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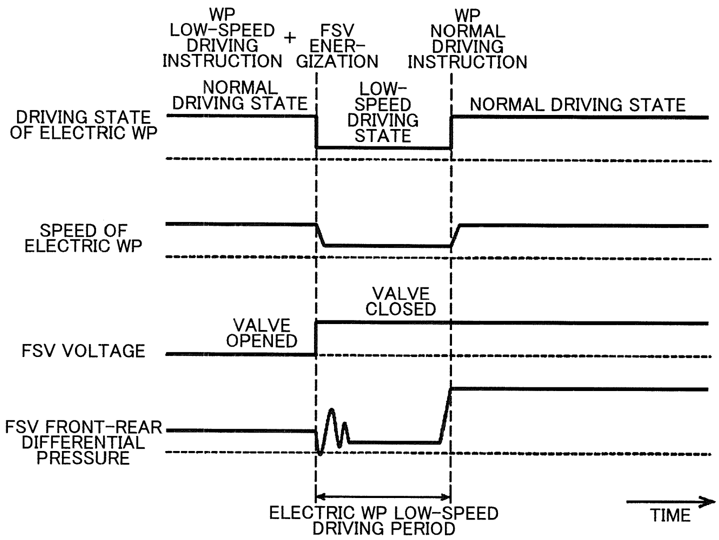
(54) ENGINE COOLING DEVICE

(57) An engine cooling device (100) includes: a water pump; a radiator (2); a first cooling water channel (8a) going through the radiator (2); a second cooling water channel (8b) not going through the radiator (2); a solenoid valve (6) provided in the second cooling water channel (8b); and a control unit (7). The control unit (7) moves, at a time of closing the solenoid valve (6), a valve body (62) in a valve closing direction while the cooling water is passing at a decreased flow rate so as to close the solenoid valve (6) to cut off passage of the cooling water in the second cooling water channel (8b).

FIG. 5



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to an engine cooling device.

2. Description of Related Art

[0002] An engine cooling device including a water pump and a solenoid valve is known (see, for example, Japanese Patent Application Publication No. 2013-108398).

[0003] The engine cooling system disclosed in JP 2013-108398 A includes: an electrically-operated pump that discharges coolant for cooling an engine; a first channel and a second channel that pass cooling water to the engine through a radiator; a third channel that passes the cooling water to the engine without going through the radiator; a valve provided in the third channel to switch presence and absence of passage of the coolant in the third channel; and a control unit that controls the electrically-operated pump and the valve. The valve of the engine cooling system includes a valve body, a valve seat, an urging member that urges the valve body toward the valve seat side, and a solenoid that provides close contact between the valve seat and the valve body upon energization. Accordingly, the control unit is configured to energize the solenoid at the time of closing the valve in the third channel, so that the valve body and the valve seat are contacted with urging force by the urging member and suction force by the solenoid. The control unit is also configured to stop energization of the solenoid at the time of opening the valve in a closed state, while passing the coolant with the electrically-operated pump, so that the valve body and the valve seat are separated against the urging force of the urging member.

[0004] In the engine cooling system described in JP 2013-108398 A, the control unit is configured to stop the electrically-operated pump, at the time of closing the valve in the opened state in the third channel, to stop passage of the coolant, and then energize the solenoid of the valve in the third channel.

SUMMARY OF THE INVENTION

[0005] However, the engine cooling system disclosed in JP 2013-108398 A is configured to stop the electrically-operated pump to thereby stop passage of the coolant in order to close the valve in the third channel that passes the cooling water to the engine without going through radiator. This causes an inconvenience that the passage of the coolant is stopped in the engine cooling system during the period when the electrically-operated pump is stopped. Accordingly, since the engine is hardly cooled in the period when the electrically-operated pump is stopped, the engine during driving may become high in temperature.

[0006] The present invention provides an engine cooling device capable of preventing the engine during driving from becoming high in temperature when the solenoid valve in the cooling water channel that passes cooling water to the engine without going through a radiator is put in a closed state.

[0007] An engine cooling device according to an aspect of the present invention includes: a water pump that controls a flow rate of cooling water for cooling an engine; a radiator; a first cooling water channel that passes the cooling water to the engine through the radiator; a second cooling water channel that passes the cooling water to the engine without going through the radiator; a solenoid valve provided in the second cooling water channel, the solenoid valve including a valve body, the valve body being moved by electric suction force to open and close the solenoid valve; and a control unit configured to execute control, at a time of closing the solenoid valve in the second cooling water channel, to close the solenoid valve so as to cut off passage of the cooling water in the second cooling water channel by moving the valve body in a valve closing direction with at least electric suction force while the cooling water is passing at a decreased flow rate, the decreased flow rate being achieved by driving the water pump so as to decrease the flow rate of the cooling water.

[0008] In the above aspect, as described in the foregoing, the engine cooling device includes the control unit that executes control, at the time of closing the solenoid valve in the second cooling water channel not going through the radiator, to close the solenoid valve while the cooling water is passed at a decreased flow rate to cut off passage of the cooling water in the second cooling water channel. Accordingly, even in the case of closing the solenoid valve in the second cooling water channel not going through the radiator, the cooling water can be passed into the engine cooling device (a first cooling water channel passing through the radiator) since the solenoid valve is closed while the cooling water is passing. This makes it possible to prevent passage of the cooling water to the engine from being stopped. As a result, in the case of closing the solenoid valve in the second cooling water channel not extending through the radiator, the engine can continue to be cooled by the passing cooling water, which makes it possible to prevent the engine during driving from becoming high in temperature. When the valve body is moved in the valve closing direction, the cooling water is passed at a decreased flow rate, which makes it possible to suppress increase in the force to move the valve body in the valve closing direction against the passing cooling water. This makes it possible to suppress increase in the electric suction force necessary in the solenoid valve. Therefore, increase in the electric power necessary for closing the solenoid valve can be suppressed, and upsizing of the solenoid valve to generate larger electric suction force can also be suppressed.

[0009] In the above aspect, the solenoid valve may include an urging member that urges the valve body in the valve closing direction, the valve body being configured to be moved in the valve closing direction with urging force of the urging member and the electric suction force while the water pump is driven. According to such configuration, the valve body can easily be moved in the valve closing direction in proportion to the urging force given by the urging member against the passing cooling water. This eliminates the necessity of significant decrease in the flow rate of the cooling water to close the solenoid valve in the second cooling water channel not going through the radiator. Accordingly, even when the flow rate of the cooling water is in a decreased state, the cooling water can sufficiently be passed into the engine cooling device (the first cooling water channel going through the radiator).

[0010] In the above aspect, the control unit may be configured to execute control to close the solenoid valve in the second cooling water channel by acquiring a valve-closable maximum speed of the water pump based on at least flow resistance of the cooling water and moving the valve body while the water pump is driven at a speed equal to or less than the valve-closable maximum speed. In such configuration, the valve body is moved while the water pump is driven at the speed equal to or less than the valve-closable maximum speed, so that the solenoid valve in the second cooling water channel not extending through the radiator can reliably be closed while the cooling water is passed into the engine cooling device (the first cooling water channel going through the radiator). In the engine cooling device, a front-rear differential pressure between upstream pressure and downstream pressure of the solenoid valve changes in accordance with the flow resistance of the cooling water, which results in change in valve-closable maximum speed of the water pump. Accordingly, when the valve-closable maximum speed of the water pump is acquired based on the flow resistance of the cooling water relating to the valve-closable maximum speed of the water pump, it becomes possible to more reliably close the solenoid valve based on a precise valve-closable maximum speed of the water pump.

