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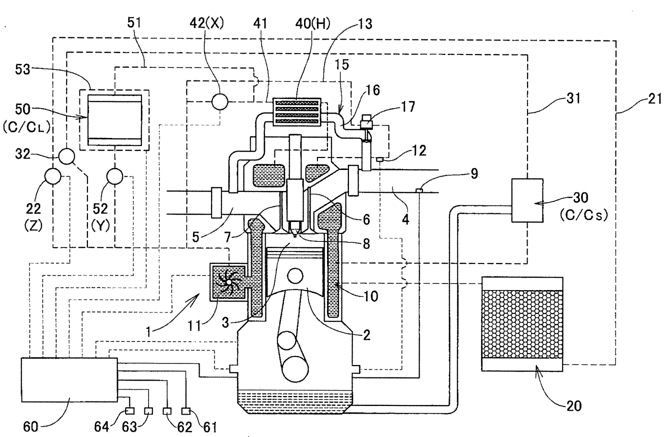
(54) ENGINE COOLING SYSTEM

(57) An engine cooling system is provided which includes a cooled portion (10) of an engine (1), a radiator (20) and a sub-heat exchanger (30, 40, 50). If the temperature of a refrigerant at the cooled portion (10) is less than a first predetermined value (T1), the supply of the refrigerant to the cooled portion (10), the radiator (20) and the sub-heat exchanger (30, 40, 50) is reduced. When the temperature of the refrigerant at the cooled portion (10) rises to the first predetermined value (T1) or more, the reduction of supply of the refrigerant to the cooled portion (10) is lifted. Further, if the temperature of the refrigerant is equal to or higher than the first predetermined value (T1) and lower than a second predetermined value (T2), the supply of the refrigerant to the radiator (20) is stopped while the refrigerant is supplied to the sub-heat exchanger (30, 40, 50), and if the temperature of the refrigerant is equal to or higher than the second predetermined value (T2), the refrigerant is supplied to the radiator (20).

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to an engine cooling system including a liquid-cooling device for cooling a cooled portion of an engine with a refrigerant.

BACKGROUND ART

[0002] Vehicles on which an engine such as a gasoline engine or a diesel engine is mounted include a water-cooling device for cooling the engine body around the cylinders by circulating cooling water as a refrigerant.

[0003] The water-cooling device for cooling the engine body includes a pump device called a water pump which supplies cooling water to a space, such as a water jacket, in the cylinder block, thereby preventing the temperature of the engine body from rising excessively due to the combustion of fuel in the cylinders. The cooling water is cooled by a refrigerant-cooling heat exchanger such as a radiator, and circulates to the engine body through the pump device again.

[0004] Such a water-cooling device switches cooling water flow paths according to the temperature of the cooling water to accelerate the warm-up of the engine (e.g., see the below-identified Patent Document 1).

PRIOR ART DOCUMENT(S)

PATENT DOCUMENT(S)

[0005] Patent document 1: Japanese Unexamined Patent Application Publication No. 2015-175296

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0006] Patent Document 1 discloses an exhaust gas recirculation device for returning a portion of exhaust gas into the intake air as returned exhaust gas. The exhaust gas recirculation device includes a returned exhaust gas cooler of the water-cooling type for cooling the returned exhaust gas with the same cooling water as used to cool the engine body. The engine cooling system of Patent Document 1 further includes a sub-radiator disposed forward of, and separately from, a radiator for decreasing the temperature of cooling water, and comprising a heat exchanger for cooling the refrigerant.

[0007] The engine cooling system of Patent Document 1 is controlled as follows: (i) while the temperature of cooling water in an area located downstream of the returned exhaust gas cooler is less than a (low) threshold value, a thermostat is closed to prevent cooling water from circulating to the engine; (ii) when the above temperature is equal to or higher than the threshold value, the thermostat is opened to circulate cooling water to the engine while using only the radiator to cool the cooling water; and (iii) when the above temperature further rises, only the sub-radiator disposed forward of the radiator is used with the thermostat opened.

[0008] In this conventional engine cooling system, when it is necessary to heat the engine quickly, such as during the warm-up of the engine, the thermostat is closed to limit the circulation of cooling water. When, thereafter, the temperature of cooling water rises to some extent, and the thermostat is opened, low-temperature cooling water that has passed through the radiator may rush into the engine in a very short period of time. Therefore, even though the engine has been heated quickly up to this point, the cooling water flowing into the engine from the radiator may prevent further quick heating of the engine.

[0009] It is an object of the present invention to avoid a situation in which an engine cannot be heated sufficiently quickly when this is desired, such as during the warm-up of the engine, due to a low-temperature refrigerant flowing into the engine.

MEANS FOR SOLVING THE PROBLEMS

[0010] In order to achieve the above object, the present invention provides an engine cooling system comprising: a pump device configured to feed a refrigerant; a cooled portion of an engine configured to be cooled by heat exchange with the refrigerant; a radiator configured to cool the refrigerant; a refrigerant circulation circuit through which the pump device, the cooled portion, and the radiator are connected together, and in which the refrigerant circulates; at least one sub-refrigerant circulation circuit to which the refrigerant is supplied, and which includes a sub-heat exchanger lower in heat exchange performance than the radiator; and a refrigerant temperature obtaining means for obtaining information correlated to a temperature of the refrigerant at the cooled portion, wherein the engine cooling system is configured: such that, during warm-up of the engine, if the temperature of the refrigerant at the cooled portion is less than a first predetermined value, supply of the refrigerant to the radiator and the sub-heat exchanger is reduced, and when the temperature of the refrigerant at the cooled portion rises to the first predetermined value or more, the reduction of supply of the refrigerant is lifted; and such that, when lifting the reduction of supply of the refrigerant, if the temperature of the refrigerant at the cooled portion is less than a second predetermined value higher than the first predetermined value, supply of the refrigerant to the radiator is stopped while the refrigerant is supplied to the sub-heat exchanger, and if the temperature of the refrigerant at the cooled portion is equal to or higher than the second predetermined value, the refrigerant is supplied to the radiator.

[0011] In the above engine cooling system, an amount of the refrigerant flowing out of the sub-heat exchanger per unit time may be smaller than the amount of the refrigerant flowing out of the radiator per unit time.

[0012] In the above engine cooling system, a temperature of the refrigerant that has passed through the sub-heat exchanger, and has been cooled by heat dissipation may be higher than a temperature of the refrigerant that has passed through the radiator.

[0013] The above engine cooling system may be configured such that, during warm-up of the engine, if the temperature of the refrigerant at the cooled portion is less than the first predetermined value, the supply of the refrigerant to the radiator and the sub-heat exchanger is stopped, and when the temperature of the refrigerant at the cooled portion rises to the first predetermined value or more, supply of the refrigerant to the sub-heat exchanger is started.

[0014] The at least one sub-refrigerant circulation circuit may comprise first and second sub-refrigerant circulation circuits. The sub-heat exchanger of the first sub-refrigerant circulation circuit may comprise a first type of sub-heat exchanger configured to increase a temperature of the refrigerant that passes therethrough. The sub-heat exchanger of the second sub-refrigerant circulation circuit may comprise a second type of sub-heat exchanger configured to decrease a temperature of the refrigerant that passes therethrough. The engine cooling system may be configured such that, if the temperature of the refrigerant at the cooled portion is less than a third predetermined value between the first predetermined value and the second predetermined value, the refrigerant is supplied to the first type of sub-heat exchanger, and is not supplied to the second type of sub-heat exchanger, and if the temperature of the refrigerant at the cooled portion is equal to or higher than the third predetermined value, the refrigerant is supplied to the second type of sub-heat exchanger.

