lower side starting value of received heat amount of the phase transition temperature zone, the electronic thermostat 9 is controlled to an opening side so as to increase the amount of the cooling water flowing into the radiator 3.

[0038] According to this, it is possible to set the target received heat amount of the cooling water to the lower side starting value of received heat amount of the phase transition temperature zone, and hence, even if an additional amount of heat is further received by the cooling water, the temperature of the cooling water is maintained within the phase transition temperature zone, thus making it possible to avoid such a situation that the specific heat of the cooling water may immediately become low thereby to cause the temperature of the cooling water to go up rapidly, resulting in an overheat. In addition, it is not necessary to set the target amount of received heat of the cooling water to be an excessively low value, so it is possible to avoid such a situation that the temperature of the cooling water becomes too low, then the oil in the internal combustion engine from gets cold, resulting in increasing the friction of the internal combustion engine.

[0039] According to this embodiment, in cases where the cooling water with its specific heat being variable is used, it is possible to make effective use of the phase transition temperature zone of the cooling water by controlling the control valve for changing the temperature of the cooling water in an appropriate manner.

[0040] Fig. 12 is a view showing a problem with the control of the electronic thermostat 9 based on the inlet received heat amount according to this embodiment. When the electronic thermostat 9 is controlled based on the inlet received heat amount, as shown in Fig. 12, the outlet received heat amount may become a high or large amount of received heat in excess of the phase transition temperature zone. Such a case may occur at the time of a high load, etc., thus easily causing an overheat.

[0041] Accordingly, in cases where the outlet received heat amount becomes a high or large amount of received heat in excess of an amount of received heat of the phase

transition temperature zone, the electronic thermostat 9 is controlled in such a manner that the outlet received heat amount is brought near to a higher amount of received heat within the phase transition temperature zone. Here, note that the electronic thermostat 9 may be controlled in such a manner that the outlet received heat amount is included in a range of amount of received heat corresponding to the phase transition temperature zone.

[0042] As specific control in this embodiment, when the electronic thermostat 9 is controlled in such a manner that the inlet received heat amount comes near to the lower side starting value of received heat amount of the phase transition temperature zone, the outlet received heat amount may become a high amount of received heat in excess of an amount of received heat of the phase transition temperature zone, as shown in Fig. 12. In that case, the control based on the inlet received heat amount is stopped, and the electronic thermostat 9 is controlled in such a manner that the outlet received heat amount comes near to a higher received heat amount within the phase transition temperature zone, as shown in Fig. 13. Fig. 13 is a view showing the control of the electronic thermostat 9 based on the outlet received heat amount according to this embodiment. Here, the reason for bringing the outlet received heat amount near to a higher amount of received heat within the phase transition temperature zone is because the outlet received heat amount can be maintained to be an amount of received heat higher or larger than the inlet received heat amount, so that effective use of the phase transition temperature zone of the cooling water can be made.

[0043] According to this, it is possible to set the target outlet received heat amount of the cooling water to a higher or larger amount of received heat within the phase transition temperature zone, as a result of which the temperature of the cooling water flowing out of the internal combustion engine is maintained within the phase transition temperature zone, thus making it possible to avoid such a situation that the specific heat of the cooling water may immediately become low thereby to cause the temperature of the cooling water to go up rapidly, resulting in an overheat.

[0044] As mentioned above, when the electronic thermostat 9 is controlled based on the inlet received heat amount or the outlet received heat amount, there may be a case where it becomes impossible to calculate the inlet received heat amount or the outlet received heat amount due to some cause such as sensor abnormality, engine abnormality, and abnormality of the various kinds of equipment, etc. In this case, it becomes impossible to control the electronic thermostat 9 based on the inlet received heat amount or the outlet received heat amount.

[0045] Accordingly, in cases where the inlet received heat amount or the outlet received heat amount can not be calculated, the electronic thermostat 9 is controlled in such a manner as to lower the temperature of said cooling water.

[0046] Fig. 14 is a view showing the control of the elec-

tronic thermostat 9 in cases where the inlet received heat amount or the outlet received heat amount can not be calculated, according to this embodiment. As specific control in this embodiment, the electronic thermostat 9 is controlled to an opening side at a degree of opening equal to or more than a fixed or prescribed degree of opening so that an amount of cooling water equal to or more than a fixed or prescribed amount is caused to circulate through the radiator 3 so as to make the outlet received heat amount lower or smaller value than the range corresponding to the phase transition temperature zone. Here, note that this is an abnormal situation, and the outlet received heat amount may be made lower than that in the case shown in Fig. 14, and hence, the electronic thermostat 9 may be controlled to a fully opened state so that the whole amount of cooling water to be able to circulate is caused to flow through the radiator 3. [0047] According to this, in cases where the amount of received heat can not be calculated, the temperature of the cooling water is made to fall, thus making it possible to avoid the temperature of the cooling water from going up to cause an overheat.

(Cooling Water Temperature Control Routine)

[0048] Reference will be made to a cooling water temperature control routine in the ECU 12 based on a flow chart shown in Fig. 15. Fig. 15 is a flow chart showing the cooling water temperature control routine according to this embodiment. This routine is carried out by means of the ECU 12. The ECU 12 executing this routine corresponds to a control unit of the present invention.

[0049] When the routine shown in Fig. 15 is started, in step S101, an inlet received heat amount is calculated. In this case, an outlet received heat amount is also calculated. In S102, it is determined whether an error (NG) has occurred in the calculation of the inlet received heat amount and the outlet received heat amount in step S101. In cases where an affirmative determination is made in step S102, the routine advances to step S106. On the other hand, in cases where a negative determination is made in step S102, the routine shifts to step S103. In step S103, it is determined whether the outlet received heat amount becomes a high amount of received heat in excess of the phase transition temperature zone. In cases where an affirmative determination is made in step S103, the routine advances to step S105. On the other hand, in cases where a negative determination is made in step S103, the routine advances to step S104. In step S104, the electronic thermostat 9 is controlled in such a manner that the inlet received heat amount comes near to the lower side starting value of received heat amount of the phase transition temperature zone. In step S105, the electronic thermostat 9 is controlled in such a manner that the outlet received heat amount comes near to a higher received heat amount within the phase transition temperature zone. In S106, the electronic thermostat 9 is controlled so as to lower the temperature of the cooling

water. After the processing of steps S104 through S106, this routine is once ended.

[0050] With this routine as described above, by controlling the control valve for changing the temperature of the cooling water in an appropriate manner, it is possible to make effective use of the phase transition temperature zone of the cooling water as much as possible.

<Others>

[0051] The cooling water temperature control apparatus for an internal combustion engine according to the present invention is not limited to the embodiment as mentioned above, but can be subjected to various changes and modifications within the scope not departing from the gist of the present invention.

Reference Signs List

[0052]

- 1 internal combustion engine
- 2 cooling water passage
- 3 radiator
- 4 oil cooler
- 5a throttle valve
- 5b EGR valve
- 6 reservoir tank
- 7 heater core
- 8 EGR cooler
- 9 electronic thermostat
- 10 water pump
- 11 water temperature sensor
- 12 ECU

Claims

1. A cooling water temperature control apparatus for an internal combustion engine in which cooling water is caused to circulate, said cooling water having variable specific heat, said apparatus comprising:

a received heat amount calculation unit configured to calculate an amount of received heat which is received by said cooling water;

a control valve that is controlled to open and close according to a command so as to change a circulation route or an amount of circulation of said cooling water and to change the temperature of said cooling water; and
a control unit configured to control said control valve based on the amount of received heat which is calculated by said received heat amount calculation unit.

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2. The cooling water temperature control apparatus for an internal combustion engine as set forth in claim 1, wherein

said received heat amount calculation unit calculates an inlet received heat amount which is received by said cooling water at an inlet port from which said cooling water flows into the internal combustion engine; and

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said control unit controls said control valve in such a manner that said inlet received heat amount calculated by said received heat amount calculation unit comes near to a lower side starting value of received heat amount of a phase transition temperature zone in which said cooling water is in a state in which the specific heat thereof changes due to a phase transition of particles.

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3. The cooling water temperature control apparatus for an internal combustion engine as set forth in claim 2, wherein

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said received heat amount calculation unit calculates an outlet received heat amount which is received by said cooling water at an outlet port from which said cooling water flows out of the internal combustion engine; and

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in cases where said outlet received heat amount calculated by said received heat amount calculation unit becomes a high amount of received heat in excess of an amount of received heat of said phase transition temperature zone, said control unit controls said control valve so that said outlet received heat amount is included in the range of the amount of received heat of said phase transition temperature zone.