[0011] In the above configuration, the engine cooling device may further includes a thermostat provided in the first cooling water channel, the thermostat having opening that changes based on temperature of the cooling water, and the control unit may be configured to estimate the flow resistance of the cooling water based on the opening of the thermostat. Here, in the engine cooling device, the flow rate of the cooling water in the first cooling water channel changes in accordance with the opening of the thermostat, and the change in the flow rate results in change in the flow resistance of the cooling water. Accordingly, when the flow resistance of the cooling water is estimated based on the opening of the thermostat, it becomes possible to acquire a more precise valve-closable maximum speed of the water pump based on the flow resistance of the cooling water appropriately estimated. In the case where the thermostat is in an opened state, the cooling water can pass through the first cooling water channel even though passage of the cooling water in the second cooling water channel is cut off, so that the cooling water can be passed to the engine. The cooling water is also passed to the radiator in the first cooling water channel so that cooling water having a high temperature can effectively be cooled. The thermostat being in a closed state signifies that, as in the case of engine warm-up, cooling the engine during driving with the cooling water having a low temperature is not preferable. Accordingly, by blocking the passage of the cooling water to the radiator in the first cooling water channel, cooling of the cooling water in the radiator can be prevented, so that excessive cooling of the engine can be suppressed.

[0012] In the above aspect, the water pump may be an electrically-operated water pump including a sensorless motor. Here, in the sensorless motor, when the water pump (sensorless motor) is stopped, an initial position of a rotor of the sensorless motor is lost due to the absence of the sensor. Accordingly, in the sensorless motor, once the sensorless motor is stopped, the initial position of the rotor needs to be detected for proper driving of the sensorless motor. Therefore, at the time of driving the sensorless motor in the stopped state, start-up driving is needed for detecting the initial position of the rotor, as a result of which extra time is required for the start-up driving. As a consequence, the period when the cooling water is not passed to the engine is further lengthened. Contrary to this, in the present aspect, at the time of closing the solenoid valve in the engine cooling device, the water pump is driven so as to decrease the flow rate of the cooling water as described before. Accordingly, even when the water pump is an electrically-operated water pump including the sensorless motor, extra time such as the time for the start-up driving is not generated. Hence, the present configuration is particularly preferable in the case where the water pump includes the sensorless motor.

[0013] In the above aspect, the control unit may be configured to execute control to increase the flow rate of the cooling water with the water pump after closing of the solenoid valve in the second cooling water channel is completed. In such configuration, the flow rate of the cooling water is increased after closing of the solenoid valve is completed, so that operation such as cooling the engine with the cooling water and recovering heat from the cooling water can effectively be performed.

[0014] The engine cooling device of the present application may have other configurations as described below.

[0015] That is, the engine cooling device may further include a first heat exchanger that is arranged in the second cooling water channel to exchange heat with the cooling water.

[0016] The engine cooling device configured to include the first heat exchanger may further include: a third cooling water channel provided in parallel with the second cooling water channel, the third cooling water channel passing the cooling water; and a second heat exchanger arranged in the third cooling water channel to exchange heat with the cooling water.

[0017] In the configuration of moving the valve body while the water pump is driven at the speed equal to or less than the valve-closable maximum speed, the control unit may be configured to acquire the valve-closable maximum speed of the water pump based on a valve-closable maximum discharge pressure of the cooling water in the water pump and on the flow resistance of the cooling water.

[0018] In the configuration of increasing the flow rate of cooling water after closing of the solenoid valve in the second cooling water channel is completed, the control unit may be configured to execute control to set a period until closing of the solenoid valve is completed in accordance with the flow resistance of the cooling water and to also increase the flow rate of the cooling water with the water pump after the period until completion of closing of the solenoid valve is lapsed.

[0019] In the configuration of estimating the flow resistance of the cooling water based on the opening of the thermostat in the first cooling water channel, the thermostat may be arranged on an upstream side of the engine, a temperature detection unit arranged on the downstream side of the engine to detect downstream temperature of the cooling water on the downstream side of the engine may further be provided, and the control unit may be configured to estimate an upstream temperature of the cooling water on the upstream side of the engine based on the downstream temperature detected by the temperature detection unit and on a cooling loss in the engine and to estimate the opening of the thermostat based on the upstream temperature.

[0020] The aspect of the present invention can prevent the engine during driving from becoming high in temperature when the solenoid valve in the cooling water channel that passes cooling water to the engine without going through the radiator is put in a closed state.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

- FIG. 1 is a schematic view illustrating an engine cooling device and an engine according to one embodiment of the present invention;
- FIG. 2 illustrates an opening characteristics map according to one embodiment of the present invention;
- FIG. 3 illustrates a flow resistance map according to one embodiment of the present invention;
- FIG. 4 is a sectional view illustrating the structure of an FSV of the engine cooling device according to one embodiment of the present invention;
- FIG. 5 illustrates a timing chart at the time of closing an FSV according to one embodiment of the present invention;
- FIG. 6 illustrates a timing chart at the time of closing the FSV according to the related art;
- FIG. 7 is a flowchart illustrating a control flow of closing the FSV in the engine cooling device according to one embodiment of the present invention;
- FIG. 8 illustrates a cooling loss map according to one embodiment of the present invention;
- FIG. 9 illustrates a speed map according to one embodiment of the present invention; and
- FIG. 10 illustrates a closing time map according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENT

[0022] An embodiment of the present invention will be described hereinbelow with reference to the drawings.

[0023] First, the configuration of an engine cooling device 100 according to one embodiment of the present invention will be described with reference to FIGS. 1 to 4.

[0024] The engine cooling device 100 in one embodiment of the present invention is mounted on a vehicle which is not illustrated. The engine cooling device 100 supplies cooling water (coolant) to an engine 101 mounted on the vehicle to cool the engine 101, cools the cooling water warmed with heat of the engine 101 or the like by using a radiator 2, and recovers heat from the warmed cooling water using a heater core 3 or the like. The cooling water refers to liquid such as water that is used to cool the engine 101.

[0025] As illustrated in FIG. 1, the engine cooling device 100 includes an electric water pump (electric WP) 1, a radiator 2, a heater core 3, an oil cooler 4, a thermostat 5, and a flow shutting valve (FSV) 6. The engine cooling device 100 is configured to be controlled by an engine control unit (ECU) 7 that controls the speed of the engine 101 and the like. The electric WP 1 is one example of "a water pump" in the claims, and the FSV 6 is one example of "a solenoid valve" in the claims. The ECU 7 is one example of "a control unit" in the claims.

[0026] The engine cooling device 100 is configured so that cooling water passes and circulates through a cooling water circulation channel 8. The cooling water circulation channel 8 includes cooling water channels 8a, 8b, and 8c. The cooling water channels 8a and 8b are examples of "a first cooling water channel" and "a second cooling water channel" in the claims, respectively.

