



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
15.06.2011 Bulletin 2011/24

(51) Int Cl.:
F01P 7/16 (2006.01)

(21) Application number: **10191902.5**

(22) Date of filing: **19.11.2010**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(72) Inventors:
• **Onozawa, Satoru**
Kariya-shi Aichi 448-8650 (JP)
• **Suzuki, Takashi**
Toyota-shi Aichi 471-8571 (JP)

(30) Priority: **24.11.2009 JP 2009266408**

(74) Representative: **Kramer - Barske - Schmidtchen**
European Patent Attorneys
Landsberger Strasse 300
80687 München (DE)

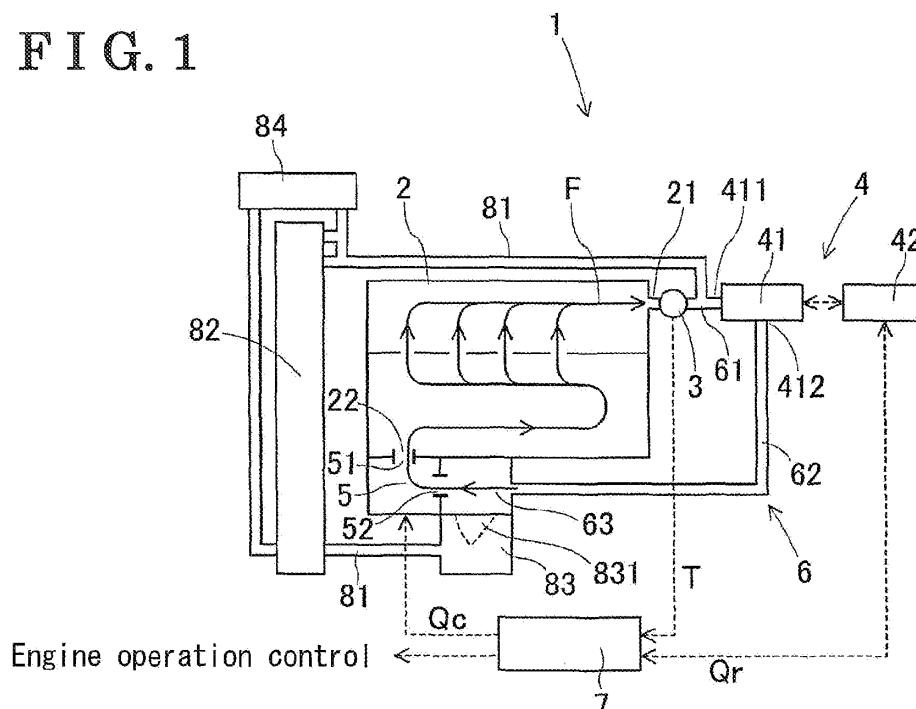
(71) Applicant: **AISIN SEIKI KABUSHIKI KAISHA**
Kariya-shi, Aichi 448-8650 (JP)

(54) **Cooling system for engine**

(57) A cooling system (1) includes a cooling portion (2) for flowing a coolant therethrough, a coolant sensitive sensor portion (3) detecting a temperature of the coolant, a heat exchanging device (4) using a heat of the coolant, a circulation flow varying device (5) for varying a circulation flow, a circulation path (6) for flowing the coolant therethrough, and a controller (7) for regulating the circulation flow by controlling the circulation flow varying device while referring to the temperature of the coolant

upon a receipt of a request for a requested flow from the heat exchanging device. The controller (7) determines a condition for warming-up when the warming-up of the engine is performed in accordance with the temperature of the coolant, controls the circulation flow varying device for warming-up the engine without circulating the coolant, and increases the circulation flow to the requested flow for a predetermined period of time when the requested flow is requested during the warming-up.

FIG. 1



Description

TECHNICAL FIELD

[0001] This disclosure relates to a cooling system for cooling an engine by circulating a coolant. More particularly, the disclosure pertains to a cooling system for an engine which includes a heat exchanging device which uses the heat of a coolant.

BACKGROUND DISCUSSION

[0002] Known water-cooling type cooling systems for cooling an engine by compulsorily circulating a coolant are widely in application. A mechanical water pump which is actuated by a crankshaft of the engine, or an electric water pump which is actuated by an electric power supplied from a vehicle mounted battery is generally applied to circulate the coolant. JPH08-14043A (hereinafter referred to as Patent reference 1) discloses a cooling system of this kind which enhances an efficiency of warming-up without circulating a coolant until the water temperature reaches a predetermined level at an warming-up of an engine.

[0003] According to a water pump control apparatus for an internal combustion disclosed in Patent reference 1, an electric motor is applied to a water pump for circulating a coolant, and the electric motor is controlled by a control means in accordance with the temperature of the coolant detected by a temperature sensor positioned in the vicinity of an outlet port for the coolant. According to the disclosure of Patent reference 1, an operation of the water pump is stopped when the temperature of the coolant is equal to or lower than a lower limit temperature required for a normal start of the engine. When the temperature of the coolant is higher than the lower limit temperature for the normal start of the engine and equal to or lower than a higher limit temperature for accelerating warming-up, the water pump is rotated at high speeds. Thus, a cranking time for a starter and a time for a self operation of the engine are shortened by stopping the operation of the water pump and a smooth engine operation is performed by swiftly warming-up the entire engine by rotating the water pump at high speeds.

[0004] JP2008-303775A (hereinafter referred to as Patent reference 2) discloses a cooling system for an internal combustion which includes a water level detection means provided at a portion of a coolant conduit, and a boiling detection means which detects that the coolant boils based on an increasing rate of the water level. Patent reference 2 discloses that a response of the detection that the coolant boils based on the water level is faster than a response of the detection that the coolant boils based on the temperature. Particularly, it is disclosed that the detection based on the water level is notably more responsive than the detection based on the temperature when the water pump is stopped during the warming-up of the engine, or the like. Further, it is dis-

closed that the boiling state of the coolant can be detected promptly to increase a flow of the coolant thus to decline the water temperature when the water pump is stopped. Namely, reliability when performing a warm-up of the engine while stopping the water pump is enhanced according to the disclosure of Patent reference 2.

[0005] On the other hand, generally, a heat of the coolant is applied for defrosting or heating the vehicle, which is favorable in terms of energy efficiency. For example, the construction disclosed in Patent reference 1 includes an air conditioner for heating besides a radiator for radiating the heat of the coolant. The air conditioner for heating uses a part of the coolant as a heat source.

[0006] In a case where a heat exchanging means requests a circulation flow during a warming-up of the engine without circulating the coolant in a known cooling system which includes the heat exchanging means such as the air conditioner for heating, a trouble may be caused if the coolant is circulated in response to the request of the heat exchanging means. Conditions for the warming-up when warming-up the engine, for example, idle speed, fuel injection amount, an ignition timing, or the like, are determined in accordance with the temperature of the coolant to be controlled. In those circumstances, the temperature of the coolant is generally detected at a point of a coolant temperature sensitive sensor portion positioned at an outlet port of an engine cooling portion, and a high temperature coolant in the engine flows to the sensor portion first after starting a circulation and next a lower temperature coolant outside the engine flows to the sensor portion. Thus, a fluctuation of the detected water temperature is increased so that the conditions for the warming-up when warming-up the engine are assumed to be unstable and a control for the warming-up is assumed to be difficult. Particularly, when the requested flow is suddenly circulated in a state where the warming-up is proceeded to some extent, the detected water temperature is largely fluctuated, which may influence the engine. As a countermeasure against the foregoing drawback, the fluctuation of the water temperature may be reduced if the warming-up is performed while circulating the coolant. However, the efficiency of the warming-up is declined by a degree that the heat is radiated from the coolant by the circulation of the coolant.

[0007] A need thus exists for a cooling system for an engine which stably controls a warming-up of the engine even if a coolant is circulated when a circulation flow of the coolant is requested from a heat exchanging device when the warming-up of the engine is performed without circulating the coolant and which does not influence the engine.