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4. The cooling water temperature control apparatus for an internal combustion engine as set forth in any of claims 1 through 3, wherein

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in cases where said received heat amount calculation unit can not calculate the amount of received heat, said control valve is controlled in such a manner as to lower the temperature of said cooling water.

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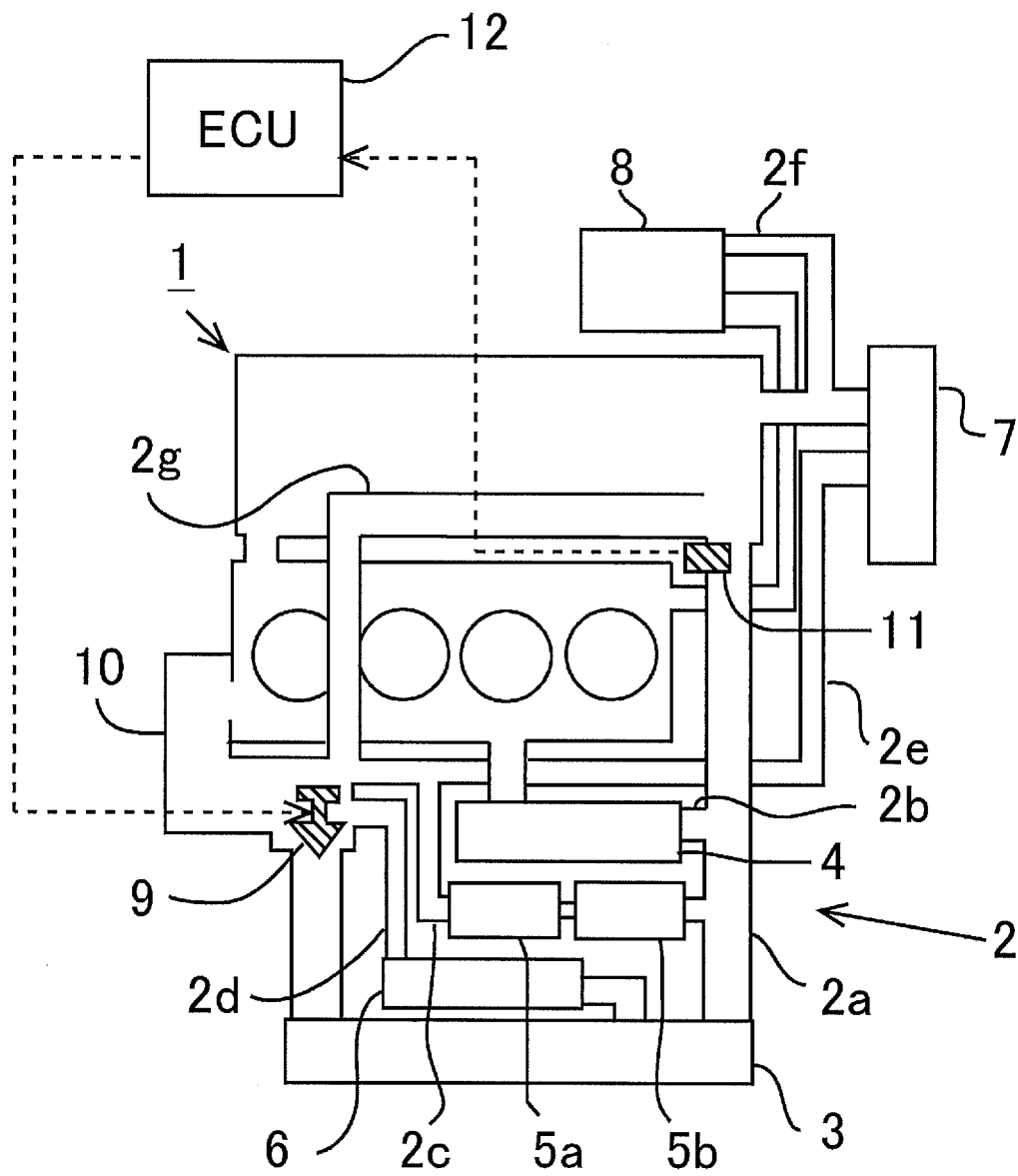