[0027] In the cooling water channel 8a, the engine 101, the electric WP 1, the radiator 2, and the thermostat 5 are arranged. The electric WP 1 is arranged on the upstream side of the engine 101, the radiator 2 is arranged on the downstream side of the engine 101, and the thermostat 5 is arranged on the downstream side of the radiator 2. That is, the cooling water channel 8a is configured to pass the cooling water to the engine 101 through the radiator 2. Note that "upstream side" and "downstream side" in the present embodiment refer to the upstream side and the downstream side in a cooling water passage direction (chain double-dashed lines in FIG. 1), respectively.

[0028] The cooling water channels 8b and 8c each branch at a branch point 9a of the cooling water channel 8a that is on the downstream side of the engine 101 and on the upstream side of the radiator 2, and join at a junction 9b of the cooling water channel 8a that is on the downstream side of the thermostat 5 and on the upstream side of the electric WP 1. In short, the cooling water channel 8b and the cooling water channel 8c are provided in parallel.

[0029] In the cooling water channel 8b, the heater core 3 and the FSV 6 are arranged. More particularly, the cooling water channel 8b, which is the cooling water channel provided with the FSV 6, is also configured to join the cooling water channel 8a at the junction 9b without going through the radiator 2 so that the cooling water can be passed to the engine 101. The heater core 3 is arranged on the side of the branch point 9a, while the FSV 6 is arranged on the side of the junction 9b.

[0030] In the cooling water channel 8c, the oil cooler 4 is also arranged. More particularly, the cooling water channel 8c is configured to join the cooling water channel 8a at the junction 9b without going through the radiator 2 so that the cooling water can be passed to the engine 101.

[0031] The electric WP 1, which is electrically operated, is configured to control the flow rate of the cooling water discharged under the control of the ECU 7. The electric WP 1 is configured to suck the cooling water in the cooling water channel 8a on the side opposite to the engine 101 and to discharge the cooling water toward the engine 101. The electric WP 1 is a centrifugal pump having excellent discharging efficiency.

[0032] The electric WP 1, which is a centrifugal pump, includes a brushless sensorless motor 1a for rotating an impeller which is not unillustrated. Accordingly, the electric WP 1 can be driven independently of the engine 101. Note that "the brushless motor" is a motor driven so that operation such as switching the direction of an electric current is controlled by electric control without use of brushes that contact-slides and commutators that switch the direction of the electric current. Accordingly, in the case of using the brushless sensorless motor 1a, which is free from wear of the brushes unlike the case of using a motor with brushes, the life of the electric WP 1 can be lengthened. The brushless sensorless motor 1a does not include a sensor (Hall element or the like) that detects the position of a rotor (permanent magnet). Accordingly, the brushless sensorless motor 1a is configured to detect an initial position of the rotor based on change in electromotive force generated upon rotation of the rotor. The brushless sensorless motor 1a is one example of "a sensorless motor" in the claims.

[0033] The electric WP 1 is configured to be able to transmit speed of the brushless sensorless motor 1a (speed of an impeller) to the ECU 7 as pump speed information.

[0034] The radiator 2 is configured to perform heat exchange between the cooling water passing inside the radiator 2 and the running wind (air). Accordingly, the cooling water passing through the radiator 2 is cooled.

[0035] The heater core 3 is configured to receive air sent from a fan, which is not illustrated, based on a signal from the ECU 6 when heating operation is performed inside the vehicle which is not illustrated. This leads to heat exchange between the cooling water passing through the heater core 3 (cooling water channel 8b) and wind (air), so that the cooling water is cooled and warm air is supplied into the vehicle to heat the inside of the vehicle.

[0036] The oil cooler 4 exchanges heat between the cooling water passing through the oil cooler 4 (cooling water channel 8c) and oil used for such purposes as lubricating a sliding portion (not illustrated) of the engine 101, so that the cooling water is warmed and the oil is cooled.

[0037] The thermostat 5 is configured to have opening that changes based on the temperature of cooling water. Accordingly, the thermostat 5 has a function of switching between passing and not passing the cooling water to the radiator 2 in the cooling water channel 8a, and a function of regulating the flow rate of the cooling water when the cooling water is passed to the radiator 2.

[0038] Specifically, the thermostat 5 is configured to be fully closed (having an opening of 0%), as illustrated in FIG. 2, to prevent the cooling water from passing to the radiator 2 in the cooling water channel 8a when the temperature of the cooling water passing through the thermostat 5 is less than a first temperature (= about 80°C). In this case, the cooling water passes from the branch point 9a to the cooling water channel 8b (with the FSV in the opened state) and to the cooling water channel 8c, and then passes (circulates) back to the electric WP 1 again from the junction 9b, so that the cooling water is not cooled in the radiator 2. The thermostat 5 is configured to regulate the flow rate of the cooling water passing through the thermostat 5 based on the opening that changes in accordance with the temperature of cooling water when the temperature of the cooling water is equal to or more than the first temperature. In this case, the cooling water passes through the radiator 2 in the cooling water channel 8a at the flow rate regulated in accordance with the opening of the radiator 2, so that part of the cooling water is cooled in the radiator 2, while the remaining cooling water passes through the cooling water channel 8b (when the FSV is in the opened state) and through the cooling water channel 8c, and then passes (circulates) back to the electric WP 1 again from the junction 9b. The thermostat 5 is configured to be fully opened (having an opening of 100%) when the temperature of the cooling water is equal to or more than a second temperature. In this case, the cooling water passes through the cooling water channel 8a, the cooling water channel 8b (with the FSV in the opened state), and the cooling water channel 8c, and then passes (circulates) back to the electric WP 1 again, so that part of the cooling water is cooled in the radiator 2.

[0039] As a result, in the engine cooling device 100, the channels that pass the cooling water and the flow rate of each channel change in accordance with the opened state of the thermostat 5. Therefore, the engine cooling device 100 is configured so that resistance (flow resistance) of cooling water passing through the engine cooling device 100 (cooling water circulation channel 8) changes in accordance with the opening of the thermostat 5. When the opening of the thermostat 5 is small as illustrated in FIG. 3, the flow resistance with respect to the flow rate of cooling water becomes large, whereas when the opening of the thermostat 5 is large, the flow resistance with respect to the flow rate of the cooling water becomes small. Since the flow resistance changes depending on structural factors of the engine cooling device 100, such as a diameter of the cooling water circulation channel 8, the flow resistance is calculated for each of the engine cooling devices 100 having different structural factors.

[0040] The FSV 6, which is a valve member that is opened and closed by electric suction force, has a function of cutting off passage of cooling water in the cooling water channel 8b upon being closed. As illustrated in FIG. 4, the FSV 6 includes a cylindrical housing 61, and a valve body 62, a valve seat 63, an urging member 64 and a solenoid 65 which are arranged inside the housing 61. The housing 61 has an inflow passage 61 a that receives inflow of cooling water coming from side of the heater core 3, an outflow passage 61b extending in a direction substantially orthogonal to the direction (Z direction) that the inflow passage 61 a extends, the outflow passage 61b making the cooling water flowing out to the side of the electric WP 1, and a valve body housing portion 61c that provides connection between the inflow passage 61a and the outflow passage 61b. The valve body housing portion 61c houses the valve body 62 and the urging member 64.