SUMMARY

[0008] In light of the foregoing, the disclosure provides a cooling system for an engine, which includes a cooling portion formed at the engine for flowing a coolant there-through, a coolant sensitive sensor portion detecting a

temperature of the coolant, a heat exchanging device using a heat of the coolant, a circulation flow varying device for varying a circulation flow of the coolant, a circulation path for flowing the coolant therethrough via the cooling portion, the coolant sensitive sensor portion, the heat exchanging device, and the circulation flow varying device, and a controller for regulating the circulation flow of the coolant by controlling the circulation flow varying device while referring to the temperature of the coolant upon a receipt of a request for a requested flow from the heat exchanging device. The controller determines a condition for warming-up the engine when the warming-up of the engine is performed in accordance with the temperature of the coolant, controls the circulation flow varying device for warming-up the engine without circulating the coolant, and increases the circulation flow to the requested flow for a predetermined period of time in a case where the requested flow is requested during the warming-up operation of the engine.

[0009] According to the disclosure, the cooling system for the engine includes cooling portion of the engine, the coolant sensitive sensor portion, the heat exchanging device, the circulation flow varying device, the circulation path, and the controller. The controller determines the condition for warming-up the engine when warming-up the engine in accordance with the temperature of the coolant, warms-up the engine without circulating the coolant by controlling the circulation flow varying device, and increases the circulation flow to the requested flow for the predetermined period of time when receiving a request of the requested flow from the heat exchanging device during the warming-up of the engine. Namely, the circulation flow of the coolant less than the requested flow starts to flow after receiving the request. Thus, the coolant positioned outside the engine which is not warmed by the warming-up of the engine slowly passes through cooling portion of the engine and reaches the coolant sensitive sensor portion after being warmed-up. To the contrary, according to known apparatuses which control the circulation flow to be the requested flow immediately, the coolant positioned outside the engine passes through cooling portion of the engine at a speed that is too fast to warm up the coolant sufficiently. Accordingly, with the construction of the disclosure, a difference between the temperature of the coolant warmed up in the engine from the start of the warming-up of the engine and the temperature of the coolant initially positioned outside the engine and warmed up after passing through cooling portion of the engine is assumed to be smaller compared to the known apparatuses. Further, according to the construction of the disclosure, the fluctuation of the water temperature detected at the coolant sensitive sensor portion is assumed to be smaller, the control of the warming-up operation of the engine is assumed to be stable, which does not influence the engine.

[0010] According to another aspect of the disclosure, the controller increases the circulation flow stepwise. According to still another aspect of the disclosure, the con-

troller increases the circulation flow proportionally to an elapsed time. According to further aspect of the disclosure, the controller increases the circulation flow in accordance with a characteristic of a first order lag filter.

[0011] According to the disclosure, the controller increases the circulation flow stepwise. According to the disclosure, the controller increases the circulation flow proportionally to the elapsed time. Further, according to the disclosure, the controller increases the circulation flow in accordance with the characteristic of the first order lag filter. According to the foregoing constructions of the disclosure, the circulation flow of the coolant less than the requested flow is started to flow after receiving the request of the requested flow from the heat exchanging device, and the circulation flow of the coolant is increased to the requested flow amount for the predetermined period of time. Thus, according to the foregoing constructions of the disclosure, the coolant positioned outside the engine, which is not warmed by the warming-up of the engine slowly, passes through cooling portion of the engine and reaches the coolant sensitive sensor portion after being warmed-up. A difference between the temperature of the coolant warmed up in the engine and the temperature of the coolant initially positioned outside the engine and warmed up after passing through cooling portion of the engine is assumed to be smaller compared to the known apparatuses. Further, according to the construction of the disclosure, the fluctuation of the water temperature detected at the coolant sensitive sensor portion is assumed to be smaller, the control of the warming-up operation of the engine is assumed to be stable, which does not influence the engine.

[0012] According to further aspect of the disclosure, the controller regulates the circulation flow with a feedback control to limit a fluctuation of the temperature of the coolant.

[0013] According to the disclosure, the controller regulates the circulation flow by a feedback control to restrict the fluctuation of the temperature of the coolant. This enables to securely restrict the fluctuation of the temperature of the coolant within a range which does not influence the control of the warming-up of the engine and to respond to the request from the heat exchanging device by swiftly increasing the circulation flow within the range which does not influence the control of the warming-up of the engine.

[0014] According to further aspect of the disclosure, the controller determines the condition for warming-up the engine in accordance with an amended temperature of the coolant which is obtained by filtering the temperature of the coolant after increasing the circulation flow to the requested flow.

[0015] According to the disclosure, the cooling system for the engine includes the cooling portion of the engine, the coolant sensitive sensor portion, the heat exchanging device, the circulation flow varying device, the circulation path, and the controller. The controller determines the condition for warming-up the engine when warming-up

the engine in accordance with the temperature of the coolant, warms-up the engine without circulating the coolant by controlling the circulation flow varying device, and increases the circulation flow to the requested flow immediately when receiving a request of the requested flow from the heat exchanging device during the warming-up of the engine, and determines the condition for warming-up in accordance with the modified temperature of the coolant which changes gradually compared to the actually detected temperature of the coolant by applying the filtering processing to the temperature of the coolant thereafter. Namely, because the condition for the warming-up operation of the engine is determined in accordance with the modified temperature of the coolant which changes more gradually compared to the actually detected temperature of the coolant after starting the circulation of the coolant, the control of the warming-up is not influenced. Further, by immediately increasing the circulation flow to the requested flow, the cooling system for the engine respond to the request from the heat exchanging device.

[0016] According to another aspect of the disclosure, a cooling system for an engine includes a cooling portion formed at the engine for flowing a coolant therethrough, a coolant sensitive sensor portion detecting a temperature of the coolant, a heat exchanging device using a heat of the coolant, a circulation flow varying device for varying a circulation flow of the coolant, a circulation path for flowing the coolant therethrough via the cooling portion, the coolant sensitive sensor portion, the heat exchanging device, and the circulation flow varying device, and a controller for regulating the circulation flow of the coolant by controlling the circulation flow varying device while referring to the temperature of the coolant upon a receipt of a request for a requested flow from the heat exchanging device. The controller determines a condition for warming-up the engine when the warming-up of the engine is performed in accordance with the temperature of the coolant, controls the circulation flow varying device for warming-up the engine without circulating the coolant, and increases the circulation flow to the requested flow immediately in a case where the requested flow is requested during the warming-up operation of the engine, and determines the condition for the warming-up of the engine in accordance with an amended temperature of the coolant which is obtained by filtering the temperature of the coolant and changes gradually thereafter.

[0017] According to further aspect of the disclosure, the circulation flow varying device corresponds to an electric water pump which varies a flow amount, a mechanical water pump actuated by the engine, or a flow regulating valve.

[0018] According to the disclosure, the electric water pump which can change the flow amount, the mechanical water pump actuated by the engine, or the flow regulating valve may be applied as the circulation flow varying device. According to the disclosure, the construction of the cooling system for the engine is not limited to the struc-

tures and variations of the water pump and is applicable to a wide range.

[0019] According to the disclosure, the cooling system for the engine includes a heat radiation path being branched from the circulation path between the coolant sensitive sensor portion and the heat exchanging device and joining the circulation path at a suction port of the electric water pump, a radiator provided within the heat radiation path, and a thermostat valve. The circulation flow varying device corresponds to an electric water pump which varies a flow amount, the coolant sensitive sensor portion is positioned at an outlet port of the cooling portion of the engine, and an outlet port of the electric water pump is positioned at an inlet port of the cooling portion.