Fig. 1

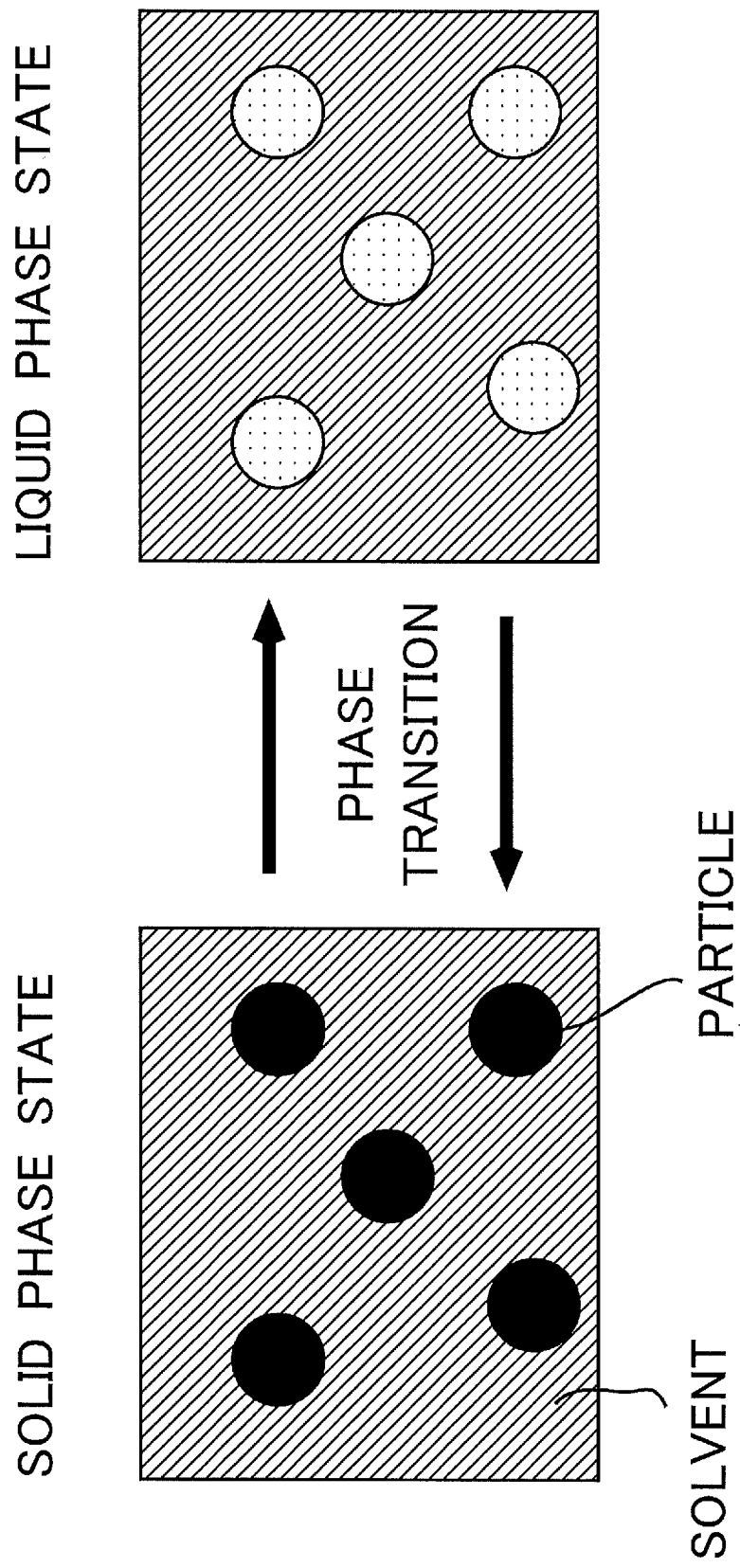


Fig.2

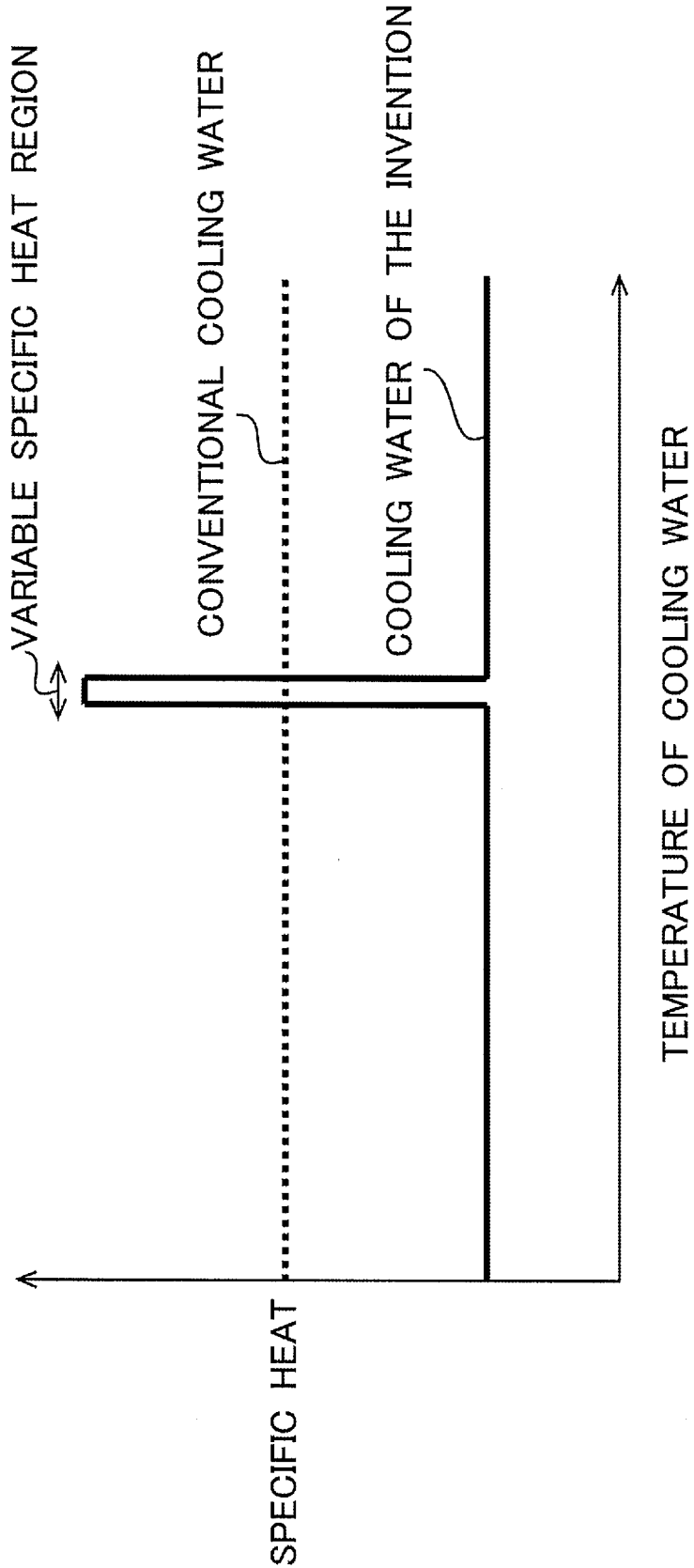
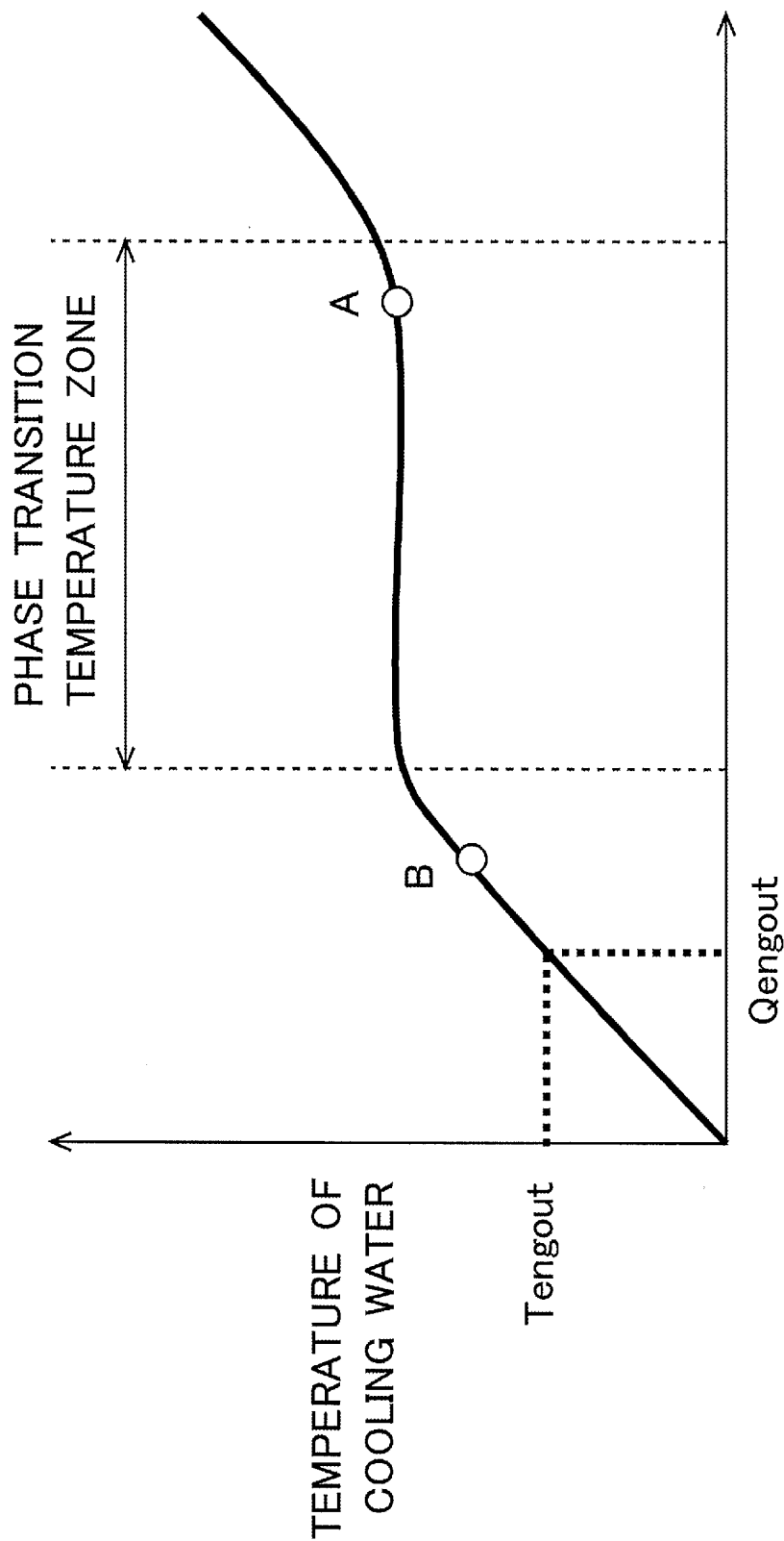