[0015] The at least one sub-refrigerant circulation circuit may comprise first and second sub-refrigerant circulation circuits. The sub-heat exchanger of the first sub-refrigerant circulation circuit may comprise a small capacity sub-heat exchanger configured to decrease a temperature of the refrigerant that passes therethrough. The sub-heat exchanger of the second sub-refrigerant circulation circuit may comprise a large capacity sub-heat exchanger configured to decrease a temperature of the refrigerant that passes therethrough and higher in cooling performance than the small capacity sub-heat exchanger. The engine cooling system may be configured such that if the temperature of the refrigerant at the cooled portion is less than a fourth predetermined value between the first predetermined value and the second predetermined value, the refrigerant is supplied to the small capacity sub-heat exchanger, and is not supplied to the large capacity sub-heat exchanger, and if the temperature of the refrigerant at the cooled portion is equal to or higher than the fourth predetermined value, the refrigerant is supplied to the large capacity sub-heat exchanger.

[0016] In the above engine cooling system, the engine may include an exhaust gas recirculation device configured to return a portion of exhaust gas as returned exhaust gas into intake air, the exhaust gas recirculation device may include a returned exhaust gas cooler of a liquid-cooling type configured to cool the returned exhaust gas with the refrigerant, the at least one sub-refrigerant circulation circuit may comprise a plurality of sub-refrigerant circulation circuits, and the sub-heat exchanger of one of the plurality of sub-refrigerant circulation circuits may comprise the returned exhaust gas cooler.

[0017] In the above engine cooling system, the at least one sub-refrigerant circulation circuit may comprise a plurality of sub-refrigerant circulation circuits, and the sub-heat exchanger of one of the plurality of sub-refrigerant circulation circuits may comprise a heater core of an air conditioner of a vehicle on which the engine is mounted.

[0018] In the above engine cooling system, the at least one sub-refrigerant circulation circuit may comprise a single sub-refrigerant circulation circuit, or a plurality of sub-refrigerant circulation circuits, and the sub-heat exchanger of the single sub-refrigerant circulation circuit, or each of the sub-heat exchanges of at least some of the plurality of sub-refrigerant circulation circuits may comprise one of: a liquid-cooling engine oil cooler configured to cool lubricating oil for the engine with the refrigerant; a liquid-cooling intercooler configured to cool intake air with the refrigerant; and a liquid-cooling transmission oil cooler configured to cool, with the refrigerant, lubricating oil for a transmission to which a driving force of the engine is transmitted.

EFFECTS OF THE INVENTION

[0019] The engine cooling system according to the present invention includes a sub-heat exchanger or exchangers to which the same refrigerant as used in the radiator is supplied, and which is configured to increase the temperature of the refrigerant or lower in cooling performance than the radiator, and this engine cooling system is configured such that when the temperature of the engine needs to be increased quickly e.g., during the warm-up of the engine, before supplying the refrigerant from the radiator to the engine, the refrigerant which has passed through the sub-heat exchanger(s) is supplied to the engine. This avoids a situation in which an engine cannot be heated sufficiently quickly when this is desired, such as during the warm-up of the engine, due to a low-temperature refrigerant flowing into the engine.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

Fig. 1 is a schematic diagram of a refrigerant circulation circuit embodying the present invention.

Fig. 2 is a graph showing how the temperature of a refrigerant changes.

Fig. 3 is a graph illustrating the control according to the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[0021] An engine cooling system embodying the present invention is now described with reference to the drawings. The engine cooling system includes a liquid-cooling device for cooling, by heat exchange with a refrigerant, the body of an engine 1 which comprises a cylinder block including a cylinder in which a piston 2 is received to define a combustion chamber 3 therein; and members around the cylinder block. Therefore, the above-defined body of the engine 1, designated by numeral 10, is hereinafter referred to as the "cooled portion".

[0022] An intake passage 4 and an exhaust passage 5 are connected to the combustion chamber 3 so that air is sucked into the combustion chamber 3 through the intake passage 4, and exhaust gas is discharged from the combustion chamber 3 through the exhaust passage 5. The openings of the intake passage 4 and the exhaust passage 5 communicating with the combustion chamber 3 are opened and closed by an intake valve 6 and an exhaust valve 7, respectively. Numeral 8 in the figures designates an ignition device for generating an ignition spark in the combustion chamber 3. The engine 1 is a gasoline engine in the embodiment, but may be a diesel engine, in which case no ignition device 8 is used.

[0023] The liquid-cooling device of the embodiment is a water-cooling device which uses water (hereinafter referred to as "cooling water") as the refrigerant. The water-cooling device includes a pump device 11 for feeding cooling water (known as a "water pump"); and a radiator 20 comprising a cooling core for cooling cooling water. The pump device 11, the cooled portion 10 and the radiator 20 are annularly connected together through a refrigerant passage, thereby constituting a refrigerant circulation circuit 21 in which cooling water circulates. The pump device 11 is driven by an electric motor or the engine to feed cooling water. The radiator 20 functions to reduce the temperature of cooling water by heat exchange with, e.g., air.

[0024] The pump device 11 supplies cooling water to a space, such as a water jacket, provided in the cylinder block of the engine 1, thereby preventing the temperature of the engine 1 from rising excessively due to the combustion of fuel in the combustion chamber 3. The cooling water cooled by the radiator 20 circulates and returns to the body of the engine 1 through the pump device 11.

[0025] The refrigerant circulation circuit 21 includes a valve 22 so that, by opening the valve 22 cooling water can circulate in the refrigerant circulation circuit 21, and by closing the valve 22, cooling water cannot circulate in the refrigerant circulation circuit 21.

[0026] The water-cooling device includes a bypass circulation passage 13 branching off from an intermediate portion of the refrigerant circulation circuit 21. Part of the cooling water from the pump device 11 is circulated at all times through the bypass circulation passage 13 to the cooled portion 10, without passing through any heat exchanger. A water temperature sensor 12 as a refrigerant temperature obtaining means is mounted to the bypass circulation passage 13 so as to obtain information correlated to the refrigerant temperature (this temperature is hereinafter referred to as the "water temperature" because the refrigerant is cooling water in the embodiment) at the cooled portion 10. If it is determined, based on the information obtained by the water temperature sensor 12, that the water temperature at the cooled portion 10 is equal to or higher than a first predetermined value T1, the valve 22 is opened so that cooling water is fed, under the driving force of the pump device 11, to the cooled portion 10 of the engine 1 while circulating in the refrigerant circulation circuit 21. When the temperature of the engine needs to be increased, e.g., while the engine 1 is warming up, and if the water temperature is less than the first predetermined value T1, the valve 22 is closed so that cooling water is not fed or supplied to the cooled portion 10 of the engine 1, thereby enabling the engine 1 to warm up quickly.

[0027] The water-cooling device is controlled by an electronic control unit 60 mounted on the vehicle on which the above-described engine 1 is mounted. More specifically, the electronic control unit 60 controls the operation of the engine 1, and also controls the water-cooling device based on the temperature conditions of the cooled portion 10, the water temperature at the cooled portion 10, various operation states, etc.