[0020] According to the disclosure, the electric water pump which varies the flow amount is applied as the circulation flow varying device. Further, the cooling system includes the heat radiation path which branches from the circulation path and joins the circulation path after passing through the radiator and the thermostat valve. The thermostat valve automatically adjusts an opening degree thereof in accordance with the temperature of the coolant, the flow of the coolant in the heat radiation path increases as the temperature of the coolant increases to increase the heat radiation from the radiator. Accordingly, the heat of the coolant is preferentially radiated at the heat exchanging device, and the excessive heat which is not radiated at the heat exchanging device is radiated at the radiator. The constructions of the cooling system according to the disclosure may be varied with the construction which radiates the heat only with the heat exchanging device, the construction in which the heat is preferentially radiated at the heat exchanging device and the excessive heat which is not radiated at the heat exchanging device is radiated at the radiator, and the construction which radiates the heat by both of the heat exchanging device and the radiator.

[0021] According to another aspect of the disclosure, the engine is mounted to a vehicle and the heat exchanging device corresponds to either a heater or a defroster.

[0022] According to the disclosure, the engine is mounted to the vehicle, and the heater or the defroster is applied as the heat exchanging device. The cooling system of the disclosure is applicable to the cooling system which is configured to cool the engine mounted to the vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The foregoing and additional features and characteristics of this disclosure will become more apparent from the following detailed description considered with the reference to the accompanying drawings, wherein:

[0024] Fig. 1 is a schematic view of a cooling system for an engine according to a first embodiment disclosed here;

[0025] Fig. 2 is an explanatory graph of a first control-

ling method for increasing a circulation flow of coolant for a predetermined period of time by an engine control ECU according to the first embodiment;

[0026] Fig. 3 shows a flow for a cooling control when warming-up the engine by the engine control ECU according to the first embodiment;

[0027] Fig. 4 is an explanatory graph showing effects when the circulation flow of the coolant is increased for the predetermined period of time by the engine control ECU as shown in Fig. 2;

[0028] Fig. 5 is an explanatory graph of a second controlling method for increasing a circulation flow of coolant proportionally to an elapsed time by the engine control ECU according to the first embodiment;

[0029] Fig. 6 is an explanatory graph of a third controlling method for increasing a circulation flow of coolant in accordance with characteristics of a first order lag filter by the engine control ECU according to the first embodiment;

[0030] Fig. 7 shows a flow for a cooling control when warming-up the engine by the engine control ECU according to a second embodiment; and

[0031] Fig. 8 is an explanatory graph showing effects when obtaining a modified water temperature by applying a filtering processing to the temperature of the coolant.

DETAILED DESCRIPTION

[0032] Embodiments of a cooling system for an engine will be explained with reference to illustrations of drawing figures as follows.

[0033] A first embodiment of the cooling system for the engine will be explained with reference to Figs. 1 to 6. As illustrated in Fig. 1, a cooling system 1 is configured to cool an engine mounted to a vehicle and to heat a vehicle compartment using a heat of a coolant. The cooling system 1 includes a water jacket 2, a coolant temperature sensitive sensor portion 3, a heater 4, an electric water pump 5, a circulation water path 6, an engine control ECU 7, a radiation water path 81, a radiator 82, and a thermostat valve 83.

[0034] The water jacket 2 serves as a cooling portion of the engine. The water jacket 2 is formed surrounding a cylinder of the engine and a coolant flows inside the water jacket 2. The coolant sensitive sensor portion 3, which detects a temperature T of the coolant, is positioned at an outlet port 21 of the water jacket 2. The heater 4 serves as a heat exchanging device. The heater 4 includes a heater core (i.e., serving as a heat exchanging body) 41 which takes in the heat of the coolant and a control unit 42 controlling an operation of the heater core 41. The electric power pump 5 serves as a circulation flow varying device which varies circulation flow Qc by controlling an input electric power. A vane pump, or a centrifugal pump, or the like, may be applied as the electric water pump 5. An outlet port 51 of the electric water pump 5 is connected to an inlet port 22 of the water jacket 2.

[0035] The circulation water path 6 is configured to allow the coolant to circulate through the water jacket 2, the coolant sensitive sensor portion 3, the heater core 41 of the heater 4, and the electric water pump 5. A flowing direction of the coolant is indicated with an arrow F in Fig. 1. The circulation water path 6 includes a first path 61 which connects the coolant sensitive sensor portion 3 and an inlet port 411 of the heater core 41 and a second path 62 which connects an outlet port 412 of the heater core 41 and a confluence portion 63. A heat radiation path 81 joins the circulation water path 6 at the confluence portion 63. The confluence portion 63 is connected to an inlet port 52 of the electric water pump 5.

[0036] The heat radiation path 81 branches from the first path 61 of the circulation path 6 and is connected to the thermostat valve 83 via the radiator 82. The heater core 41 of the heater 4 and the radiator 82 are arranged in parallel to each other with respect to the electric water pump 5. The radiator 82 includes an internal path through which the coolant passes to radiate the heat. The thermostat valve 83 is configured to automatically adjusting an opening degree thereof in accordance with the temperature of the coolant. An outlet port 831 whose opening degree is variable of the thermostat valve 83 opens to the confluence portion 63. A temperature sensitive portion of the thermostat valve 83 is positioned within the confluence portion 63. The thermostat valve 83 is configured to be closed at a low water temperature during the warming-up of the engine. The thermostat valve 83 is configured to automatically open when the water temperature rises in response to the operation of the engine thus to flow the coolant to the heat radiation path 81. Accordingly, the heat is radiated by the radiator 82. Further, a reservoir tank 84 which is connected to the heat radiation path 81 and the radiator 82 is provided to absorb changes in a level of the coolant in response to changes in temperature and to compensate for a shortage of the coolant.

[0037] The engine control ECU 7 is an electronic control unit for controlling an operation of the engine and serves as a controller for adjusting/regulating the circulation flow Qc of the coolant. The engine control ECU 7 is configured to receive information of the temperature T of the coolant from the coolant temperature sensitive sensor portion 3 and to receive information of a requested flow Qr necessary for heating the vehicle compartment from the control unit 42 of the heater 4. Further, the engine control ECU 7 controls the input electric power supplied to the electric water pump 5 to regulate the circulation flow Qc. The engine control ECU 7 controls the operation of the engine based on operational conditions of the engine in accordance with the temperature T. Control amounts controlled by the engine control ECU 7 includes the engine rotation speed, the fuel injection amount, and the ignition timing.

[0038] Further, the engine control ECU 7 determining the conditions for warming-up the engine in accordance with the temperature T and warms-up the engine without

circulating the coolant by controlling the electric water pump 5. That is, the engine control ECU 7 warms-up the engine when determining that the circulation flow Q_c is equal to zero ($Q_c = 0$). The foregoing warming-up operation is defined as a warming-up without coolant circulation. On the other hand, when the temperature T reaches a predetermined value (level), the engine control ECU 7 circulates the coolant by controlling the electric water pump 5 to continue the warming-up operation so that an entire system including the circulation path 6 is warmed-up. The foregoing warming-up operation is defined as a warming-up with coolant. The engine control ECU 7 controls the electric water pump 5 to increment the circulation flow Q_c to the requested flow Q_r for a predetermined period of time when receiving a request for the requested flow Q_r from the control unit 42 of the heater 4 during the warming-up without coolant circulation at which the circulation flow Q_c is equal to zero ($Q_c = 0$). The engine control ECU 7 includes a timer for timing an elapsed time t_x from a request time t_1 at which the requested flow Q_r is requested.