Fig.3



AMOUNT OF RECEIVED HEAT PER UNIT AMOUNT
AT REFERENCE TEMPERATURE OF 25 DEGREES C

Fig.4

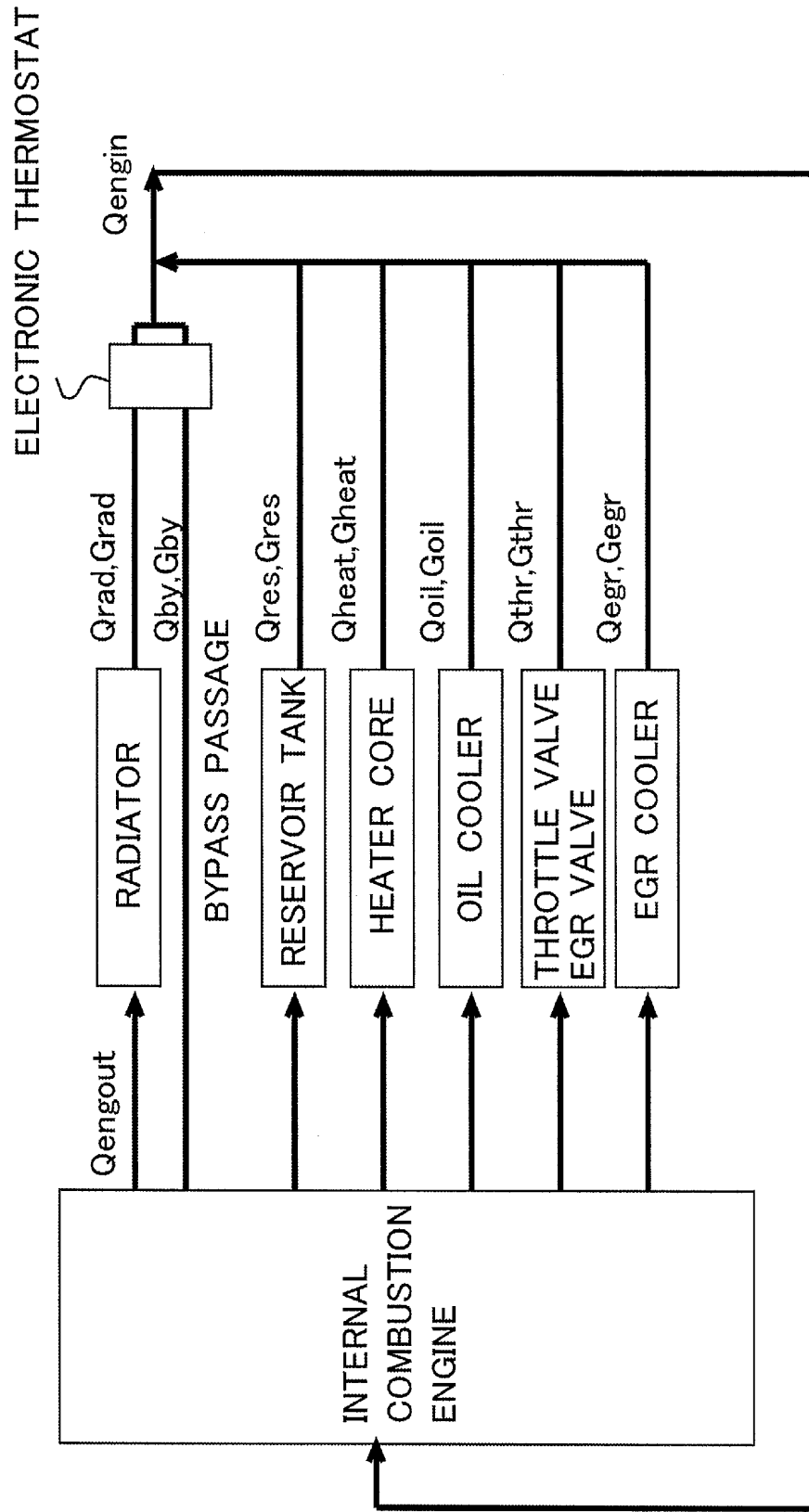


Fig.5