[0028] The water-cooling device includes three sub-refrigerant circulation circuits 31, 41 and 51 to which the same refrigerant (cooling water) as used in the refrigerant circulation circuit 21 is supplied, and which include, respectively, three sub-heat exchangers 30, 40 and 50 each configured to increase or decrease the refrigerant temperature (water temperature). All of the sub-heat exchangers 30, 40 and 50 are lower in refrigerant cooling performance, i.e., in heat exchange performance with the refrigerant, than the radiator 20. Also, the sub -heat exchangers 30, 40 and 50 are designed such that the amount of refrigerant flowing out of each sub-heat exchanger 30, 40, 50 per unit time is smaller than the amount of refrigerant flowing out of the radiator 20 per unit time, and such that, if cooling water of the same temperature flows into the sub-heat exchangers 30, 40 and 50, and the radiator 20, the temperature of the cooling water leaving each sub-heat exchanger 30, 40, 50 after being cooled by heat dissipation is higher than the temperature of the cooling water leaving the radiator 20.

[0029] Of these sub-heat exchangers, the sub-heat exchanger 30 is constituted by a liquid-cooling engine oil cooler that cools lubricating oil of the engine 1 with the same cooling water as used in the refrigerant circulation circuit 21. Thus, in the embodiment, the sub-heat exchanger 30 is hereinafter referred to as the engine oil cooler 30.

[0030] The sub-refrigerant circulation circuit 31 including the engine oil cooler 30 has a valve 32 so that, by opening the valve 32, cooling water can circulate in the sub-refrigerant circulation circuit 31, and by closing the valve 32, cooling water cannot circulate in the sub-refrigerant circulation circuit 31.

[0031] The sub-refrigerant circulation circuit 31 including the engine oil cooler 30 may merge with the refrigerant circulation circuit 21 at positions downstream of the radiator 20 and upstream of the valve 22, respectively, so the valve 22 of the refrigerant circulation circuit 21 can control the circulation of cooling water in the sub-refrigerant circulation circuit 31, too. In this arrangement, cooling water is supplied simultaneously to both the radiator 20 and the engine oil cooler 30.

[0032] The engine 1 includes an exhaust gas recirculation device 15 that returns a portion of the exhaust gas discharged from the combustion chamber 3 into the intake air as returned exhaust gas to introduce the thus-returned exhaust gas into the combustion chamber 3. The exhaust gas recirculation device 15 includes an exhaust gas return passage 16 that connects the intake passage 4 to the exhaust passage 5; an exhaust return valve 17 configured to open and close the exhaust gas return passage 16; and a throttle valve (not shown) which is mounted in the intake passage 4 at its portion upstream of the position where the exhaust gas return passage 16 merges with the intake passage 4, and which is configured to create a negative pressure in the intake passage 4. The exhaust gas recirculation device 15 further includes a returned exhaust gas cooler 40 of the liquid-cooling type mounted to an intermediate portion of the exhaust gas return passage 16.

[0033] Of the three sub-heat exchangers, the sub-heat exchanger 40 is constituted by this returned exhaust gas cooler of the exhaust gas recirculation device 15. Thus, in the embodiment, the sub-heat exchanger 40 is hereinafter referred to as the returned exhaust gas cooler 40. The returned exhaust gas cooler 40 cools returned exhaust gas passing through its core connected to the exhaust gas return passage 16, by use of cooling water circulating through the core of the cooler 40. The cooling water supplied to the returned exhaust gas cooler is the same cooling water as used in the refrigerant circulation circuit 21 including the radiator 20.

[0034] The sub-refrigerant circulation circuit 41 including the returned exhaust gas cooler 40 has a valve 42 so that, by opening the valve 42, cooling water can circulate in the sub-refrigerant circulation circuit 41, and by closing the valve 42, cooling water cannot circulate in the sub-refrigerant circulation circuit 41.

[0035] The vehicle on which the above-described engine 1 is mounted includes an air conditioner 53. The air conditioner 53 includes a heater core 50 for generating a flow of warm air in the passenger compartment.

[0036] Of the three sub-heat exchangers, the sub-heat exchanger 50 is constituted by this heater core 50 of the air conditioner 53. Thus, in the embodiment, the sub-heat exchanger 50 is hereinafter referred to as the heater core 50. An electric fan for moving air is provided adjacent to the heater core 50. The same cooling water as used in the refrigerant circulation circuit 21 including the radiator 20 is supplied into the heater core 50. By rotating the air moving fan, heat of the cooling water is transferred to and heats air to be blown into the passenger compartment, and the heated air blown into the passenger compartment increases the temperature of the passenger compartment.

[0037] The sub-refrigerant circulation circuit 51 including the heater core 50 branches off from the sub-refrigerant circulation circuit 41 at a position downstream of the returned exhaust gas cooler 40; extends through the heater core 50; merges with the sub-refrigerant circulation circuit 41 at a position downstream of the valve 42; and returns to the pump device 11. The sub-refrigerant circulation circuit 51 has a valve 52 at its position downstream of the heater core 50 so that, by opening the valve 52, cooling water can circulate in the sub-refrigerant circulation circuit 51, and by closing the valve 52, cooling water cannot circulate in the sub-refrigerant circulation circuit 51.

[0038] As an alternative arrangement, the sub-refrigerant circulation circuit 51 including the heater core 50 may branch off from the sub-refrigerant circulation circuit 41 at a position upstream of the returned exhaust gas cooler 40. Further alternatively, the sub-refrigerant circulation circuit 51 may extend directly from the cooled portion 10 as with the sub-refrigerant circulation circuits 31 and 41.

[0039] The electronic control unit 60 controls the air conditioner 53, and the valves 32, 42 and 52 of the sub-refrigerant circulation circuits 31, 41 and 51.

[0040] In the embodiment, the valves 22, 32, 42 and 52 are rotary valves, which each includes a rotating member such as a rotor, and controls the amount of cooling water flowing therethrough by rotating the rotating member. Specifically, by rotating the rotating member of each valve 22, 32, 42, 52, the valve is opened and cooling water flows therethrough at a rate corresponding to the rotation speed of the rotating member. By stopping the rotating member of each valve 22, 32, 42, 52, the valve is closed and the flow of cooling water stops. Instead of such rotary valves, valve devices having a different structure to control the amount of cooling water flowing therethrough may be used as the valves 22, 32, 42 and 52.

[0041] The air conditioner 53 including the heater core 50 can be manually controlled based on an input signal when a driver turns on a passenger compartment air conditioning switch 61 and/or a passenger compartment fan switch 62 which are both mounted in the passenger compartment. The air conditioner 53 can also be automatically controlled based on information from a passenger compartment temperature detecting means 63 for detecting the temperature of the passenger compartment, and/or an outside air temperature detecting means 64 for detecting the temperature outside the vehicle.