[0039] Referring to Fig. 2, a horizontal axis indicates a time t , a vertical axis indicates a flow Q , a dotted line indicates the requested flow Q_r , and a solid line indicates the circulation flow Q_c . The graph in Fig. 2 shows a case where the requested flow Q_r is requested at the request time t_1 during the warming-up without coolant circulation in which the circulation flow Q_c is equal to zero ($Q_c = 0$). As shown in Fig. 2, the engine control ECU 7 does not increase the circulation flow Q_c to the requested flow Q_r immediately at the request time t_1 and increases the circulation flow Q_c to a reduced flow Q_d which is less than the requested flow Q_r . Thereafter, the circulation flow Q_c is increased from the reduced flow Q_d to the requested flow Q_r at a time t_2 at which the elapsed time t_x reaches a predetermined period of time t_r . Namely, the engine control ECU 7 increases the circulation flow Q_c stepwise as a transitional transaction when increasing the circulation flow Q_c to the requested flow Q_r . In those circumstances, in a case where the requested flow Q_r is equal to or less than a predetermined flow Q_0 , the warming-up of the engine is continued maintaining the circulation flow Q_c to be zero ($Q_c = 0$).

[0040] The reduced flow Q_d , the predetermined period of time t_r , and the predetermined flow Q_0 may be defined as fixed amounts, however, preferably, may be defined to be variable in accordance with the temperature T and the requested flow Q_r at the timing. In order to reduce the fluctuation of the temperature T , the reduced flow Q_d may be reduced, the predetermined period of time t_r is elongated, and the predetermined flow Q_0 may be determined to be greater. To the contrary, the foregoing settings do not meet the request from the heater 4 and a start of the heater 4 is delayed. Thus, according to the construction of the embodiment, the appropriate reduced flow Q_d , the predetermined period of time t_r , and the predetermined flow Q_0 which enable to start the heater 4 swiftly while restricting the fluctuation of the temperature

T to be equal to or less than a predetermined level are determined so as not to influence the control of the warming-up of the engine. Those appropriate values may be obtained by experiments performed by changing various conditions, and may further be memorized as a map in the engine control ECU 7.

[0041] An operation of the cooling system 1 for the engine according to the first embodiment will be explained with reference to Fig. 3. As illustrated in Fig. 3, when the warming-up of the engine is started at Step S1, whether the control ECU 7 operates the warming-up without coolant circulation or the warming-up with coolant circulation is judged at Step S2. When the warming-up with coolant circulation is operated, the transaction proceeds to Step S8. When the warming-up without coolant circulation is operated, whether the requested flow Q_r is requested from the heater 4 is judged at Step S3. When the requested flow Q_r is not requested, the transaction advances to Step S7. When the requested flow Q_r is requested for the first time, a timer is started and the transaction advances to Step S4 after start timing the elapsed time t_x . When the requested flow Q_r continues, the transaction also advances to Step S4.

[0042] Next, whether the requested flow Q_r exceeds the predetermined flow Q_0 is judged at step S4. When the requested flow Q_r does not exceed the predetermined flow Q_0 , the transaction advances to step S7. When the requested flow Q_r exceeds the predetermined flow Q_0 , whether the elapsed time t_x timed by the timer is equal to or greater than the predetermined period of time t_r is judged at Step S5. In those circumstances, when the elapsed time t_x is equal to or greater than the predetermined period of time t_r , the transaction advances to step S8, and the transaction advances to step S6 when the elapsed time t_x is less than the predetermined period of time t_r . Accordingly, the transaction reaches one of Steps S6 to S8 eventually.

[0043] Under the conditions that the requested flow Q_r exceeding the predetermined flow Q_0 is received during the warming-up without coolant circulation and the elapsed time t_x is less than the predetermined period of time t_r , the transaction reaches Step S6. In those circumstances, the engine control ECU 7 controls the electric water pump 5 to change the circulation flow Q_c to the reduced flow Q_d . Under the conditions that warming-up without coolant circulation is operated and the requested flow Q_r is zero or equal to or less than predetermined flow Q_0 , the transaction reaches Step S7. In those circumstances, the engine control ECU 7 controls the circulation flow Q_c to be zero ($Q_c = 0$) and the operation of warming-up without coolant circulation continues. Under the conditions that the warming-up with coolant circulation is operated or when the requested flow Q_r exceeds the predetermined flow Q_0 and the elapsed time t_x is equal to or greater than the predetermined period of time t_r , the transaction reaches Step S8. The condition that the requested flow Q_r exceeds the predetermined flow Q_0 and the elapsed time t_x is equal to or greater than

the predetermined period of time t_r corresponds to a situation after the transitional transaction with the reduced flow Q_d for the predetermined period of time t_r is completed. In those circumstances, the engine control ECU 7 performs a control for a normal warming-up with coolant circulation. In other words, the engine control ECU 7 controls the circulation flow Q_c to immediately respond to changes in the requested flow Q_r .

[0044] One cycle of the control is completed at one of Steps S6 to S8, and the transaction returns to Step S2 to repeat the transactions of the control.

[0045] Advantages and effects of the cooling system 1 for the engine according to the first embodiment will be explained with reference to Fig. 4. Effects when the circulation flow Q_c is increased for the predetermined period of time based on Fig. 2 are shown in Fig. 4. The horizontal axis in Fig. 4 indicates time t and the vertical axis in Fig. 4 indicates the temperature T of the coolant detected by the coolant sensitive sensor portion 3. Fig. 4 shows an example in which the warming-up of the engine starts at a warm-up starting time t_0 and a request of the requested flow Q_r is received at a request time t_1 . A solid line (i.e., hereinafter referred to as line 1) in Fig. 4 shows changes of the temperature T of the coolant when the circulation flow Q_c is increased stepwise to the requested flow Q_r via the reduced flow Q_d from a state of the warming-up without coolant circulation based on Fig. 2. A dotted line (i.e., hereinafter referred to as line 2) in Fig. 4 shows changes of the temperature T of the coolant when a known control method for immediately increasing the circulation flow Q_c to the requested flow Q_r at the request time t_1 in the state of warming-up without coolant circulation. A double chain dotted line (i.e., hereinafter referred to as line 3) in Fig. 4 shows changes of the temperature of the coolant when a known control method for circulating the coolant is applied from the warm-up starting time t_0 .

[0046] First, comparing the line 1 and the line 2 to the line 3, effects of the warming-up without coolant circulation during which the coolant is not circulated will be explained as follows. The line 1 and the line 2 at which the warming-up without coolant circulation is performed show that the temperature T surge immediately after the warm-up starting time t_0 compared to the known control method for circulating the coolant indicated with line 3 in which the warming-up without coolant circulation is not performed. This indicates that an inside of the engine including a piston is swiftly warmed-up.

[0047] Next, comparing the line 1 and the line 2, effects of increasing the circulation flow Q_c stepwise will be explained as follows. The engine control ECU 7 immediately increases the circulation flow Q_c to the requested flow Q_r at the request time t_1 . Consequently, the temperature T rises to P1 in Fig. 4 during the coolant, which is warmed-up in the water jacket 2 of the engine from a start of an operation of the engine, flows, however, the temperature T declines to P2 in Fig. 4 after the coolant in the second path 62 outside the engine comes to flow

the coolant sensitive sensor portion 3, which causes a sharp fluctuation of the temperature. Thus, it becomes difficult for the engine control ECU 7 to determine stable conditions for the warming-up in accordance with the temperature T , the control of the warming-up is assumed to be difficult, which may influence the engine.

[0048] On the other hand, as indicated with line 1 in Fig. 4, the engine control ECU 7 increases the circulation flow Q_c to the reduced flow Q_d immediately after the request time t_1 . In consequence, the coolant positioned at the second path 62 outside the engine at the start of the operation of the engine reaches the coolant sensitive sensor portion 3 after being warmed up by slowly passing through the water jacket 2. Accordingly, as illustrated in Fig. 4, the fluctuation of the temperature T of the line 1 is assumed to be smaller than the fluctuation at the line 2, stable conditions for the warming-up can be determined, which does not influence the engine.