[0041] The solenoid 65, which is configured with an annular member, has a body 65a made of a magnetic substance, a bobbin 65b arranged inside the body 65a, and a winding wire 65c wound around the bobbin 65b to generate a magnetic field upon energization. The solenoid 65 is arranged inside the housing 61 so that an inner side of the solenoid 65 forms the inflow passage 61a, and a surface of the solenoid 65 on the side of the valve body housing portion 61c (Z1 side) serves as the valve seat 63 that comes into contact with the valve body 62.

[0042] The valve body 62, which has a cross section formed into a reversed T-shaped circular cylindrical form, is configured to be movable in Z direction. The valve body 62 is formed of a magnetic substance such as iron. Accordingly, when the solenoid 65 is magnetized by energization of the winding wire 65c of the solenoid 65, electric suction force is generated between the valve body 62 and the solenoid 65 in a valve closing direction (Z2 direction) in which the valve body 62 moves toward the valve seat 63. The urging member 64, which is configured with a coiled spring, is arranged in the valve body housing portion 61c while the valve body 62 is urged in the valve closing direction.

[0043] As a result of these arrangements, the FSV 6 is configured to be in the closed state when the urging force by the urging member 64 and the electric suction force by the energized solenoid 65 move the valve body 62 in the valve closing direction (Z2 direction) and puts the valve body 62 in contact with the valve seat 63. In the state where energization of the solenoid 65 is canceled, the force applied to the valve body 62 from Z2 side based on the pressure of the cooling water in the inflow passage 61a and on the pressure of the cooling water in the outflow passage 61b and in the valve body housing portion 61c may exceed the urging force. In this case, the valve body 62 is moved in the valve opening direction (Z1 direction), and the FSV 6 is switched from the closed state to the opened state.

[0044] Here, both the urging force of the urging member 64 and the suction force by the solenoid 65 are small. The area (area of a region surrounded by a chain double-dashed line in the drawing of the valve in the opened state in FIG. 4) S1 of the valve body 62 that receives pressure from Z2 side in the opened state is larger than the area (area of a region surrounded by a chain double-dashed line in the drawing of the valve in the closed state in FIG. 4) S2 of the valve body 62 that receives pressure from Z2 side in the closed state. As a result, in a normal driving state where the electric WP 1 is driven at the speed of discharging the cooling water at a large flow rate, such as about 2000 rpm, the FSV 6 in the opened state cannot resist the pressure of the cooling water only with the urging force of the urging member 64 and the suction force by the solenoid 65. Therefore, in the case of passing the cooling water through the FSV 6 in the opened state at a normal flow rate, it is difficult to switch the FSV from the opened state to the closed state.

[0045] Accordingly, in the engine cooling device 100 of the present embodiment, the ECU 7 is configured to, at the time of switching the FSV 6 in the cooling water channel 8b from the opened state to the closed state, energize the solenoid 65 while performing low-speed driving of the electric WP 1 at a low speed of, for example, about 700 rpm or less to make the flow rate of the cooling water discharged from the electric WP 1 smaller than the normal flow rate. Accordingly, in the engine cooling device 100, the valve body 62 is moved in the valve closing direction with the urging force of the urging member 64 and the electric suction force while the electric WP 1 is driven, so that the FSV 6 in the cooling water channel 8b is closed. As a result, passage of the cooling water in the cooling water channel 8b is cut off. Meanwhile, even during valve closing operation of the FSV 6 and after completion of the valve closing operation, the cooling water passes through the cooling water channels other than the cooling water channel 8b, including the cooling water channel 8a when the thermostat 5 is opened and the cooling water channel 8c. This makes it possible to pass the cooling water to the engine 101. A detailed description of the control executed by the ECU 7 to close the FSV 6 will be given later.

[0046] The FSV 6 is closed to cut off the passage of the cooling water to the heater core 3 in such cases as the case of preventing the cooling water warmed with the engine 101 from passing to the heater core 3 (cooling water channel 8b) to enhance cooling efficiency inside the vehicle, and the case of cutting off the passage of the cooling water to the heater core 3 and increasing the flow rate of the cooling water passing through the side of the oil cooler 4 (cooling water channel 8c) to enhance cooling efficiency of the oil in the oil cooler 4. It is determined by the ECU 7 whether or not the FSV 6 is closed to cut off passage of the cooling water to the heater core 3.

[0047] As illustrated in FIG. 1, a water temperature sensor 7a is arranged in the engine cooling device 100 to detect downstream temperature (outlet temperature To) of the cooling water in the cooling water channel 8a on the downstream side of the engine 101. The water temperature sensor 7a is configured to transmit information (outlet water temperature information) about the outlet water temperature To to the ECU 7.

[0048] A description is now given of comparison between a timing chart at the time of closing the FSV 6 in one embodiment of the present invention and a timing chart at the time of closing an FSV in the related art with reference to FIG. 1 and FIGS. 4 to 6.

[0049] First, the timing chart at the time of closing the FSV 6 in the present embodiment illustrated in FIG. 5 will be described.

[0050] In the case of cutting off the passage of cooling water to the heater core 3 (see FIG. 1) in the cooling water channel 8b while the electric WP 1 is in a normal driving state, the ECU 7 first calculates a maximum speed of the electric WP 1 that can close the FSV 6 (valve-closable maximum speed) in the present embodiment. Then, the ECU 7 performs drive control of the electric WP 1 to conduct low-speed driving of the electric WP 1 at the calculated valve-closable maximum speed. As a consequence, the electric WP 1 is put in a low-speed driving state, though the passage (circulation) of cooling water in the engine cooling device 100 (the cooling water channel 8a going through the radiator 2 (when the thermostat 5 is opened) and the cooling water channel 8c) is continued. The ECU 7 energizes the FSV 6 at substantially the same time when instructing low-speed driving of the electric WP 1. Consequently, electric suction force in the valve closing direction (see FIG. 4) is applied to the valve body 62. Here, even when the cooling water is passed through the FSV 6, the total force made up of the suction force by the solenoid 65 and the urging force by the urging member 64 is larger than the force based on the pressure of the cooling water, because the electric WP 1 is driven at the valve-closable maximum speed. Accordingly, the FSV 6 is closed.

[0051] After closing of the FSV 6 is completed, the ECU 7 performs drive control to normally drive the electric WP 1. Consequently, the speed of the electric WP 1 increases, which increases the flow rate of the cooling water to be discharged.

[0052] A description is now given of the timing chart at the time of closing the FSV in the related art illustrated in FIG. 6. An engine cooling device in the related art has the configuration same as that of the engine cooling device 100 in the embodiment, though driving of an electric WP is stopped at the time of closing the FSV.

[0053] Assume the case where passage of cooling water to the heater core is desired to be cut off when the electric WP is in the normal driving state. In this case, the ECU stops driving of the electric WP in the related art. Then, after fluctuation in a front-rear differential pressure of the FSV is settled down and the differential pressure almost disappears, the ECU energizes the FSV. As a consequence, the FSV is closed. The ECU performs drive control of the electric WP to re-drive the electric WP at substantially the same time when energizing the FSV. In this case, a start-up driving period is needed until normal-driving of the electric WP is actually performed after the ECU instructs driving of the electric WP, because the electric WP includes a brushless sensorless motor.