[0042] During the manual control mode of the air conditioner, an air flow is created based on an ON signal from the passenger compartment fan switch 62, and stops based on an OFF signal from the switch 62 or when the ON signal stops. While the ON signal is being received, it is possible to adjust the strength of the air flow. When an ON signal is received from the passenger compartment air conditioning switch 61, air passes through the core, so that the air flow introduced into the passenger compartment changes from a normal-temperature air flow to a high-temperature air flow thereby heating the passenger compartment. When an OFF signal is received from the passenger compartment air conditioning switch 61 or when the ON signal from the switch 61 stops, the air flow changes from a warm air flow to a normal-temperature air flow. During the automatic control mode of the air conditioner, the temperature and strength of an air flow, and whether or not to create an air flow, are automatically controlled such that the temperature of the passenger compartment approaches the preset temperature (target temperature). The preset temperature can be also automatically set based upon the temperature outside the vehicle.

[0043] In most conventional air conditioners, cooling water is supplied to the heater core at all times. However, in the present invention, when it is not necessary to heat the passenger compartment, it is possible to stop the supply of cooling water to the heater core 50 of the air conditioner 53 by closing the valve 52 of the sub-refrigerant circulation circuit 51. This makes it possible to minimize a decrease in cooling water temperature when such temperature decrease is not desirable according to the operating condition.

[0044] In this regard, determination may be made that it is not necessary to heat the passenger compartment when the temperature detected by an intake air temperature sensor 9, the outside air temperature detecting means 64, or the passenger compartment temperature detecting means 63 is equal to or higher than a predetermined temperature, when the passenger compartment air conditioning switch 61 is off, or when the passenger compartment fan switch 62 is off.

[0045] It is now described how the engine cooling system of the present invention is controlled.

[0046] As its basic control, first, when it is necessary to increase the temperature of the engine 1 quickly, such as during the warm-up of the engine 1, and if the water temperature is less than the first predetermined value T1 (see range a in Fig. 3), the valve 22 of the refrigerant circulation circuit 21 including the radiator 20 is closed to stop the supply of cooling water in the refrigerant circulation circuit 21 to the cooled portion 10 of the engine 1. However, instead of completely stopping the supply of cooling water in the refrigerant circulation circuit 21 to the cooled portion 10 of the engine 1, the amount of cooling water supplied to the cooled portion 10 may be reduced. By stopping or reducing the supply of cooling water to the cooled portion 10, the supply of cooling water to the radiator 20 and the sub-heat exchangers is also stopped or reduced.

[0047] During this control mode, since the pump device 11 keeps operating while the engine 1 is running, and the other valves 32, 42 and 52 are also closed, cooling water fed from the pump device 11 circulates in the bypass circulation passage 13 without passing through any heat exchangers, including the radiator 20, and the three sub-heat exchangers, namely the engine oil cooler 30, the returned exhaust gas cooler 40, and the heater core 50.

[0048] The valve 22 of the refrigerant circulation circuit 21 may have a thermostat function such that it opens only if the water temperature rises to the first predetermined value T1 or more.

[0049] When the water temperature rises to the first predetermined value T1 or more during the warm-up of the engine 1, cooing water is supplied through one or more of the heat exchangers to the cooled portion 10 of the engine 1.

[0050] When starting the supply, or lifting the reduction of supply, of cooling water to the cooled portion 10 of the engine 1 through one or more of the heat exchangers, if the water temperature is less than a second predetermined value T2 which is higher than the first predetermined value T1 (see ranges b, c and d in Fig. 3), while keeping the valve 22 closed so that cooling water is not supplied to the radiator 20, the valves 32, 42 and 53 are opened selectively or in an predetermined order to supply cooling water to the corresponding one or ones of the three sub-heat exchangers, i.e., the engine oil cooler 30, the returned exhaust gas cooler 40, and the heater core 50.

[0051] The returned exhaust gas cooler 40, which is the sub-heat exchanger of the sub-refrigerant circulation circuit 41, is a heat exchanger of the type that increases the water temperature, and is hereinafter referred to as the "first type" of sub-heat exchanger H. The engine oil cooler 30, which is the sub-heat exchanger of the sub-refrigerant circulation circuit 31, and the heater core 50, which is the sub-heat exchanger of the sub-refrigerant circulation circuit 51, are heat exchangers of the type that decreases the water temperature, and are hereinafter referred to as the "second type" of sub-heat exchangers C.

[0052] As described above, when the water temperature at the cooled portion 10is equal to or higher than the first predetermined value T1 and lower than the second predetermined value T2, cooling water is supplied to the sub-heat exchangers. Specifically, if the water temperature is less than a third predetermined value T3 between the first predetermined value T1 and the second predetermined value T2 (see range b in Fig. 3), cooling water is supplied to the first type of sub-heat exchanger H, and is not supplied to the second type of sub-heat exchangers C.

[0053] The first type of sub-heat exchanger H is a heat radiator. That is, cooling water supplied to the first type of sub-heat exchanger H receives the heat of returned exhaust gas, and thus is heated. Therefore, by supplying, to the cooled portion 10, cooling water that has been somewhat heated after passing through the first type of sub-heat exchanger H, before starting to supply cooling water that has passed through the second type of sub-heat exchangers C, it is possible to prevent low-temperature cooling water from rushing into the engine 1 in a very short period of time, so that the engine temperature rises sufficiently quickly.

[0054] When the water temperature rises to the third predetermined value T3 or more (see ranges c and d in Fig. 3), the supply of cooling water to the second type of sub-heat exchangers C is started. Since the water temperature has risen to the third predetermined value T3 or more at this time, cooling water that has passed through the sub-heat exchangers that decrease the temperature of cooling water, and is supplied to the engine 1 would not prevent the engine temperature from rising sufficiently quickly, as long as the temperature of this cooling water is not extremely low, i.e., as low as the temperature of cooling water in the refrigerant circulation circuit 21 that has passed through the radiator 20.

[0055] The second type of sub-heat exchangers C, which are configured to decrease the temperature of cooling water, comprise a small capacity sub-heat exchanger Cs, and a large capacity sub-heat exchanger C_L higher in cooling performance than the small capacity sub-heat exchanger Cs.

[0056] Cooling water is supplied to the second type of sub-heat exchangers C in the following manner. While the water temperature is less than a fourth predetermined value T4 between the first predetermined value T1 and the second predetermined value T2 (see range c in Fig. 3), cooling water is supplied to only the small capacity sub-heat exchanger C_S, and is not supplied to the large capacity sub-heat exchanger C_L. As a result thereof, relatively high-temperature cooling water that has passed through the small capacity (low cooling performance) sub-heat exchanger C_S is supplied to the engine 1 before relatively low-temperature cooling water that has passed through the large capacity (high cooling performance) sub-heat exchanger C_L is supplied to the engine 1.

[0057] In the embodiment, since both the first type of sub-heat exchanger H and the second type of sub-heat exchangers C are used as the sub-heat exchangers of the engine cooling system, the fourth predetermined value T4 is set between the second predetermined value T2 and the third predetermined value T3, the latter being the boundary based on which it is determined whether cooling water is to be supplied to both the first type of sub-heat exchanger H and the second type of sub-heat exchanger(s) C, or to only the first type of sub-heat exchanger H. However, if only the second type of sub-heat exchangers C are used as the sub-heat exchangers of the engine cooling system, the third predetermined value T3 is not set, and the fourth predetermined value T4 is set between the first predetermined value T1 and the second predetermined value T2.