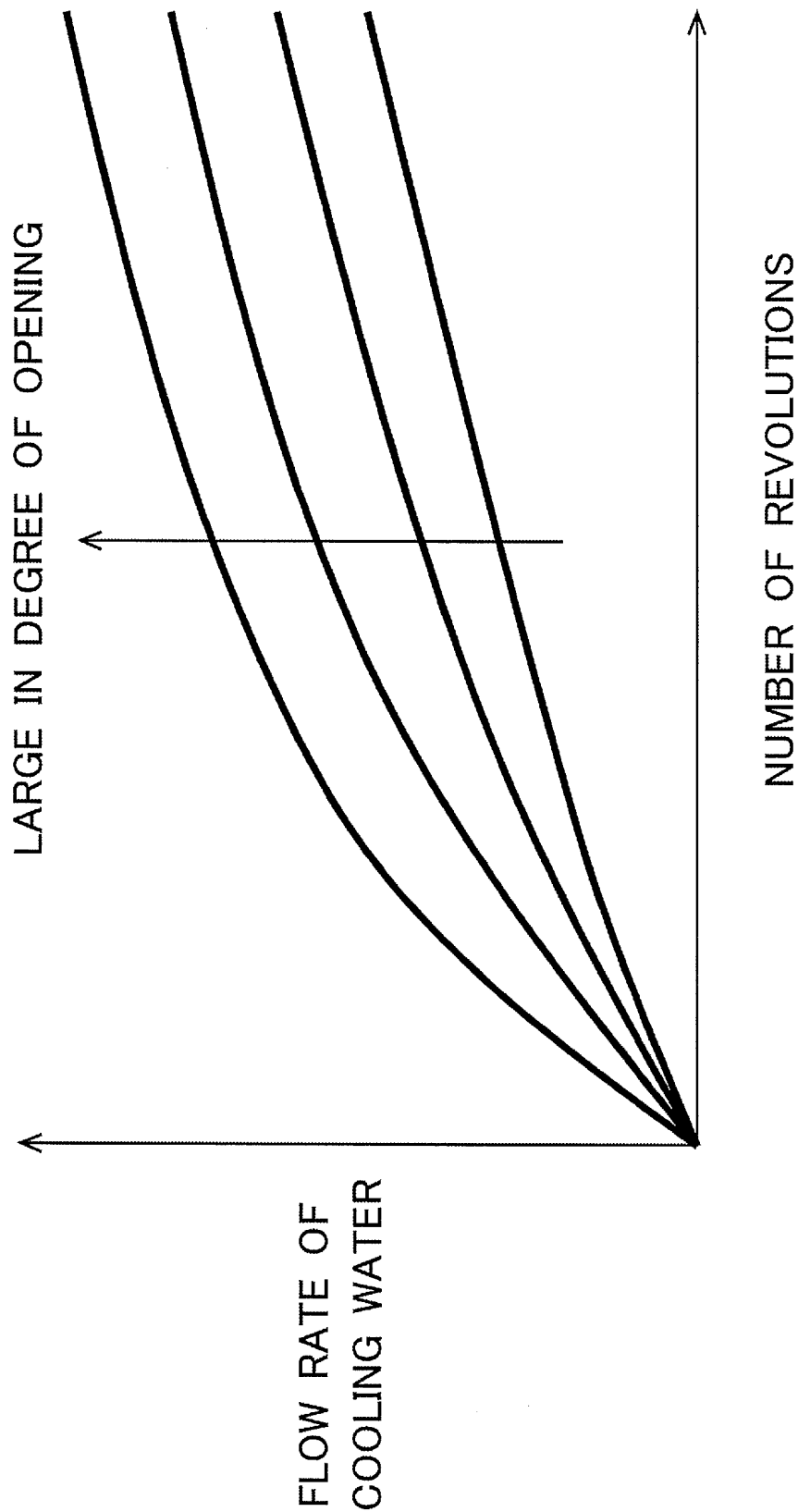


Fig.6

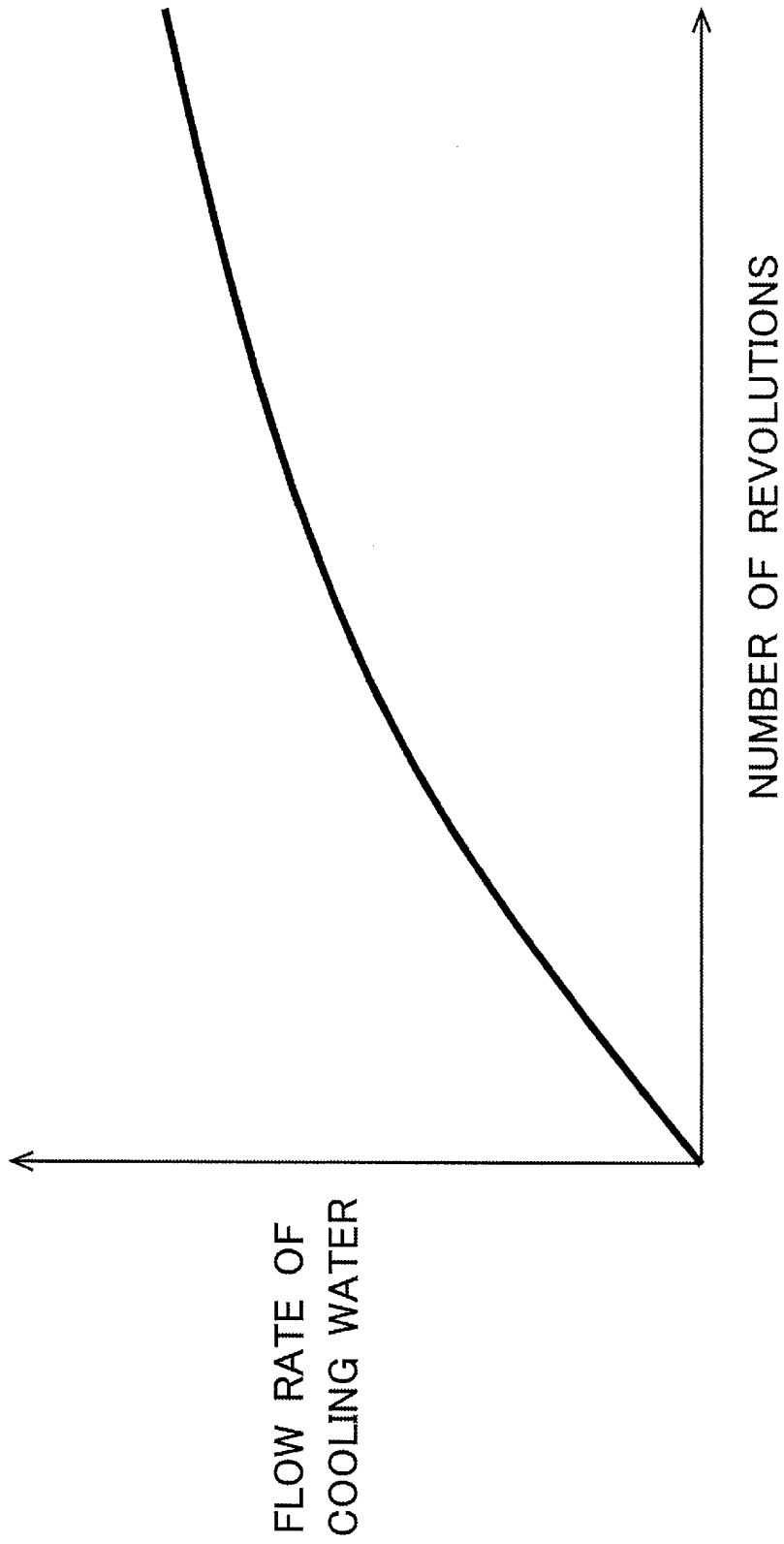


Fig. 7

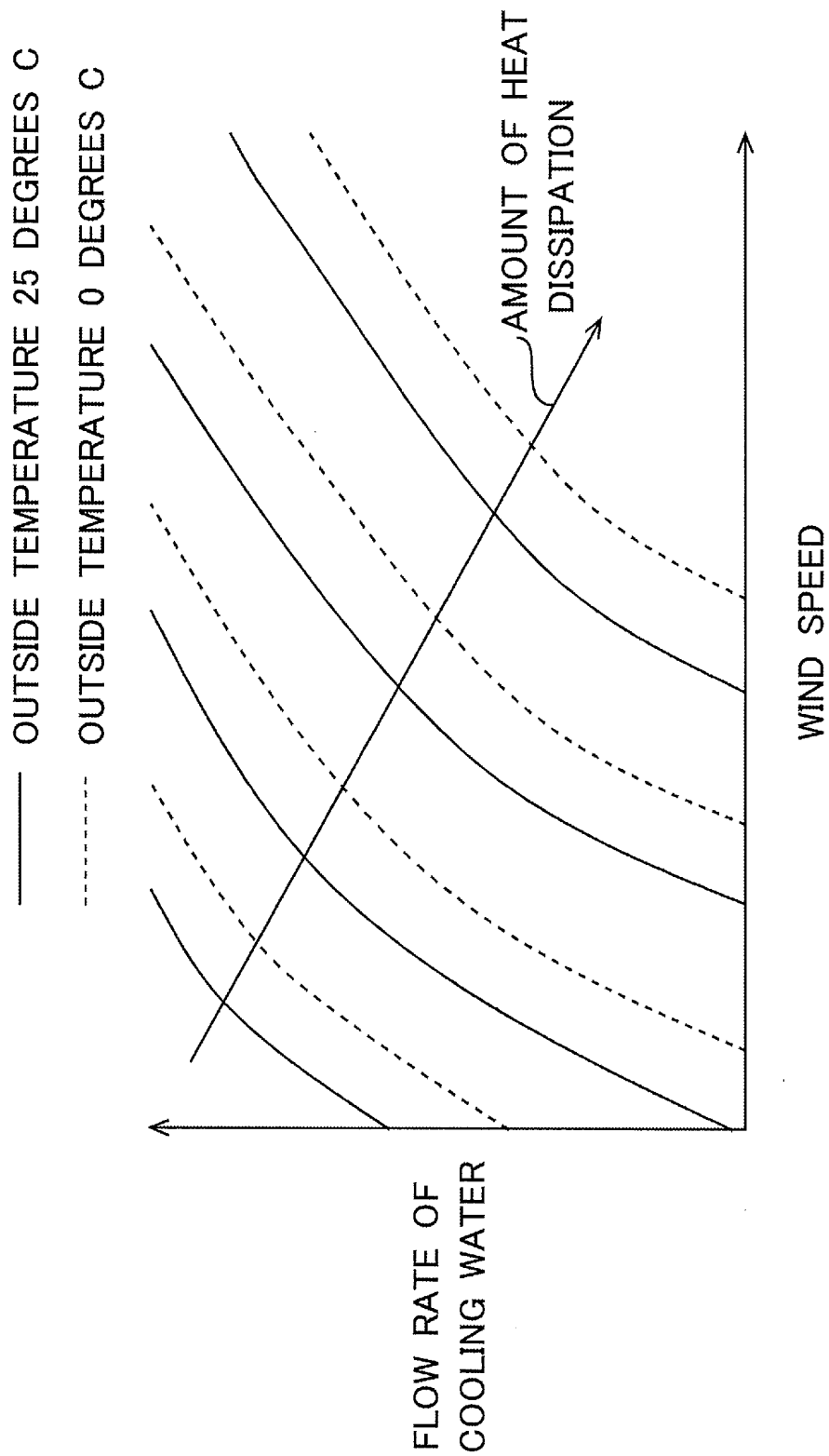