[0054] As a result, at the time of closing the FSV in the engine cooling device in the related art, circulation of the cooling water in the engine cooling device is stopped during a stop period of the electric WP that is required to close the FSV and during a period for start-up driving. This lengthens the period when the engine is not cooled, as a result of which the engine becomes high in temperature due to insufficient cooling of the engine during driving. Contrary to this, in the engine cooling device 100 of the present embodiment, low-speed driving of the electric WP 1 continues even while the FSV 6 is controlled to be closed. Accordingly, the cooling water is passed into the engine cooling device 100 (the cooling water channel 8a when the thermostat 5 is opened and the cooling water channel 8c), so that the cooling water is passed to the engine 101 during driving. Furthermore, unlike the engine cooling device in the related art, the period for start-up driving of the electric WP 1 is not generated. This makes it possible to effectively prevent the inconvenience attributed to insufficient cooling of the engine 101 from occurring.

[0055] A description is now given of the control flow of closing the FSV 6 in one embodiment of the present invention with reference to FIGS. 1 to 5 and FIGS. 7 to 10. The control flow is performed by the ECU 7 (see FIG. 1).

[0056] First, as illustrated in FIG. 7, in step S1, it is determined whether or not the FSV 6 in the cooling water channel 8b needs to be closed, and the control operation in step S1 is repeated until it is determined that the FSV 6 needs to be closed. When it is determined that the FSV

6 needs to be closed, a downstream temperature (outlet water temperature To) of the cooling water on the downstream side (outlet) of the engine 101 is acquired based on the outlet water temperature information transmitted from the water temperature sensor 7a in step S2. In step S3, current engine speed and engine torque of the engine 101 are acquired based on engine speed information and torque information transmitted from the engine 101, and a current speed (pump speed) of the electric WP 1 is acquired based on the pump speed information transmitted from the electric WP 1.

[0057] Then, in step S4, an upstream temperature (inlet water temperature Ti) of the cooling water on the upstream side (inlet) of the engine 101 is estimated based on the acquired outlet temperature To, engine speed, and engine torque.

[0058] Specifically, the ECU 7 first calculates a cooling loss from the acquired engine speed and engine torque based on a cooling loss map illustrated in FIG. 8, the cooling loss map being prestored in a storage unit (not illustrated) of the ECU 7. The cooling loss map depicts the cooling loss with respect to the engine torque for each engine speed. For example, when the engine speed is about 2000 rpm, and the engine torque is about 150 N·m, the ECU 7 calculates the cooling loss to be about 25 kW with reference to the cooling loss map.

[0059] Then, an engine inlet-outlet water temperature difference ΔT and an inlet water temperature Ti are estimated based on the cooling loss and the outlet water temperature To by using Expression (1): engine inlet-outlet water temperature difference ΔT = (cooling temperature To - inlet water temperature Ti) = (cooling loss / (flow rate of cooling water x specific heat of cooling water x density of cooling water)). In Expression (1), "flow rate of cooling water" is the flow rate of cooling water discharged from the electric WP 1, the flow rate being acquired by the ECU 7 based on the pump speed. In Expression (1), "specific heat of cooling water" and "density of cooling water" may simply be approximated to 1, respectively, or may be calculated by conducting measurement and the like in advance, respectively.

[0060] Next, in step S5, an opening of the thermostat 5 is estimated based on the inlet water temperature Ti. Specifically, the inlet water temperature Ti is substantially equal to the temperature of the cooling water in the thermostat 5 arranged in the vicinity of the engine 101 on the upstream side of the engine 101. Accordingly, the ECU 7 estimates the opening of the thermostat 5 based on the inlet water temperature Ti using the opening characteristics map illustrated in FIG. 2, the opening characteristics map being prestored in the storage unit of the ECU 7. The opening characteristics map depicts the opening of the thermostat 5 with respect to the inlet water temperature Ti. For example, when the inlet water temperature Ti is about 80°C, the opening of the thermostat 5 is estimated to be 0% with reference to the opening characteristics map.

[0061] Next, in step S6, flow resistance of the cooling water with respect to the flow rate of the cooling water discharged from the electric WP 1 is estimated based on the opening of the thermostat 5. Specifically, the ECU 7 estimates the flow resistance of the cooling water corresponding to the estimated opening of the thermostat 5 with use of a flow resistance map illustrated in the FIG. 3, the flow resistance map being stored in the storage unit of the ECU 7. The flow resistance map depicts the flow resistance of the cooling water with respect to the flow rate of the cooling water in the electric WP 1 for each opening of the thermostat 5. As the opening of the thermostat 5 becomes smaller, the flow resistance of the cooling water with respect to the flow rate of the cooling water is larger.

[0062] Then in step S7, a maximum speed of the electric WP 1 that can close the FSV 6 (valve-closable maximum speed) is acquired based on the flow resistance of the cooling water. Specifically, the storage unit of the ECU 7 stores the preobtained maximum discharge pressure of the electric WP 1 that can close the FSV 6 (valve-closable maximum discharge pressure) and a speed map illustrated in FIG. 9. The speed map depicts the discharge pressure of the electric WP 1 with respect to the flow rate of the cooling water in the electric WP 1 for each speed of the electric WP 1.

[0063] The valve-closable maximum discharge pressure is calculated in advance by acquiring, through measurement and the like, a valve-closable maximum front-rear differential pressure upon energization of the FSV 6 and a ratio of the front-rear differential pressure of the FSV 6 to the pressure of the cooling water discharged from the electric WP 1, and then by dividing the valve-closable maximum front-rear differential pressure by the ratio of the front-rear differential pressure. For example, when the valve-closable maximum front-rear differential pressure upon energization of the FSV 6 is about 0.2 kPa, and the ratio of the front-rear differential pressure of the FSV 6 to the pressure of the cooling water discharged from the electric WP 1 is 10%, the valve-closable maximum discharge pressure is about 2 kPa (= 0.2/0.1).

[0064] Then, the ECU 7 acquires, as a valve-closable maximum speed, the speed of the electric WP 1 that passes an intersection O of the valve-closable maximum discharge pressure and the flow resistance of cooling water on the speed map. For example, when the flow resistance of the cooling water with respect to the flow rate of the cooling water discharged from the electric WP 1 (illustrated with a straight line) crosses the valve-closable maximum discharge pressure at the intersection O as illustrated in FIG. 9, a speed curve (= about 400 rpm) passing through the intersection O is acquired as a valve-closable maximum speed. As illustrated in FIG. 9, as the flow resistance of the cooling water becomes larger, the valve-closable maximum speed becomes smaller.

[0065] In step S8, valve closing time of the FSV 6 is acquired based on the flow resistance of the cooling water. Specifically, based on the flow rate of the cooling water corresponding to the intersection O in FIG. 9 and on a preobtained ratio of the flow rate of the cooling water in the cooling water channel 8b (FSV 6) to the flow rate of the cooling water discharged from the electric WP 1, the ECU 7 acquires the flow rate of the cooling water in the FSV 6 when the electric WP 1 is driven at the valve-closable maximum speed. The flow rate of the cooling water in the FSV 6 is preferably about 1 (L/min) or less and is more preferably about 0.5 (L/min) or less.

[0066] Then, the ECU 7 acquires valve closing time of the FSV 6 from the acquired flow rate of the cooling water in the FSV 6 and the flow resistance of the cooling water acquired in step S6, based on a valve closing time map illustrated in FIG. 10, the valve closing time map being prestored in the storage unit (not illustrated) of the ECU 7. The valve closing time map depicts valve closing time of the FSV 6 with respect to the flow rate of the cooling water in the FSV 6 for each flow resistance of the cooling water. The valve closing time becomes longer as the flow resistance of the cooling water becomes larger.