[0058] Next, when the water temperature rises to the fourth predetermined value T4 or more (see range d in Fig. 3), the supply of cooling water (refrigerant) to the large capacity sub-heat exchanger CL is started. Since the water temperature has risen to the forth predetermined value T4 or more at this time, even though relatively low-temperature cooling water that has passed through the large capacity sub-heat exchanger C_L is supplied to the engine, this would not prevent the engine temperature from rising sufficiently quickly, as long as the water temperature is not extremely low, i.e., as low as the temperature of cooling water in the refrigerant circulation circuit 21 that has passed through the radiator 20.

[0059] In this embodiment, of the second type of sub-heat exchangers C, the small capacity sub-heat exchanger C_S comprises the engine oil cooler 30, and the large capacity sub-heat exchanger C_L comprises the heater core 50. In order to supply cooling water to the engine oil cooler 30, the valve 32 is opened, and to supply cooling water to the heater core 50, the valve 52 is opened.

[0060] Lastly, when the water temperature rises to the second predetermined value T2 or more (see range e in Fig. 3), the supply of cooling water to the radiator 20 is started. Since the water temperature has risen to the second predetermined value T2 or more at this time, which means that the engine has already warmed up sufficiently, there is no problem with supplying, to the engine 1, low-temperature cooling water that has passed through the radiator 20. Cooling water is thereafter used to cool the engine.

[0061] The graph of Fig. 2 shows the cylinder (liner) temperature when, after the engine starts to warm up, cooling water is supplied only to the returned exhaust gas cooler 40 while stopping the supply of cooling water to the radiator 20. The line indicated by X in Fig. 2 shows the behavior of the cylinder temperature when only the valve 42 is opened with the other valves closed. The line indicated by X + Y in the figure shows the cylinder temperature behavior when the valves 42 and 52 are opened with the other valve closed. The line indicated by X + Y + Z shows the cylinder temperature behavior when all of the valves 42, 52 and 22 are opened

[0062] The line indicated by X + Y + Z represents a situation in which, since cooling water that has passed through the radiator 20 is supplied to the engine, the cylinder temperature rises slowly. The line indicated by X + Y shows a situation in which, since cooling water is supplied to both the returned exhaust gas cooler 40 and the heater core 50, but is not supplied to the radiator 20, the cylinder temperature rises faster than in the situation shown by line indicated by X + Y + Z. The line indicated by X show a situation in which, since cooling water is supplied to only the returned exhaust gas cooler 40, and not to the heater core 50 and the radiator 20, the cylinder temperature rises fastest. Also, in the situation represented by the line indicated by X, the amount of temporary decrease in cylinder temperature when the supply of cooling water to the engine 1 is started (i.e., the amount of undershoot at the time indicated by symbol a in the figure) is also small.

[0063] It is possible to improve the fuel economy during the warm-up of the engine by quickly increasing the temperature of the cylinder liner because the cylinder liner temperature affects the friction greatly. One way to quickly increase the cylinder liner temperature during warm-up would be to minimize or stop the flow of refrigerant in the engine during warm-up, thereby intentionally creating a non-uniform temperature distribution in the engine, i.e., intentionally preventing heat transfer from high-temperature to low-temperature engine portions.

[0064] However, the flow of low-temperature cooling water into the engine from the refrigerant circulation circuit including the radiator is automatically controlled by a thermostat, and also the refrigerant circulation circuit including the radiator has a large capacity enough to cool the engine, which means that this circuit is high in flow rate and large in the amount of heat dissipation. Therefore, when the thermostat is opened, even if the degree of opening is very small, a relatively large amount of low-temperature cooling water flows into the engine in a short period of time, so that the engine, which has been heated quickly up to this point, is temporarily cooled excessively. It is considered that this excessive cooling is related to, e.g., the amount of cooling water flowing into the engine per unit time, and the temperature of cooling water that has been cooled by heat dissipation in the heat exchanger.

[0065] In order to overcome the above problem, according to the present invention, after the water temperature at the engine 1 has risen to some extent (i.e., to the first predetermined value T1) by engine warm-up acceleration control in which the supply of cooling water from the refrigerant circulation circuit 21 including the radiator 20 is limited,, instead of directly opening a water flow control valve corresponding to the thermostat of a conventional radiator circuit, cooling water is first supplied to at least one sub-heat exchanger having lower cooling performance (i.e., lower flow rate and smaller amount of heat dissipation) than the radiator 20 of the refrigerant circulation circuit 21, and/or to a sub-heat exchanger configured to increase, instead of decrease, the temperature of cooling water passing therethrough, until the water temperature rises to a sufficient level (second predetermined value T2), which means that the engine has warmed up sufficiently. Cooling water is then suppled to the refrigerant circulation circuit 21 including the radiator 20.

[0066] In one arrangement of the present invention, the engine cooling system includes two heat exchangers different in cooling performance from each other, and during the warm-up of the engine, the heat exchanger lower in cooling performance is used first. In another arrangement, the engine cooling system includes a water temperature decreasing heat exchanger and a water temperature increasing heat exchanger, and during the warm-up of the engine, the water temperature increasing heat exchanger is used first. In either arrangement, it is possible to prevent an excessive decrease (undershoot) in temperature of the engine cylinder.

[0067] For the above purpose, the sub-refrigerant circulation circuit(s) including the sub-heat exchanger(s) configured to decrease the water temperature needs to be lower in cooling performance than the refrigerant circulation circuit 21 including the radiator 20 as a main cooling unit. A sub-refrigerant circulation circuit is lower in cooling performance than the refrigerant circulation circuit 21 if, for example, the amount of cooling water flowing out of the sub-heat exchanger per unit time, namely the amount of cooling water flowing into the engine 1, is smaller than the amount of cooling water flowing out of the circuit 21. Also, the temperature of cooling water (refrigerant) which has passed through the sub-heat exchanger(s) and is cooled is preferably higher than the temperature of cooling water (refrigerant) which has passed through the radiator 20 as a main cooling unit.

[0068] It is possible to realize the above-mentioned smaller inflow or outflow amount of cooling water per unit time by making the water flow resistance of the sub-refrigerant circulation circuit(s) including the sub-heat exchanger(s) larger than the water flow resistance of the refrigerant circulation circuit 20 including the radiator 20 as a main cooling unit, specifically for example, by making the diameter of the piping in the core of the sub-heat exchanger(s) smaller than the diameter of the piping in the radiator 20 as a main cooling unit.

[0069] Also, it is possible to realize the above-mentioned higher temperature of cooling water after being cooled in the sub-heat exchanger(s) by making the capacity of the sub-heat exchanger(s) smaller than the capacity of the radiator 20 as a main cooling unit. Specifically for example, by shortening the piping of the sub-refrigerant circulation circuit(s) including the sub-heat exchanger(s), it is possible to reduce the amount or area of heat dissipation.

[0070] For example, since the piping in the heater core 50, which is used as one of the sub-heat exchangers in the embodiment, is smaller in diameter than the piping in the core of the radiator 20, and also the volume of the entire heater core 50 is smaller than that of the radiator 20, the water flow resistance of the heater core 50 tends to be larger than that of the radiator 20, and the amount of heat dissipation tends to be smaller than that of the radiator 20. Depending on the position where the heater core 50 is placed, the piping of the sub-refrigerant circulation circuit 51 including the heater core 50 may be longer than the piping of the refrigerant circulation circuit 21 including the radiator 20. However, in this case, since the longer the piping of a circuit, the larger the water flow resistance of the circuit, the cooling performance of the sub-refrigerant circulation circuit 51 would never exceed that of the refrigerant circulation circuit 21.