Fig.8

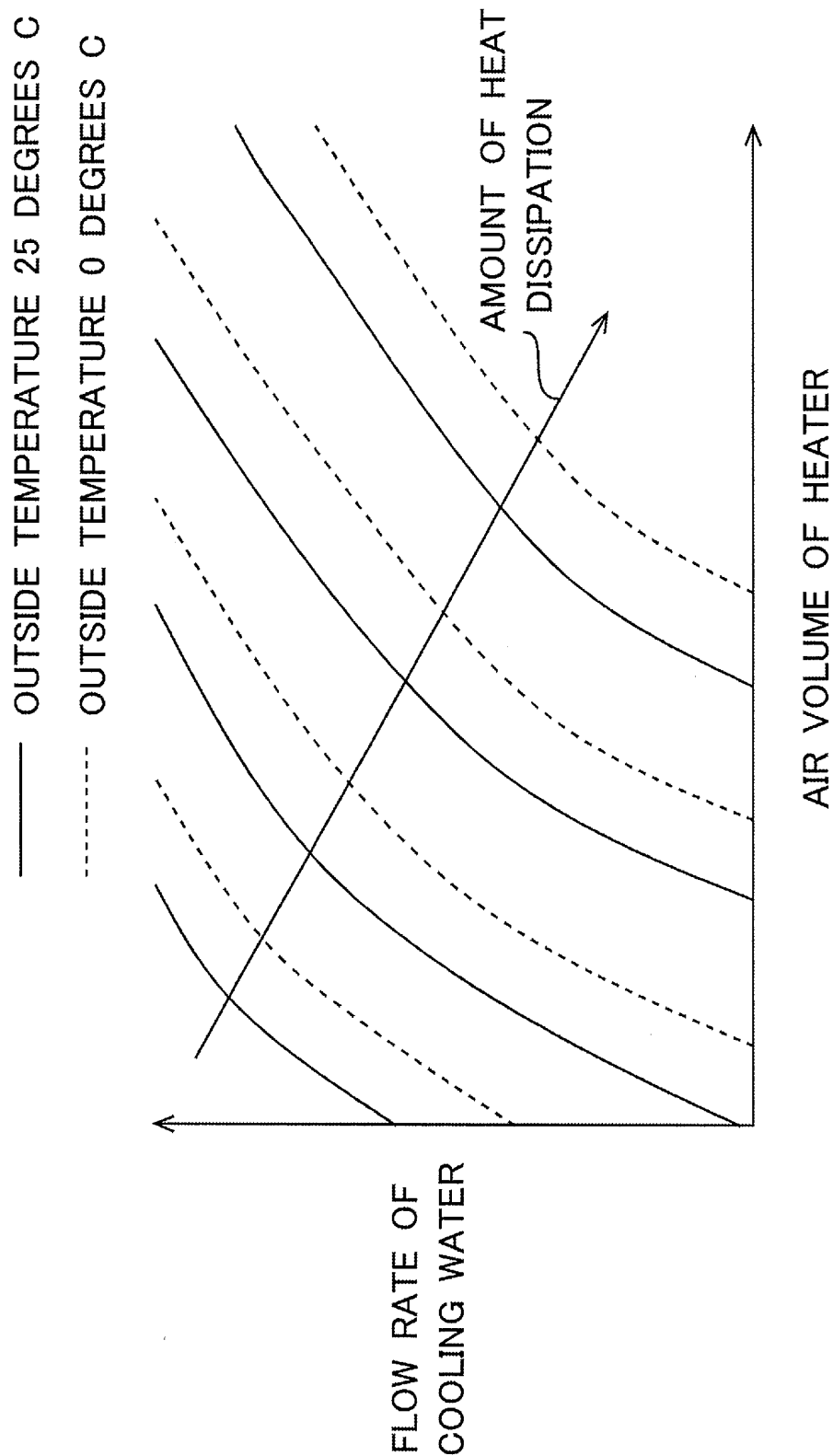


Fig.9

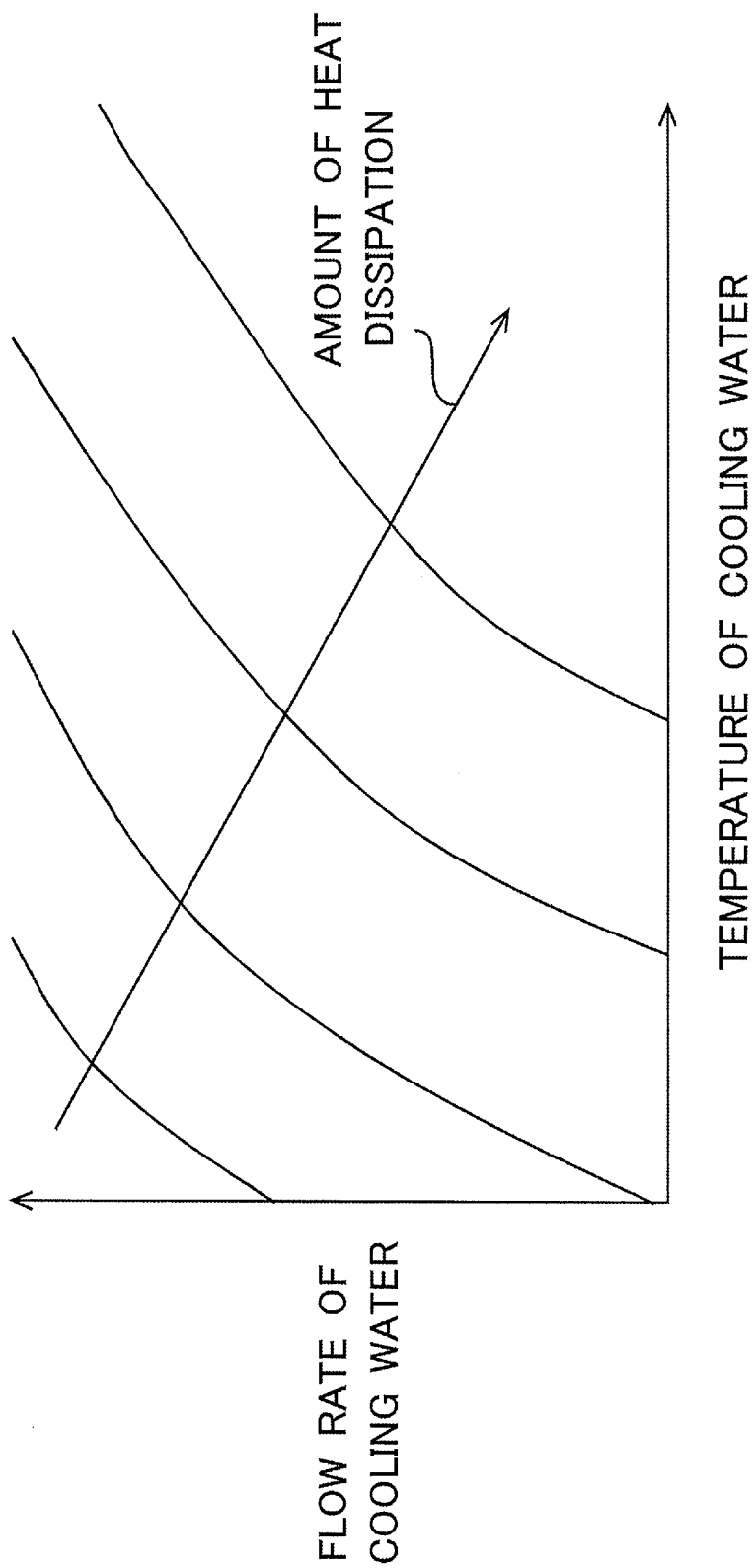


Fig.10

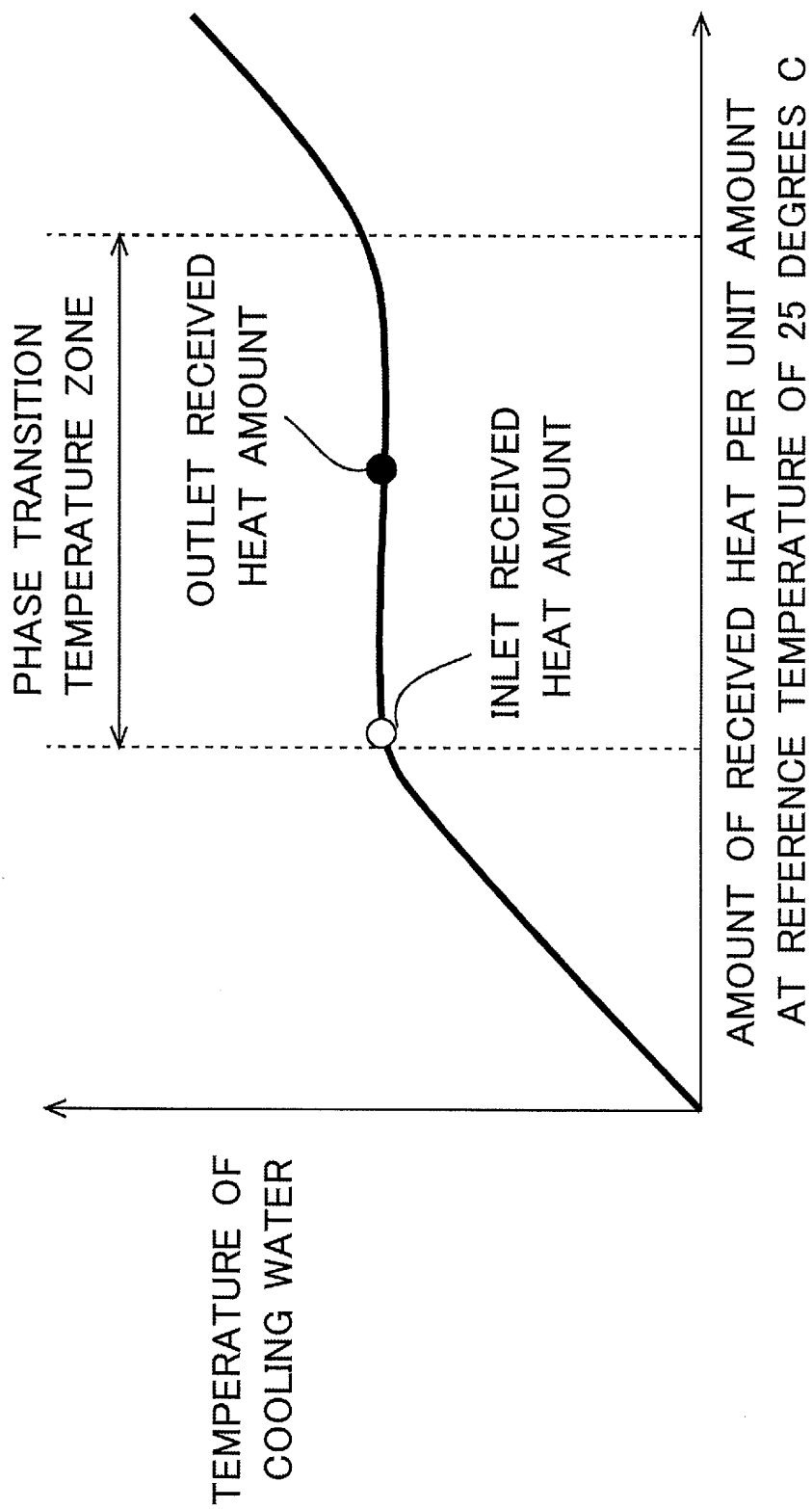