[0049] According to the first embodiment, the reduced flow Q_d for increasing the circulation flow Q_c stepwise for the predetermined period of time t_r includes one step. However, the circulation flow Q_c may be increased stepwise with plural steps. Further, with regard to the method for increasing the circulation flow Q_c for the predetermined period of time t_r , other methods may also be applied. Figs. 5 and 6 show examples of alternative methods for increasing the circulation flow Q_c for the predetermined period of time t_r .

[0050] As shown in Fig. 5, the circulation flow Q_c may be increased proportionally to the elapsed time t_x by the engine control ECU 7. As illustrated in Fig. 5, the engine control ECU 7 controls the electric water pump 5 to increase the circulation flow Q_c immediately after the request time t_1 with a constant inclination so as to reach the requested flow Q_r at time t_3 after elapsing the predetermined period of time t_r .

[0051] Further, Fig. 6 shows another control method for increasing the circulation flow Q_c in accordance with characteristics of a first order lag filter by the engine control ECU 7. As shown in Fig. 6, the engine control ECU 7 controls the electric water pump 5 to increase the circulation flow Q_c with certain increment amounts when starting to follow the characteristics of the first order lag filter immediately after the request time t_1 and to gradually reduce the increment amount to approximate the requested flow Q_r . In a case where the characteristics of the first order lag filter is applied as shown in Fig. 6, the circulation flow Q_c and the requested flow Q_r do not come to be equal to each other. However, a time during which the circulation flow Q_c and the requested flow Q_r are assumed to be substantially the same values, in other words, a time during which the circulation flow Q_c reaches a value within a range by which stable conditions for the warming-up are attained may be defined as the predetermined time.

[0052] Various control methods other than the foregoing examples may be applied for reaching the circulation flow Q_c to the requested flow Q_r for the predetermined

period of time.

[0053] A second embodiment for the cooling system for the engine will be explained with reference to Fig. 7. According to the second embodiment, a feedback control is applied for controlling the circulation flow Q_c of the coolant. Constructions of the cooling system according to the second embodiment are the same to the cooling system 1 according to the first embodiment shown in Fig. 1. A difference of the second embodiment from the first embodiment is a control method of the engine control ECU 7, that is, software. The constructions common to the first embodiment will not be repeated and only the differences of the second embodiment from the first embodiment will be explained hereinafter.

[0054] As illustrated in Fig. 7, upon a start of the warming-up at Step S11, the engine control ECU 7 compares the requested flow Q_r of the heater 4 to the circulation flow Q_c at the time at Step S12. When the requested flow Q_r is equal to or less than the circulation flow Q_c , because the request of the heater 4 is already satisfied, the transaction advances to Step S17 to control the electric water pump 5 to maintain the circulation flow Q_c . When the requested flow Q_r exceeds the circulation flow Q_c , the transaction advances to Step S13 to compare a fluctuation ΔT of the temperature T of the coolant detected by the coolant sensitive sensor portion 3 to an allowable upper limit value ΔT_U . When the fluctuation ΔT is assumed to be excessive exceeding the allowable upper limit value ΔT_U , the transaction advances to Step S15 to control the electric water pump 5 to reduce the circulation flow Q_c . Accordingly, the fluctuation ΔT of the temperature T is restrained.

[0055] When the fluctuation ΔT is equal to or less than the allowable upper limit value ΔT_U at Step S13, the transaction advances to Step S14 to compare the fluctuation ΔT of the temperature T to an allowable lower limit value ΔT_L which is smaller than the allowable upper limit value ΔT_U (i.e., $\Delta T_L < \Delta T_U$). When the fluctuation ΔT is assumed to be excessively small to be less than the allowable lower limit value ΔT_L , the transaction advances to Step S16 to control the electric water pump 5 to increase the circulation flow Q_c . Accordingly, the cooling system 1 is responsive to the request from the heater 4 quickly. Further, when the fluctuation ΔT is equal to or higher than the allowable upper limit value ΔT_U , the transaction advances to Step S17 because the fluctuation ΔT of the temperature T is appropriately maintained to control the electric water pump 5 to maintain the circulation flow Q_c . Because one cycle of the control is completed by one of Steps S15 to S17, the transaction returns to Step S12 to repeat the transactions of the control.

[0056] According to the flow for controlling the coolant of the second embodiment, the fluctuation ΔT of the temperature T of the coolant is securely controlled to be within the range between the allowable upper limit value ΔT_U and the allowable lower limit value ΔT_L , which do not influence the control of the warming-up of the engine. In addition to that, according to the second embodiment,

the cooling system 1 is responsive to the request from the heater 4 by swiftly increasing the circulation flow Q_c within an allowable range.

[0057] A third embodiment of the cooling system for the engine will be explained with reference to Fig. 8 as follows. According to the third embodiment, instead of regulating the circulation flow Q_c of the coolant, the temperature T to be detected is modified. Constructions of the cooling system according to the third embodiment are the same as the cooling system 1 according to the first embodiment shown in Fig. 1. A difference of the third embodiment compared to the first and second embodiments is a control method of the engine control ECU 7, that is, software. The constructions common to the first embodiment will not be repeated and only the differences of the third embodiment from the first and second embodiments will be explained hereinafter. According to the third embodiment, the engine control ECU 7 controls the electric water pump 5 to increase the circulation flow Q_c to the requested flow Q_r immediately when receiving the request of the requested flow Q_r from the heater 4 during the warming-up without coolant circulation. Thereafter, the temperature T of the coolant detected by the coolant sensitive sensor portion 3 is filtered to determine conditions for warming-up the engine in accordance with a gradually changing amended coolant temperature T_A of the coolant which is obtained by the filtering.

[0058] Effects of obtaining the amended temperature T_A of the coolant by filtering the temperature T of the coolant according to the third embodiment are shown in Fig. 8. Horizontal axes in Fig. 8 indicate time t . An upper portion of the graph in Fig. 8 shows changes in the circulation flow Q_c , and a lower portion of the graph in Fig. 8 shows changes in the temperature T of the coolant and the amended temperature T_A of the coolant. The request of the requested flow Q_r is received at a request time t_1 , and the requested flow Q_r returns to zero (0) at time t_4 . As shown in the upper portion of the graph, the engine control ECU 7 controls the electric water pump 5 so that the circulation flow Q_c immediately follows the requested flow Q_r in response to the changes in the requested flow Q_r . Further, as shown in the lower portion of the graph in Fig. 8, the engine control ECU 7 obtains the amended temperature T_A of the coolant (i.e., indicated with a dotted line) by filtering the detected temperature T (i.e., indicated with a solid line). The engine control ECU 7 determines conditions for the warming-up in accordance with the amended temperature T_A of the coolant which gradually changes after the request time t_1 .

[0059] Thus, according to the third embodiment, because the conditions for the warming-up is determined in accordance with the amended temperature which changes gradually compared to the actually detected temperature T , the control of the warming-up is not influenced. Further, by immediately increasing the circulation flow Q_c to the requested flow Q_r at the request time t_1 , the cooling system 1 is responsive to the request from the heater 4.

[0060] The electric water pump 5 is applied to the embodiments of the cooling system 1. Instead of the electric water pump 5, a mechanical water pump or a flow regulating valve, or the like, may also be applied. For example, an electrically controllable needle valve may be applied as the flow regulating valve to be controlled by the engine control ECU 7. According to the foregoing construction, by controlling the opening degree of the needle valve, the circulation flow Q_c can be regulated as desired within a range of an output amount of the mechanical water pump which is defined depending on a rotation speed of the engine.

[0061] Further, as a modified example of the embodiments, a bypass water path, which allows the coolant to return immediately from the outlet port 21 of the water jacket 2 to the confluence portion 63, may be provided to enhance the efficiency of the warming-up of the engine. The constructions of the embodiments are applicable to other structures.

[0062] According to the foregoing embodiments, the heater 4 serving as the heat exchanging device is provided. However, a defroster may be applied as the heat exchanging device instead of the heater and the defroster may be applied as a defroster 4 in Fig. 1.