[0071] If a plurality of sub-refrigerant circulation circuits including sub-heat exchangers configured to decrease the temperature of a refrigerant are used, in addition to setting the total cooling capacity of the sub-heat exchangers smaller than the cooling capacity of the radiator 20, the cooling capacities of the individual sub-refrigerant circulation circuits are preferably determined so as to differ from each other.

[0072] In the above embodiment, the engine oil cooler 30, the returned exhaust gas cooler 40, and the heater core 50 are used as sub-heat exchangers. In particular, the returned exhaust gas cooler 40 is used as a first type of sub-heat exchanger H (configured to increase the temperature of a refrigerant), and the engine oil cooler 30 and the heater core 50 are used as second type of sub-heat exchangers C (configured to decrease the temperature of a refrigerant). However, sub-heat exchangers which can be used in the engine cooling system of the present invention are not limited to those disclosed in the embodiment, and various heat exchanges may be used.

[0073] For example, the engine cooling system according to the present invention may include a single first type of sub-heat exchanger H while not including a second type of sub-heat exchanger C; may include a plurality of first type of sub-heat exchangers H while not including a second type of sub-heat exchanger C; may include a single second type of sub-heat exchanger C while not including a first type of sub-heat exchanger H; or may include a plurality of second type of sub-heat exchangers C while not including a first type of sub-heat exchanger H.

[0074] Other sub-heat exchangers which can be used in the engine cooling system include, for example, a liquid-cooling intercooler configured to cool intake air with the same refrigerant as used in the refrigerant circulation circuit 21 including the radiator 20, or a liquid-cooling transmission oil cooler configured to cool, with the same refrigerant as used in the refrigerant circulation circuit 21, the lubricating oil of a transmission to which the driving force of the engine is transmitted. One or more of the sub-heat exchangers of the present invention may be selected from the above-mentioned various sub-heat exchangers.

[0075] While, in the above embodiment, the engine cooling system of the present invention includes, as a liquid-cooling device, a water-cooling device in which cooling water is used as a refrigerant, the engine cooling system may include a cooling device in which a different refrigerant is used, such as an oil-cooling device in which lubricating oil is used as a refrigerant.

DESCRIPTION OF REFERENCE NUMERALS

[0076]

1: engine
2: piston
3: combustion chamber
4: intake passage
5: exhaust passage
6: intake valve
7: exhaust valve
8: ignition device 8
9: intake air temperature sensor
10: cooled portion
11: pump device (water pump)
12: water temperature sensor
15: exhaust gas recirculation device
16: exhaust gas return passage
17: exhaust return valve
20: radiator
21: refrigerant circulation circuit
22: valve
30: engine oil cooler (sub-heat exchanger)
31: sub-refrigerant circulation circuit
32: valve
40: returned exhaust gas cooler (sub-heat exchanger)
41: sub-refrigerant circulation circuit
42: valve
50: heater core (sub-heat exchanger)
51: sub-refrigerant circulation circuit
52: valve
53: air conditioner
60: electronic control unit
61: passenger compartment air conditioning switch
62: passenger compartment fan switch
63: passenger compartment temperature detecting means
64: outside air temperature detecting means
H: first type of sub-heat exchanger (configured to increase the temperature of a refrigerant)
C: second type of sub-heat exchanger (configured to decrease the temperature of a refrigerant)
C_S: small capacity sub-heat exchanger
C_L: large capacity sub-heat exchanger

Claims

1. An engine cooling system comprising:

a pump device configured to feed a refrigerant;
a cooled portion of an engine configured to be cooled by heat exchange with the refrigerant;
a radiator configured to cool the refrigerant;
a refrigerant circulation circuit through which the pump device, the cooled portion, and the radiator are connected together, and in which the refrigerant circulates;
at least one sub-refrigerant circulation circuit to which the refrigerant is supplied, and which includes a sub-heat exchanger lower in heat exchange performance than the radiator; and
a refrigerant temperature obtaining means for obtaining information correlated to a temperature of the refrigerant at the cooled portion,
wherein the engine cooling system is configured:

such that, during warm-up of the engine, if the temperature of the refrigerant at the cooled portion is less than a first predetermined value, supply of the refrigerant to the radiator and the sub-heat exchanger is reduced, and when the temperature of the refrigerant at the cooled portion rises to the first predetermined value or more, the reduction of supply of the refrigerant is lifted; and

such that, when lifting the reduction of supply of the refrigerant, if the temperature of the refrigerant at the cooled portion is less than a second predetermined value higher than the first predetermined value, supply of the refrigerant to the radiator is stopped while the refrigerant is supplied to the sub-heat exchanger, and if the temperature of the refrigerant at the cooled portion is equal to or higher than the second predetermined value, the refrigerant is supplied to the radiator.

2. The engine cooling system according to claim 1, wherein an amount of the refrigerant flowing out of the sub-heat exchanger per unit time is smaller than the amount of the refrigerant flowing out of the radiator per unit time.

3. The engine cooling system according to claim 1 or 2, wherein a temperature of the refrigerant that has passed through the sub-heat exchanger, and has been cooled by heat dissipation is higher than a temperature of the refrigerant that has passed through the radiator.

4. The engine cooling system according to any one of claims 1 to 3, configured such that, during warm-up of the engine, if the temperature of the refrigerant at the cooled portion is less than the first predetermined value, the supply of the refrigerant to the radiator and the sub-heat exchanger is stopped, and when the temperature of the refrigerant at the cooled portion rises to the first predetermined value or more, supply of the refrigerant to the sub-heat exchanger is started.

5. The engine cooling system according to claim 4, wherein the at least one sub-refrigerant circulation circuit comprises first and second sub-refrigerant circulation circuits, the sub-heat exchanger of the first sub-refrigerant circulation circuit comprises a first type of sub-heat exchanger configured to increase a temperature of the refrigerant that passes therethrough, and the sub-heat exchanger of the second sub-refrigerant circulation circuit comprises a second type of sub-heat exchanger configured to decrease a temperature of the refrigerant that passes therethrough, and

wherein the engine cooling system is configured such that, if the temperature of the refrigerant at the cooled portion is less than a third predetermined value between the first predetermined value and the second predetermined value, the refrigerant is supplied to the first type of sub-heat exchanger, and is not supplied to the second type of sub-heat exchanger, and if the temperature of the refrigerant at the cooled portion is equal to or higher than the third predetermined value, the refrigerant is supplied to the second type of sub-heat exchanger.

6. The engine cooling system according to claim 4 or 5, wherein the at least one sub-refrigerant circulation circuit comprises first and second sub-refrigerant circulation circuits, the sub-heat exchanger of the first sub-refrigerant circulation circuit comprises a small capacity sub-heat exchanger configured to decrease a temperature of the refrigerant that passes therethrough, and the sub-heat exchanger of the second sub-refrigerant circulation circuit comprises a large capacity sub-heat exchanger configured to decrease a temperature of the refrigerant that passes therethrough and higher in cooling performance than the small capacity sub-heat exchanger, and

wherein the engine cooling system is configured such that if the temperature of the refrigerant at the cooled portion is less than a fourth predetermined value between the first predetermined value and the second predetermined value, the refrigerant is supplied to the small capacity sub-heat exchanger, and is not supplied to the large capacity sub-heat exchanger, and if the temperature of the refrigerant at the cooled portion is equal to or higher than the fourth predetermined value, the refrigerant is supplied to the large capacity sub-heat exchanger.