[0067] In step S9, the electric WP 1 is drive-controlled so that the electric WP 1 is driven at the acquired valve-closable maximum speed. As a consequence, as illustrated in FIG. 5, the driving state of the electric WP 1 is switched from the normal driving state to the low-speed driving state, so that the flow rate of the cooling water discharged from the electric WP 1 decreases. Then, in step S10, the solenoid 65 of the FSV 6 is energized. Accordingly, even in the state where the cooling water is passing, total force made up of the electric suction force and the urging force of the urging member 64 increases beyond the force based on the pressure of the cooling water, because the flow rate of the cooling water is decreased. As a result, the valve body 62 is moved in the valve closing direction (see FIG. 4). Consequently, the FSV 6 in the cooling water channel 8b is put in the closed state. The cooling water with a decreased flow rate passes through the cooling water channel 8a when the thermostat 5 is opened and through the cooling water channel 8c other than the cooling water channel 8b. This makes it possible to continuously pass the cooling water to the engine 101.

[0068] Then, in step S11, after the solenoid 65 of the FSV 6 is energized, it is determined whether or not the valve closing time of the FSV 6 acquired in step S8 has elapsed, and the control operation of step S11 is repeated until it is determined that the time has elapsed. When it is determined that the valve closing time of the FSV 6 has elapsed, the driving state of the electric WP 1 is returned from the low-speed driving state to the normal driving state in step S12, so that the flow rate of the cooling water discharged from the electric WP 1 is increased. That is, in the engine cooling device 100, the ECU 7 sets the valve closing time of the FSV 6, and after the lapse of the valve closing time, the ECU 7 increases the flow rate of the cooling water in the cooling water circulation channel 8. Then, the control flow of closing the FSV 6 is ended.

[0069] In this case, even in the low-speed driving period of the electric WP 1, the electric WP 1 still continues to be driven, so that the electric WP 1 is swiftly switched from the low-speed driving state to the normal driving state without requiring the period for start-up driving. Accordingly, even in the case where the engine 101 cannot sufficiently be cooled as the electric WP 1 is in the low-speed driving state, such as in the case of driving the engine 101 with a high load, the electric WP 1 is swiftly switched to the normal driving state, so that the engine 101 is swiftly and sufficiently cooled.

[0070] As a consequence, the following effects can be obtained in the present embodiment.

[0071] In the present embodiment, as described in the foregoing, there is provided the ECU 7 that executes control, at the time of closing the FSV 6 in the cooling water channel 8b not going through the radiator 2, to cut off passage of the cooling water in the cooling water channel 8b by closing the FSV 6 while the cooling water is passing at a decreased flow rate. Accordingly, since the FSV 6 is closed while the cooling water is passing, the cooling water can be passed into the engine cooling device 100 (the cooling water channel 8a going through the radiator 2 (when the thermostat 5 is opened) and the cooling water channel 8c) even in the case of closing the FSV 6 in the cooling water channel 8b not going through the radiator 2. This makes it possible to suppress the situation where the cooling water is not passed to the engine 101. As a result, in the case of closing the FSV 6 in the cooling water channel 8b not going through the radiator 2, the engine 101 can continue to be cooled by the passing cooling water, which makes it possible to prevent the engine 101 during driving from becoming high in temperature. When the valve body 62 is moved in the valve closing direction, cooling water is passed at a decreased flow rate, which can suppress increase in the force to move the valve body 62 in the valve closing direction against the passing cooling water. This makes it possible to prevent the necessary electric suction force from increasing in the FSV 6. Therefore, increase in electric power necessary for closing the FSV 6 can be suppressed, while upsizing of the FSV 6 to generate larger electric suction force can also be suppressed.

[0072] In the present embodiment, the FSV 6 is configured to move the valve body 62 in the valve closing direction with the urging force of the urging member 64 and the electric suction force, while the electric WP 1 is driven. Accordingly, the valve body 62 can easily be moved in the valve closing direction in proportion to the urging force given by the urging member 64 against the passing cooling water, which makes it possible to prevent the flow rate of the cooling water from being significantly decreased for the purpose of closing the FSV 6 in the cooling water channel 8b not going through the radiator 2. As a result, even in the state where the flow rate of the cooling water is decreased, the cooling water can sufficiently be passed into the engine cooling device 100 (the cooling water channel 8a going through the radiator 2 (when the thermostat 5 is opened) and the cooling water channel 8c).

[0073] In the present embodiment, the ECU 7 is configured to execute control to close the FSV 6 in the cooling water channel 8b by acquiring the valve-closable maximum speed of the electric WP 1 based on at least flow resistance of the cooling water and moving the valve body 62 while the electric WP 1 is driven at a speed equal to the valve-closable maximum speed. Accordingly, since the valve body 62 is moved while the electric WP 1 is driven at the valve-closable maximum speed, the FSV 6 in the cooling water channel 8b not going through the radiator 2 can reliably be closed, while the cooling water is passing into the engine cooling device 100 (the cooling water channel 8a going through the radiator 2 (when the thermostat 5 is opened) and the cooling water channel 8c). Moreover, since the valve-closable maximum speed of the electric WP 1 is acquired based on the flow resistance of the cooling water relating to the valve-closable maximum speed of the electric WP 1, the FSV 6 can more reliably be closed based on the precise valve-closable maximum speed of the electric WP 1.

[0074] In the present embodiment, the ECU 7 is configured to estimate the flow resistance of the cooling water based on the opening of the thermostat 5. Accordingly, more precise valve-closable maximum speed of the electric WP 1 can be acquired based on the appropriately estimated flow resistance of the cooling water. When the thermostat 5 is in the opened state, the cooling water can be passed to the engine 101 by passing the cooling water through the cooling water channel 8a even in the case where passage of the cooling water in the cooling water channel 8b is cut off. It also becomes possible to effectively cool the cooling water having a high temperature by passing the cooling water to the radiator 2 in the first cooling water channel 8a. When the thermostat 5 is in the closed state, it signifies that cooling the engine 101 during driving with the cooling water having a low temperature is not preferable, as in the case of engine warm-up. Accordingly, by blocking the passage of the cooling water to the radiator 2 in the first cooling water channel 8a, cooling of the cooling water in the radiator 2 can be prevented, which can suppress excessive cooling of the engine 101.

[0075] In the present embodiment, even in the case where the electric WP 1 is an electrically-operated water pump including the brushless sensorless motor 1a, the electric WP 1 is driven, at the time of closing the FSV 6 in the engine cooling device 100, to decrease the flow rate of the cooling water, which eliminates the necessity of extra time like the period for start-up driving. As a result, even in the case where the electric WP 1 includes the brushless sensorless motor 1a, it becomes possible to prevent the situation where passage of the cooling water to the engine 101 is stopped.

[0076] In the present embodiment, after closing of the FSV 6 in the cooling water channel 8b is completed, the ECU 7 executes control to increase the flow rate of cooling water with the electric WP 1. Therefore, the engine 101, the oil of the oil cooler 4, and the like can effectively be cooled by the cooling water.