Fig.11

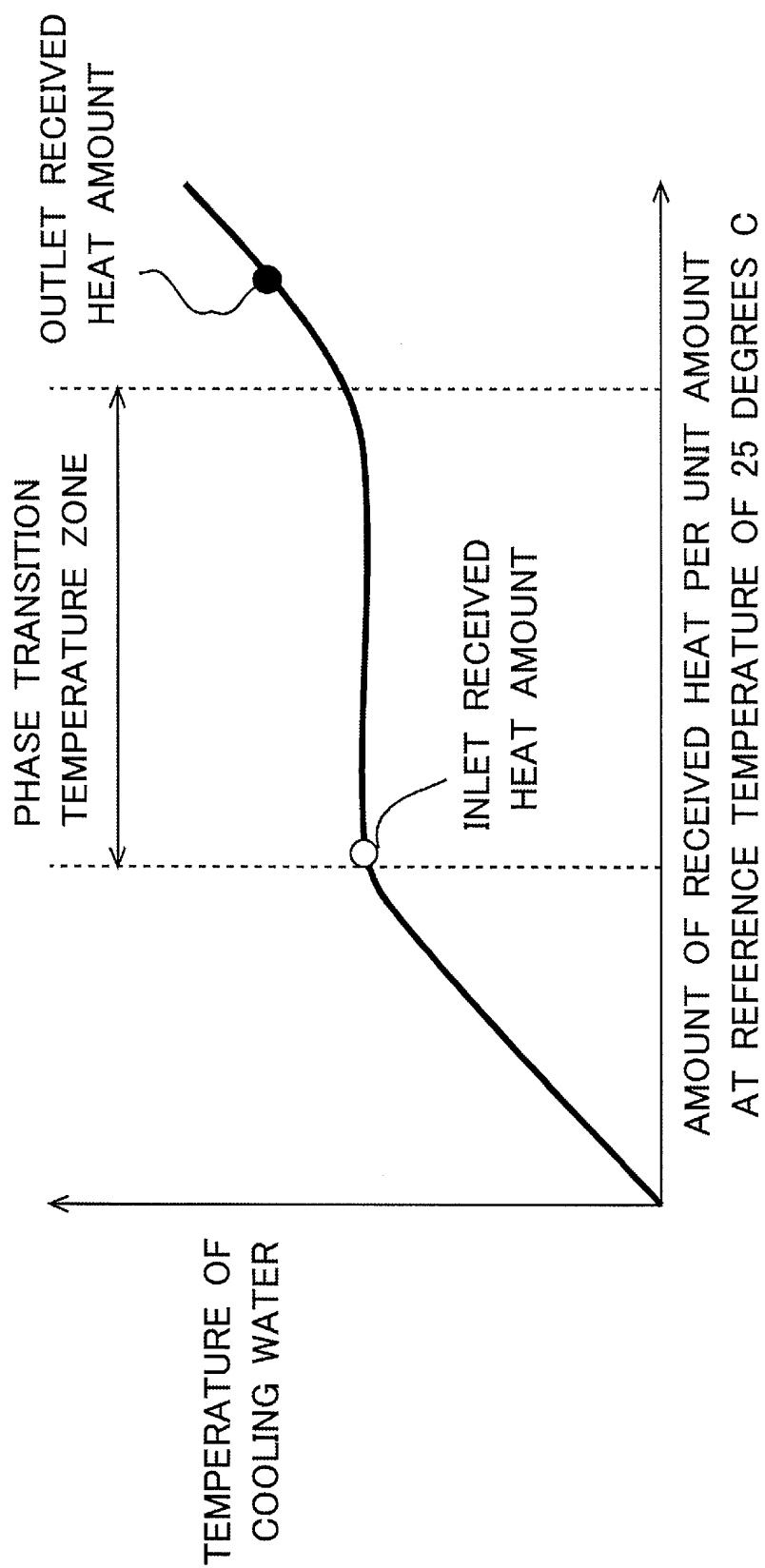


Fig.12

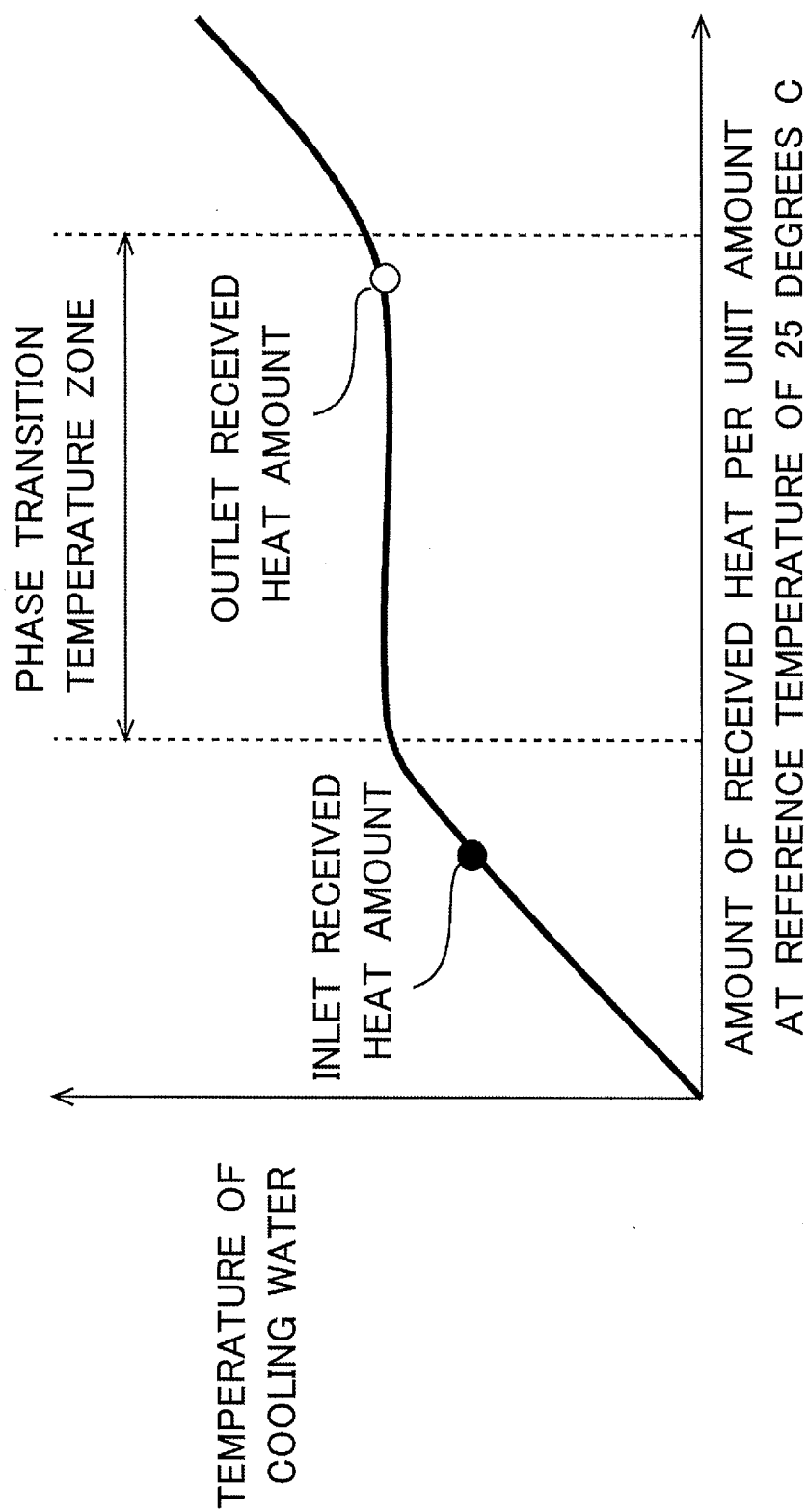
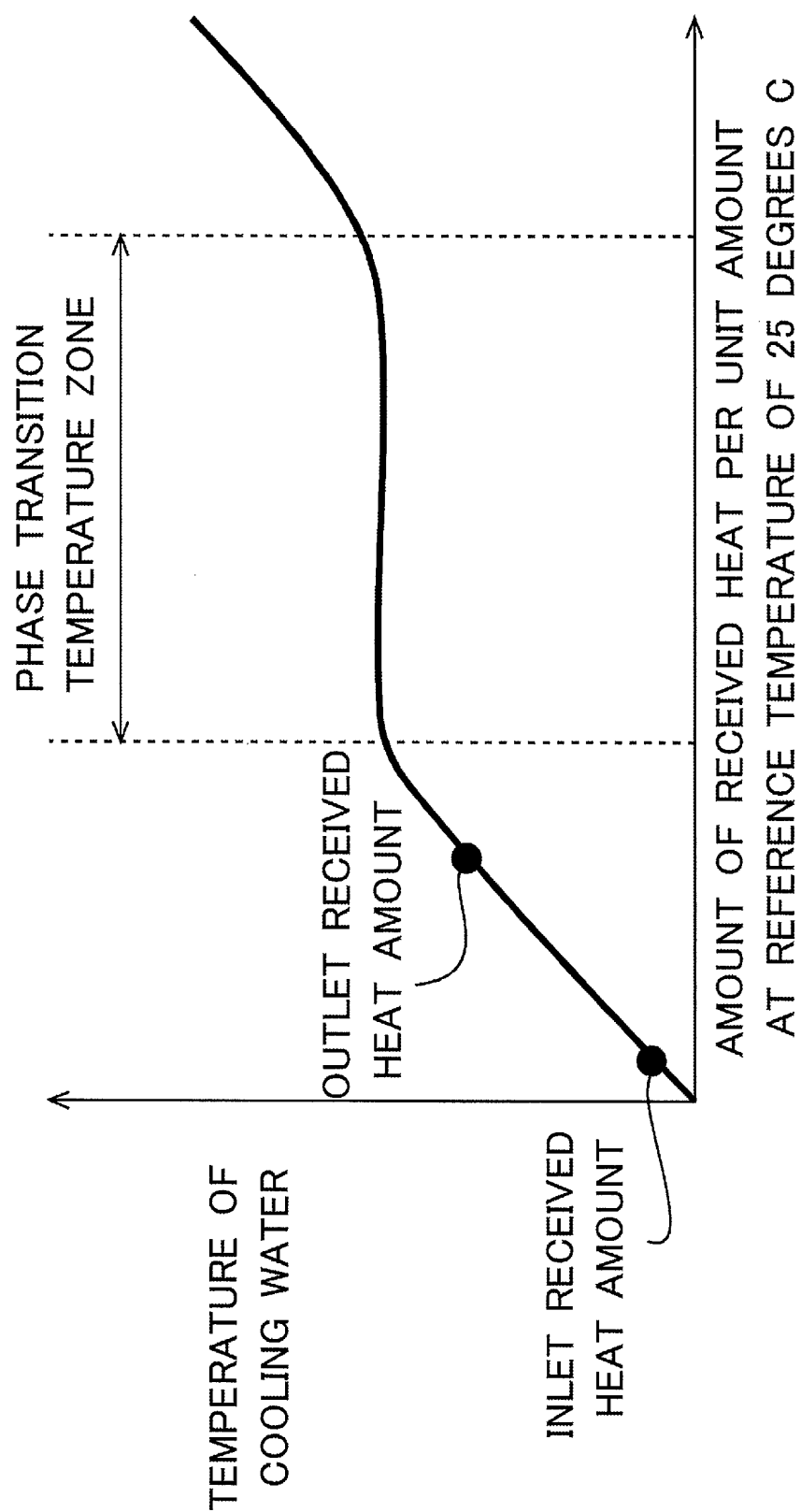