[0063] It is explicitly stated that all features disclosed in the description and/or the claims are intended to be disclosed separately and independently from each other for the purpose of original disclosure as well as for the purpose of restricting the claimed invention independent of the composition of the features in the embodiments and/or the claims. It is explicitly stated that all value ranges or indications of groups of entities disclose every possible intermediate value or intermediate entity for the purpose of original disclosure as well as for the purpose of restricting the claimed invention, in particular as limits of value ranges.

Claims

1. A cooling system (1) for an engine, comprising:

a cooling portion (2) formed at the engine for flowing a coolant therethrough;
 a coolant sensitive sensor portion (3) detecting a temperature of the coolant;
 a heat exchanging device (4) using a heat of the coolant;
 a circulation flow varying device (5) for varying a circulation flow of the coolant;
 a circulation path (6) for flowing the coolant therethrough via the cooling portion, the coolant sensitive sensor portion (3), the heat exchanging device (4), and the circulation flow varying device (5); and
 a controller (7) for regulating the circulation flow of the coolant by controlling the circulation flow varying device (5) while referring to the temper-

ature of the coolant upon a receipt of a request for a requested flow from the heat exchanging device (4); wherein

the controller (7) determines a condition for warming-up the engine when the warming-up of the engine is performed in accordance with the temperature of the coolant, controls the circulation flow varying device (5) for warming-up the engine without circulating the coolant, and increases the circulation flow to the requested flow for a predetermined period of time in a case where the requested flow is requested during the warming-up operation of the engine.

2. The cooling system for the engine according to claim 1, wherein the controller (7) increases the circulation flow stepwise.

3. The cooling system for the engine according to claim 1, wherein the controller (7) increases the circulation flow proportionally to an elapsed time.

4. The cooling system for the engine according to claim 1, wherein the controller (7) increases the circulation flow in accordance with a characteristic of a first order lag filter.

5. The cooling system for the engine according to claim 1, wherein the controller (7) regulates the circulation flow with a feedback control to limit a fluctuation of the temperature of the coolant.

6. The cooling system for the engine according to claim 1, wherein the controller (7) determines the condition for warming-up the engine in accordance with an amended temperature of the coolant which is obtained by filtering the temperature of the coolant after increasing the circulation flow to the requested flow.

7. A cooling system for an engine, comprising:

a cooling portion (2) formed at the engine for flowing a coolant therethrough;
 a coolant sensitive sensor portion (3) detecting a temperature of the coolant;
 a heat exchanging device (4) using a heat of the coolant;
 a circulation flow varying device (5) for varying a circulation flow of the coolant;
 a circulation path (6) for flowing the coolant therethrough via the cooling portion (2), the coolant sensitive sensor portion (3), the heat exchanging device (4), and the circulation flow varying device (5); and
 a controller (7) for regulating the circulation flow of the coolant by controlling the circulation flow varying device (5) while referring to the temperature of the coolant upon a receipt of a request

for a requested flow from the heat exchanging device (4); wherein
the controller (7) determines a condition for warming-up the engine when the warming-up of the engine is performed in accordance with the temperature of the coolant, controls the circulation flow varying device (5) for warming-up the engine without circulating the coolant, and increases the circulation flow to the requested flow immediately in a case where the requested flow is requested during the warming-up operation of the engine, and determines the condition for the warming-up of the engine in accordance with an amended temperature of the coolant which is obtained by filtering the temperature of the coolant and changes gradually thereafter.

8. The cooling system for the engine according to any one of claims 1 to 7, wherein the circulation flow varying device (5) corresponds to an electric water pump which varies a flow amount, a mechanical water pump actuated by the engine, or a flow regulating valve.

9. The cooling system for the engine according to any one of claims 1 to 8 further comprising:

a heat radiation path (81) being branched from the circulation path (6) between the coolant sensitive sensor portion (3) and the heat exchanging device (4) and joining the circulation path (6) at a suction port of the electric water pump (5);
a radiator (82) provided within the heat radiation path (81); and
a thermostat valve (83); wherein
the circulation flow varying device (5) corresponds to an electric water pump which varies a flow amount, the coolant sensitive sensor portion (3) is positioned at an outlet port of the cooling portion (2) of the engine, and an outlet port of the electric water pump (5) is positioned at an inlet port of the cooling portion (2).

10. The cooling system for the engine according to any one of claims 1 to 9, wherein the engine is mounted to a vehicle and the heat exchanging device (4) corresponds to either a heater or a defroster.