[0077] In the present embodiment, the heater core 3 that exchanges heat with cooling water is arranged in the cooling water channel 8b where the FSV 6 is arranged. Accordingly, when the FSV 6 is in the opened state, the inside of the vehicle can be heated with the heat recovered from the cooling water in the heater core 3, so that the heat of the cooling water can efficiently be used. Moreover, passage of the cooling water warmed by the engine 101 to the heater core 3 (cooling water channel 8b) can be cut off by putting the FSV 6 into the closed state, so that the cooling efficiency inside the vehicle can be enhanced.

[0078] In the present embodiment, the oil cooler 4 that exchanges heat with the cooling water is arranged in the cooling water channel 8c. Accordingly, oil can be cooled by using the cooling water circulating through the cooling water circulation channel 8. Moreover, when the FSV 6 is put in the closed state, passage of the cooling water through the heater core 3 (cooling water channel 8b) can be cut off and the flow rate of the cooling water passing on the side of the oil cooler 4 (cooling water channel 8c) can be increased.

[0079] Hence, the cooling efficiency of the oil in the oil cooler 4 can be enhanced.

[0080] In the present embodiment, the ECU 7 is configured to acquire the valve-closable maximum speed of the electric WP 1 based on the valve-closable maximum discharge pressure of the cooling water in the electric WP 1 and the flow resistance of the cooling water. Accordingly, the valve-closable maximum speed of the electric WP 1 can reliably be acquired.

[0081] In the present embodiment, the ECU 7 is configured to execute control to set the period (valve closing time) until closing of the FSV 6 is completed in accordance with the flow resistance of the cooling water and to increase the flow rate of the cooling water by the electric WP 1 after the lapse of the set valve closing time of the FSV 6. Accordingly, it becomes possible to prevent the flow rate of the cooling water passing through the FSV 6 from increasing in the state where the FSV 6 is not fully closed. As a result, the situation where the cooling water continues to pass through the cooling water channel 8b due to incomplete closing of the FSV 6 can be suppressed.

[0082] In the present embodiment, the ECU 7 is configured to estimate the upstream temperature (inlet water temperature Ti) of the cooling water on the upstream side of the engine 101 based on the downstream temperature (outlet water temperature To) of the cooling water on the downstream side of the engine 101 detected by the water temperature sensor 7a and on the cooling loss in the engine 101, and to estimate the opening of the thermostat 5 arranged on the upstream side of the engine 101 based on the inlet water temperature Ti. Accordingly, the opening of the thermostat 5 can be estimated using the detection result (outlet water temperature To) of the water temperature sensor 7a that is generally arranged on the downstream side of the engine 101. This eliminates the necessity of arranging another water temperature sensor separately from the water temperature sensor 7a on the upstream side of the engine 101. Thus, the number of component members can be reduced.

[0083] It should be understood that the embodiment disclosed is in all respects illustrative and is not considered as the basis for restrictive interpretation. The scope of the present invention is defined not by the foregoing description of the embodiment but by the range of appended claims. Furthermore, all changes (modifications) which come within the range of the claims and meaning and the range of equivalency thereof are therefore to be embraced therein.

[0084] For example, described in the embodiment is an example of the engine cooling device 100 configured to acquire, at the time of closing the FSV 6, the valve-closable maximum speed based on various parameters, such as an outlet water temperature, and to perform low-speed driving of the electric WP 1 at the acquired valve-closable maximum speed. However, the present invention is not limited thereto. In the present invention, the engine cooling device may be configured to close the FSV at least with electric suction force while the flow rate of the cooling water is in a decreased state. For example, the engine cooling device may be configured to perform low-speed driving of the electric WP at a preset low speed at the time of closing the FSV. This makes it unnecessary to calculate the valve-closable maximum speed, and therefore the control load of the ECU can proportionally be reduced.

[0085] Moreover, although an example in which the ECU 7 performs low-speed driving of the electric WP 1 at the acquired valve-closable maximum speed is described in the embodiment, the present invention is not limited thereto. In the present invention, the ECU may perform low-speed driving of the electric WP at speeds less than the valve-closable maximum speed. In this case, low-speed driving of the electric WP is preferably performed at speeds that are less than the valve-closable maximum speed and are in the vicinity of the valve-closable maximum speed. As a result, it becomes possible to secure a sufficient flow rate of the cooling water while the electric WP is in the low-speed driving state and to achieve more reliable closing of the FSV.

[0086] Although an example of estimating each of the inlet water temperature Ti, the opening of the thermostat 5, and the flow resistance of the cooling water is described in the embodiment, the present invention is not limited thereto. The present invention may be configured so that the inlet water temperature, the opening of the thermostat, and the flow resistance of cooling water may directly be detected using detection units such as sensors, respectively. In the case of directly detecting the flow resistance of the cooling water, it is not necessary to acquire (estimate) the inlet water temperature and the opening of the thermostat. In the case of directly detecting the opening of the thermostat, it is not necessary to acquire (estimate) the inlet water temperature.

[0087] An example in which the ECU 7 calculates the valve closing time of the FSV 6 based on the flow resistance of the cooling water and on the flow rate of the cooling water in the FSV 6 is described in the embodiment. However, the present invention is not limited thereto. In the present invention, the ECU may use a preset valve closing time as the valve closing time of the FSV. This makes it unnecessary to calculate the valve closing time, and therefore the control load of the ECU can proportionally be reduced.

[0088] Although an example of using the electric WP 1 as a water pump is described in the embodiment, the present invention is not limited thereto. For example, a non-electric water pump which receives rotation driving force delivered from an engine crankshaft or the like may be used as the water pump. In this case, if a clearance between an impeller inside the water pump and a cover is configured to be adjustable, the flow rate of the cooling water discharged from the water pump can be controlled. The flow rate of the cooling water discharged from the water pump can also be controlled by controlling the rotation driving force delivered from the crankshaft with use of a member capable of controlling the driving force, such as a gear transmission and a clutch.

[0089] Although an example in which the electric WP 1 is an electrically-operated water pump including the brushless sensorless motor 1a is described in the embodiment, the present invention is not limited thereto. The present invention may be configured so that the electric WP includes, instead of the brushless sensorless motor, a brushless motor equipped with a sensor that detects the position of a rotor, or a motor with a brush.

[0090] Although an example in which the FSV 6 (solenoid valve) includes the urging member 64 in addition to the solenoid 65 is described in the embodiment, the present invention is not limited thereto. In the present invention, the solenoid valve may be configured so that the valve body moves in the valve closing direction at least with the electric suction force. That is, the solenoid valve may be configured without the urging member.

[0091] In the embodiment, an example is described in which the thermostat 5 is arranged in the cooling water channel 8a (first cooling water channel) where the radiator 2 is arranged, the heater core 3 is arranged in the cooling water channel 8b (second cooling water channel) where the FSV 6 is arranged, and the oil cooler 4 is arranged in the cooling water channel 8c (third cooling water channel). However, the present invention is not limited thereto. In the present invention, a heat exchanger may also be arranged in addition to the radiator in the first cooling water channel. Moreover, the thermostat does not need to be arranged in the first cooling water channel. A heat exchanger other than the heater core may additionally be arranged in the second cooling water channel, or another heat exchanger may be arranged in place of the heater core, or the heat exchanger including the heater core itself does not need to be arranged. Moreover, a heat exchanger other than the oil cooler may additionally be arranged in the third cooling water channel, or another heat exchanger may be arranged in place of the oil cooler, or the heat exchanger including the oil cooler itself does not need to be arranged. Here, as a heat exchanger other than the heater core and the oil cooler, exhaust gas recirculation (EGR) coolers, exhaust heat recovery devices, mission coolers, inverter coolers and the like may be used.