Fig. 13

*Fig. 14*

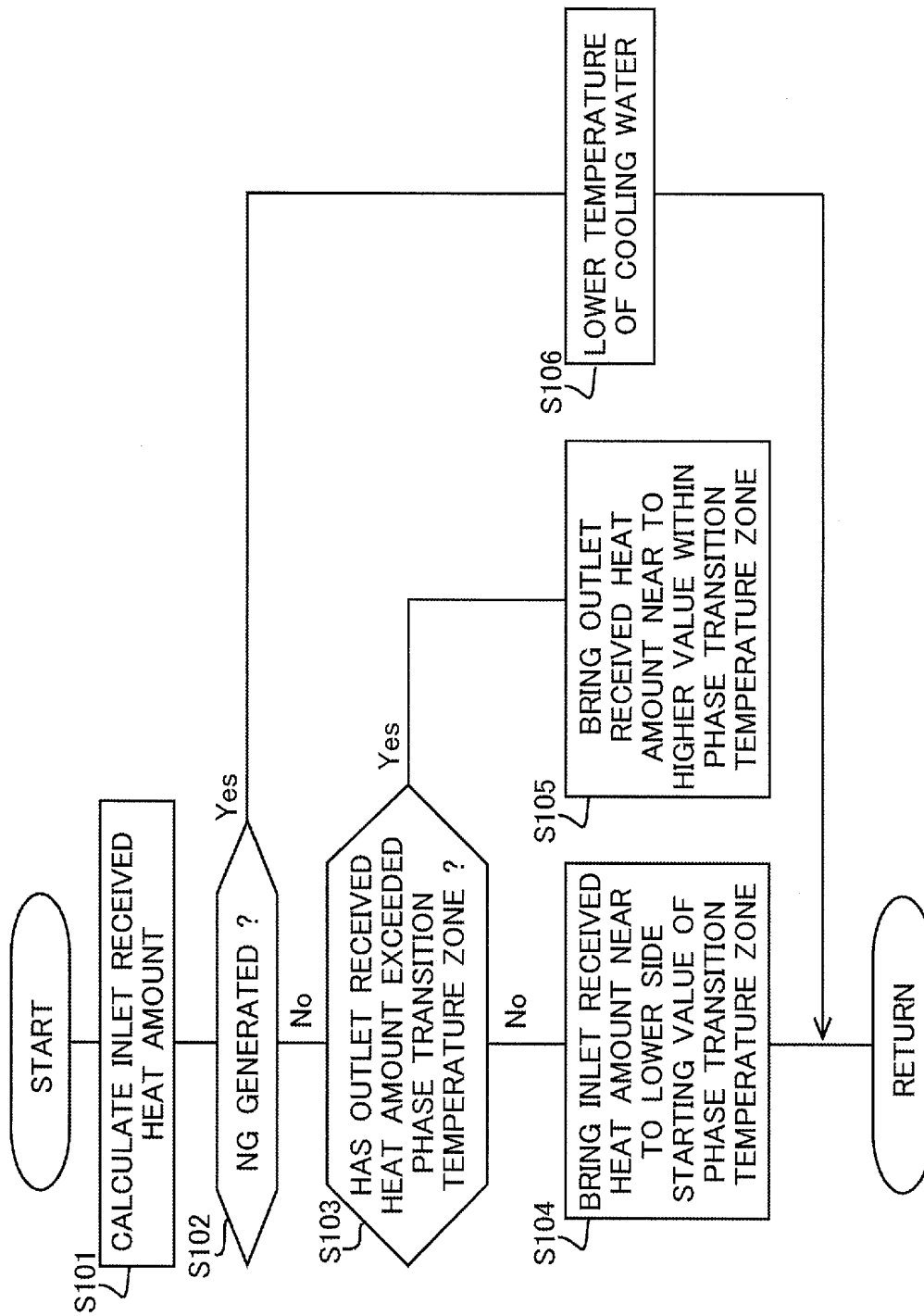


Fig. 15

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/060443

A. CLASSIFICATION OF SUBJECT MATTER

F01P7/16 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F01P7/16

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2009-174362 A (Toyota Motor Corp.), 06 August 2009 (06.08.2009), paragraphs [0012] to [0014], [0032] to [0035]; fig. 3 (Family: none)	1, 4 2, 3
Y	JP 2006-240501 A (Nissan Motor Co., Ltd.), 14 September 2006 (14.09.2006), paragraph [0007]; fig. 1 (Family: none)	1, 4
Y	JP 2007-321633 A (Nissan Motor Co., Ltd.), 13 December 2007 (13.12.2007), paragraphs [0015], [0033]; fig. 1 (Family: none)	1, 4

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

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"&" document member of the same patent family

Date of the actual completion of the international search
02 August, 2011 (02.08.11)Date of mailing of the international search report
16 August, 2011 (16.08.11)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/060443

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2009-44896 A (Nissan Motor Co., Ltd.), 26 February 2009 (26.02.2009), paragraphs [0011], [0025]; fig. 1 (Family: none)	1, 4

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- JP 2009044896 A [0004]
- JP 2005325790 A [0004]