50

55

FIG. 1

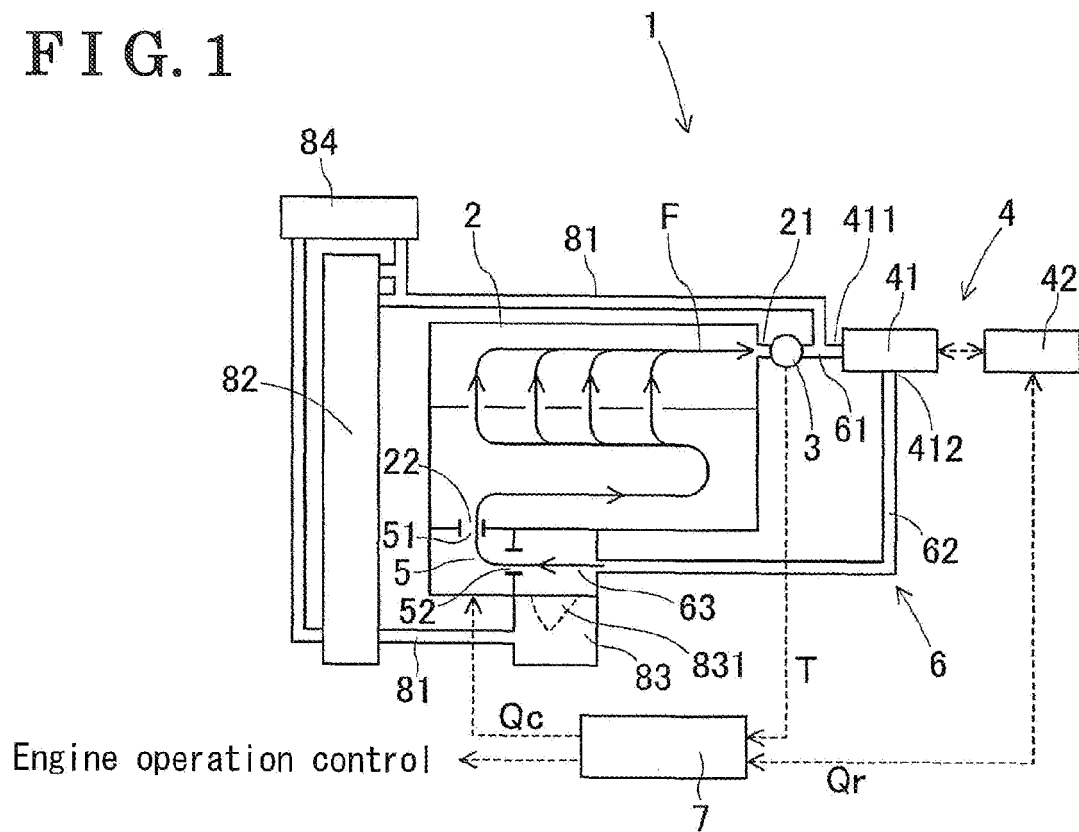


FIG. 2

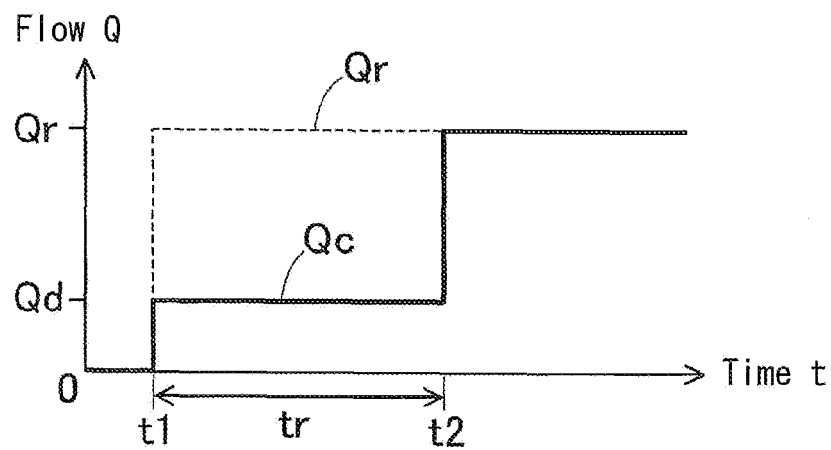


FIG. 3

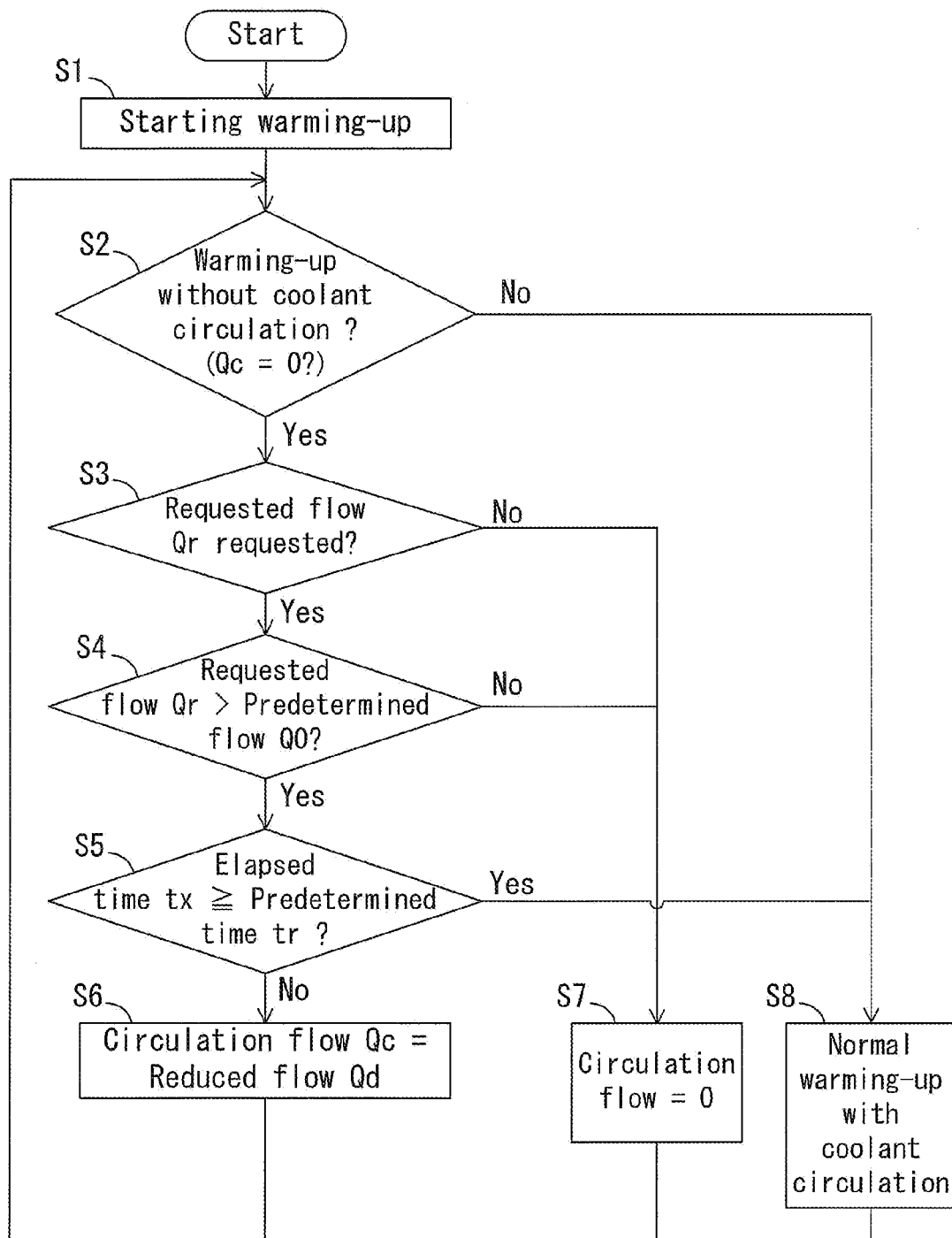


FIG. 4

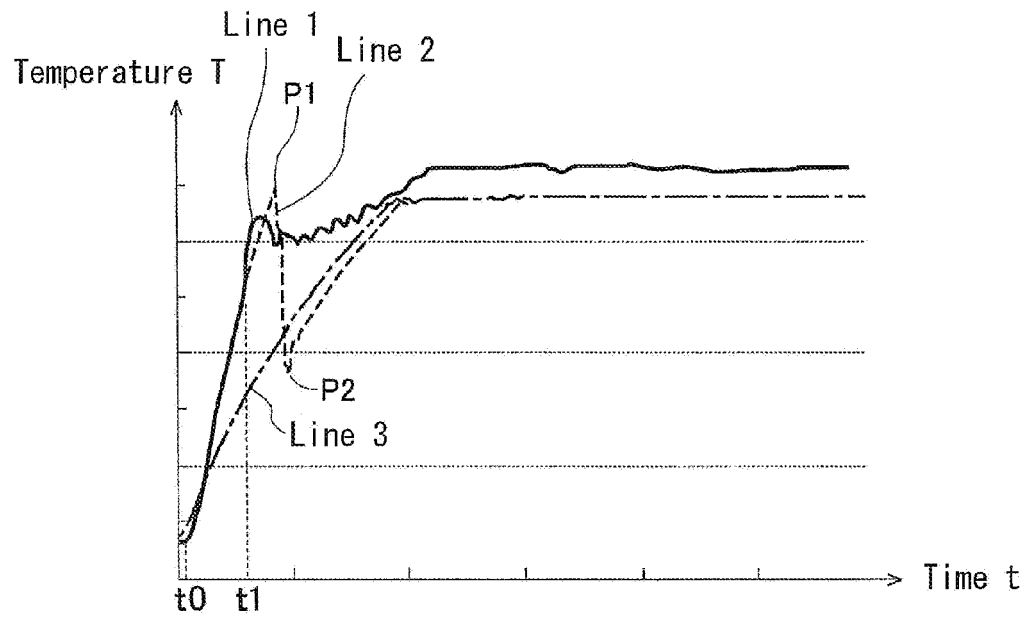


FIG. 5

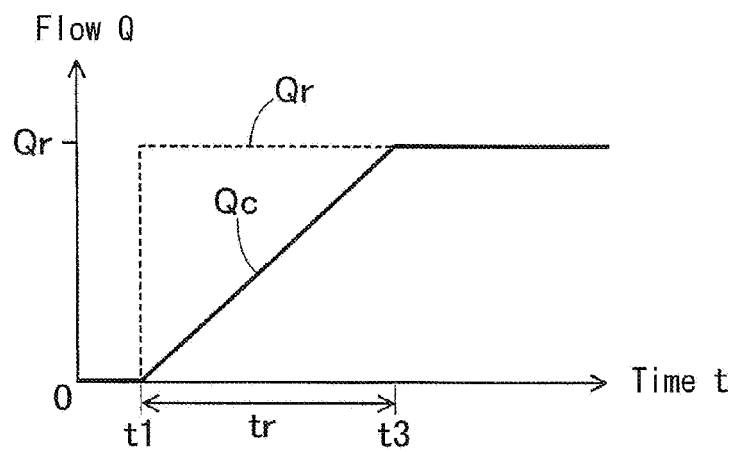