7. The engine cooling system according to any one of claims 1 to 6, wherein the engine includes an exhaust gas recirculation device configured to return a portion of exhaust gas as returned exhaust gas into intake air,

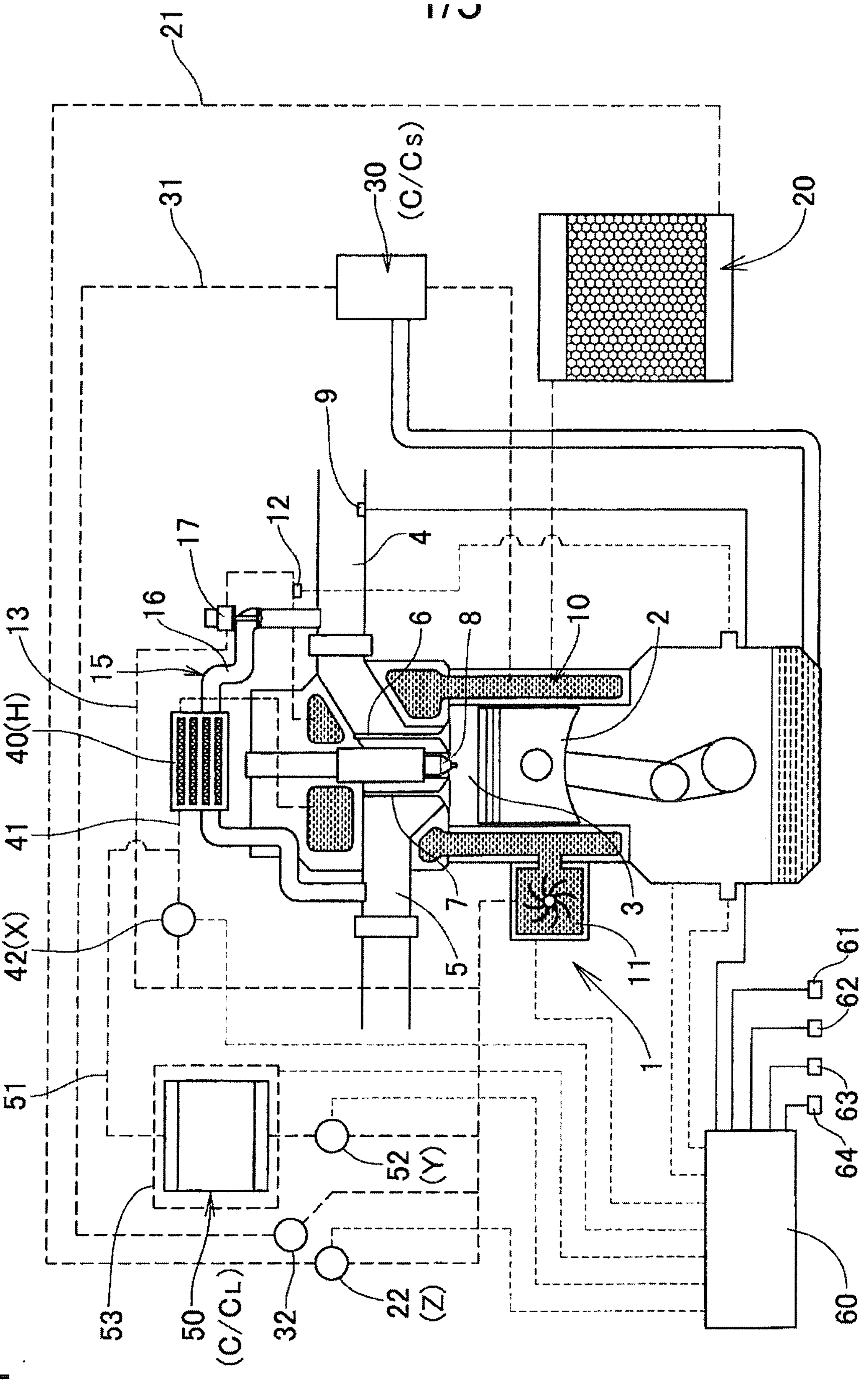
wherein the exhaust gas recirculation device includes a returned exhaust gas cooler of a liquid-cooling type configured to cool the returned exhaust gas with the refrigerant, and

wherein the at least one sub-refrigerant circulation circuit comprises a plurality of sub-refrigerant circulation circuits, and the sub-heat exchanger of one of the plurality of sub-refrigerant circulation circuits comprises the returned exhaust gas cooler.

8. The engine cooling system according to any one of claims 1 to 7, wherein the at least one sub-refrigerant circulation circuit comprises a plurality of sub-refrigerant circulation circuits, and the sub-heat exchanger of one of the plurality of sub-refrigerant circulation circuits comprises a heater core of an air conditioner of a vehicle on which the engine is mounted.

9. The engine cooling system according to any one of claims 1 to 8, wherein the at least one sub-refrigerant circulation circuit comprises a single sub-refrigerant circulation circuit, or a plurality of sub-refrigerant circulation circuits, and the sub-heat exchanger of the single sub-refrigerant circulation circuit, or each of the sub-heat exchanges of at least some of the plurality of sub-refrigerant circulation circuits comprises one of:

a liquid-cooling engine oil cooler configured to cool lubricating oil for the engine with the refrigerant;
a liquid-cooling intercooler configured to cool intake air with the refrigerant; and
a liquid-cooling transmission oil cooler configured to cool, with the refrigerant, lubricating oil for a transmission to which a driving force of the engine is transmitted.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7
3
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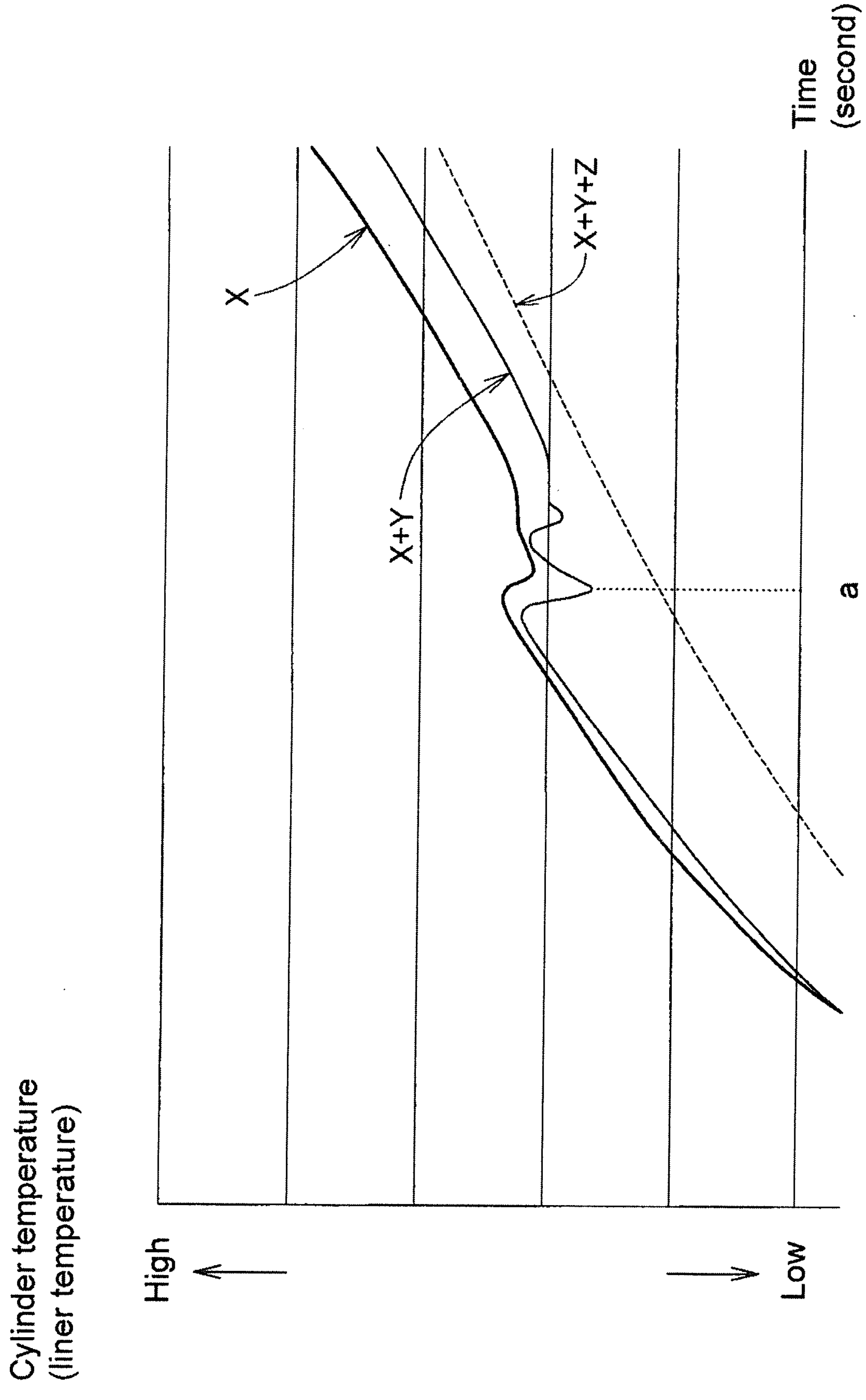
32
22 (Z)
60

FIG. 1

FIG. 2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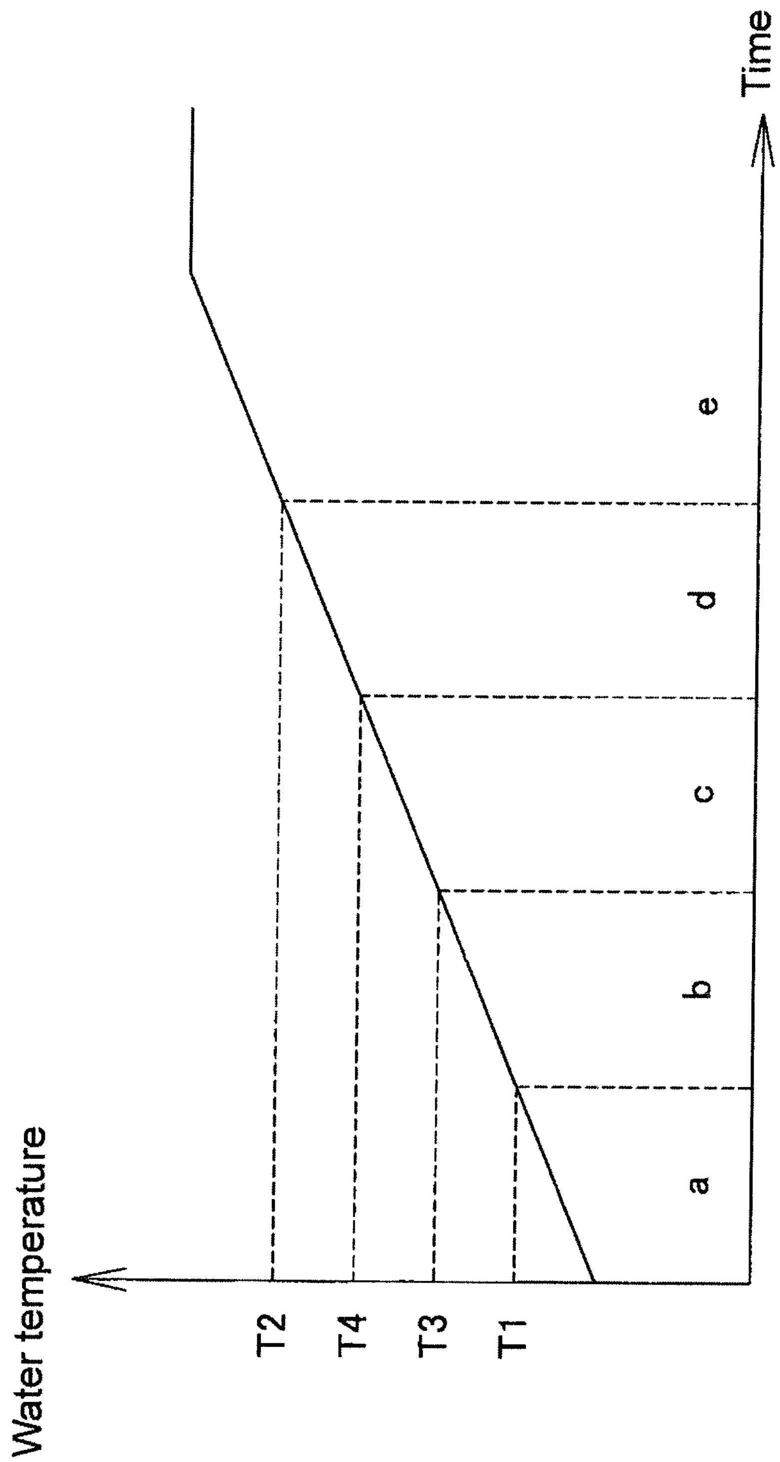
(liner temperature)
High
Low
Time
(second)
X
X+Y
X+Y+Z
a

FIG. 3



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2018/006237

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. F01P7/16(2006.01)i, F01P3/18(2006.01)i, F01P3/20(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)
Int.Cl. F01P7/16, F01P3/18, F01P3/20

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2018
Registered utility model specifications of Japan	1996-2018
Published registered utility model applications of Japan	1994-2018

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.
X Y	JP 2013-127224 A (TOYOTA MOTOR CORPORATION) 27 June 2013, paragraphs [0014]-[0027], [0039]-[0055], [0063]-[0080], fig. 1-4 (Family: none)	1-7 8-9
Y	JP 2013-87761 A (DENSO CORPORATION) 13 May 2013, paragraphs [0079]-[0081], fig. 6 (Family: none)	8-9
A	JP 2017-2787 A (TOYOTA MOTOR CORPORATION) 05 January 2017 & US 2016/0363038 A1 & EP 3103981 A1 & CN 106246322 A	1-9

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

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Date of the actual completion of the international search	Date of mailing of the international search report
13.04.2018	24.04.2018

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	 Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2018/006237

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2014/192747 A1 (NISSAN MOTOR CO., LTD.) 04 December 2014 (Family: none)	1-9

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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