FIG. 6

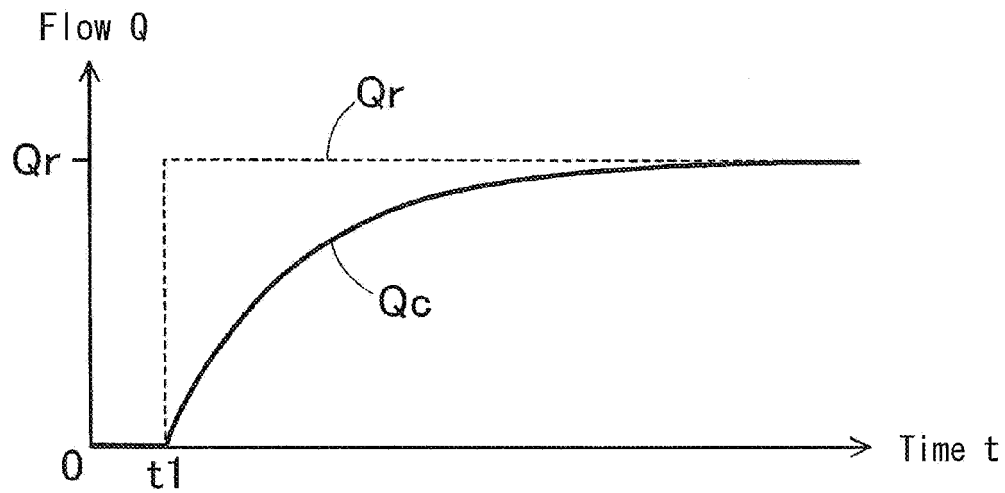


FIG. 7

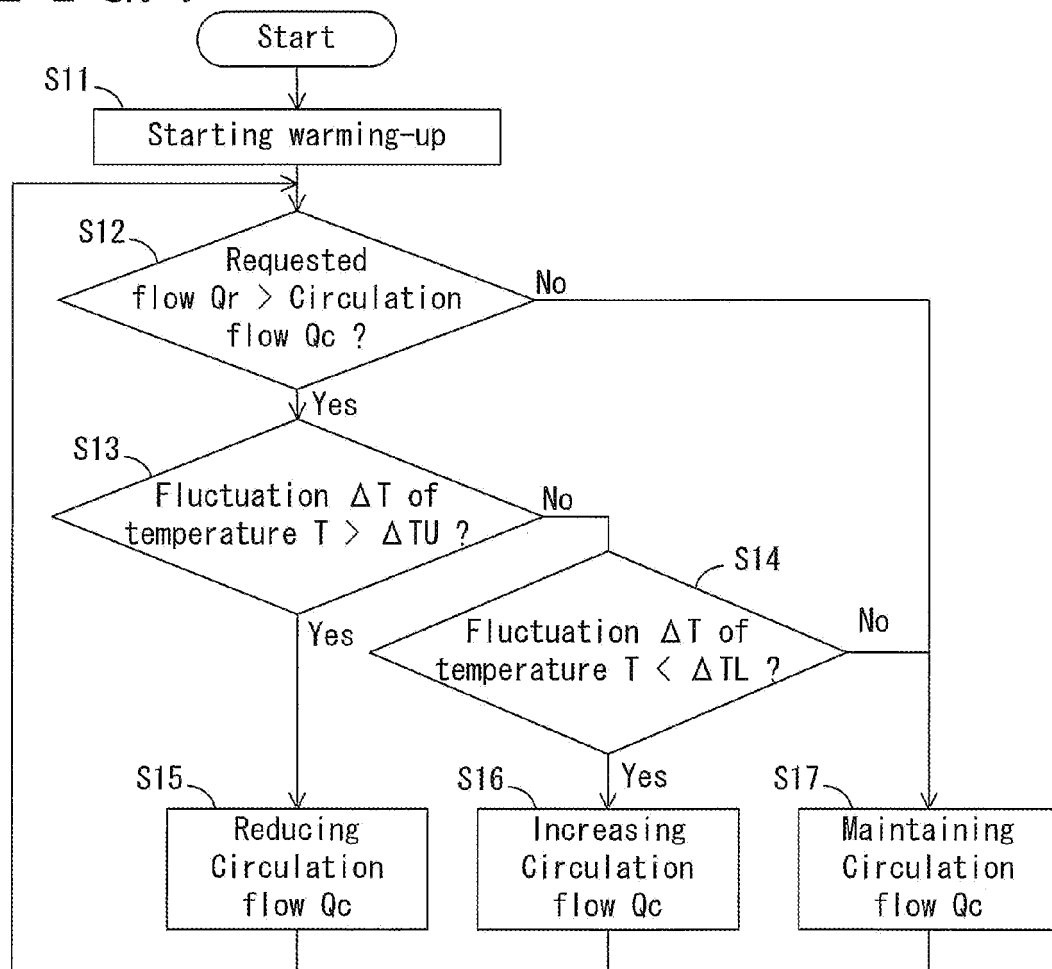
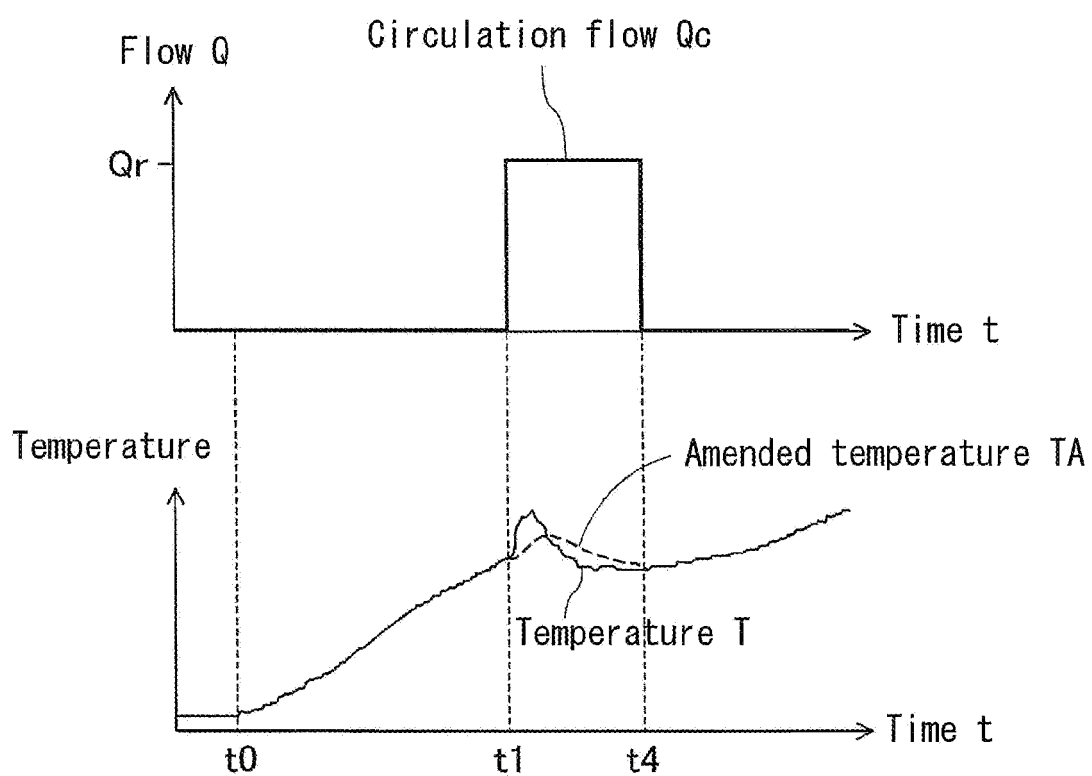


FIG. 8



REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP H0814043 A [0002]
- JP 2008303775 A [0004]