[0092] Although an example of providing the cooling water channel 8c (third cooling water channel) where the oil cooler 4 is arranged is described in the embodiment, the present invention is not limited thereto. In the present invention, the third cooling water channel does not need to be arranged.

[0093] Although an example of mounting the engine cooling device 100 on the vehicle is described in the embodiment, the present invention is not limited thereto. The engine cooling device of the present invention may be provided in a boat having an engine attached thereto, or the like.

[0094] 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. An engine cooling device comprising:

a water pump that controls a flow rate of cooling water for cooling an engine (101);
a radiator (2);
a first cooling water channel (8a) that passes the cooling water to the engine (101) through the radiator (2);
a second cooling water channel (8b) that passes the cooling water to the engine (101) without going through the radiator (2);
a solenoid valve (6) provided in the second cooling water channel (8b), the solenoid valve (6) including a valve body (62), the valve body (62) being moved by electric suction force to open and close the solenoid valve (6); and
a control unit (7) configured to execute control, at a time of closing the solenoid valve (6) in the second cooling water channel (8b), to close the solenoid valve (6) so as to cut off passage of the cooling water in the second cooling water channel (8b) by moving the valve body (62) in a valve closing direction with at least electric suction force while the cooling water is passing at a decreased flow rate, the decreased flow rate being achieved by driving the water pump so as to decrease the flow rate of the cooling water.

2. The engine cooling device according to claim 1, wherein
the solenoid valve (6) includes an urging member (64) that urges the valve body (62) in the valve closing direction, the valve body (62) being configured to be moved in the valve closing direction with urging force of the urging member (64) and the electric suction force while the water pump is driven.

3. The engine cooling device according to claim 1 or 2, wherein:

the control unit (7) is configured to execute control to close the solenoid valve (6) in the second cooling water channel (8b) by acquiring a valve-closable maximum speed of the water pump based on at least flow resistance of the cooling water and by moving the valve body (62) while the water pump is driven at a speed equal to or less than the valve-closable maximum speed.

4. The engine cooling device according to claim 3, further comprising
a thermostat (5) provided in the first cooling water channel (8a), the thermostat (5) having opening that changes based on temperature of the cooling water, wherein
the control unit (7) is configured to estimate the flow resistance of the cooling water based on the opening of the thermostat (5).

5. The engine cooling device according to any one of claims 1 to 4, wherein:

the water pump is an electrically-operated water pump (1) including a sensorless motor (1a).

6. The engine cooling device according to any one of claims 1 to 5, wherein:

the control unit (7) is configured to execute control so as to increase the flow rate of the cooling water with the water pump after closing of the solenoid valve (6) in the second cooling water channel (8b) is completed.

FIG. 1

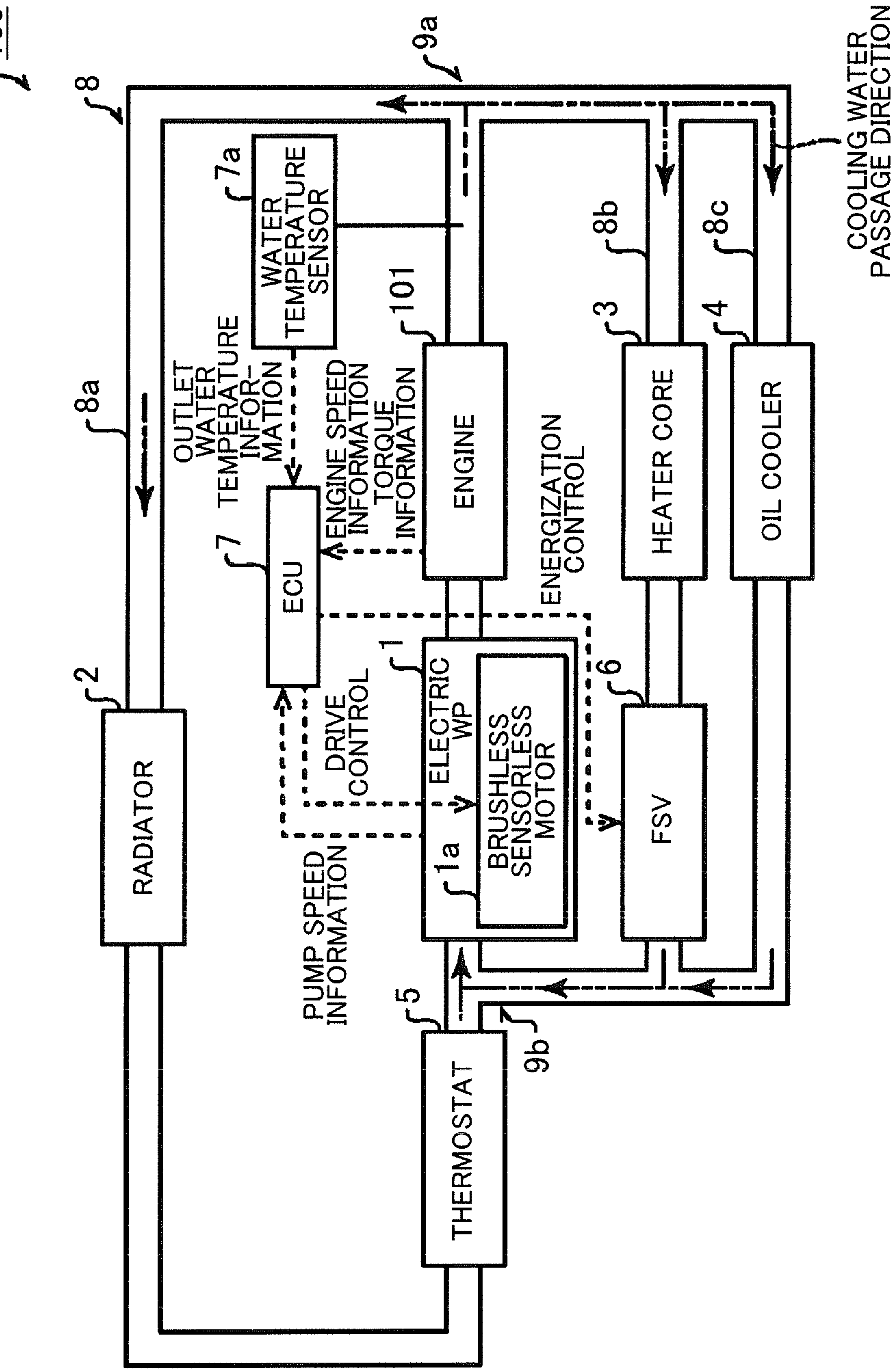

100
8
9a
8a
7a
WATER TEMPERATURE SENSOR
OUTLET WATER TEMPERATURE INFOR-MATION
ENGINE SPEED INFORMATION
TORQUE INFORMATION
101
ENGINE
8b
8c
3
4
HEATER CORE
OIL COOLER
COOLING WATER PASSAGE DIRECTION
ENERGIZATION CONTROL
7
ECU
2
RADIATOR
1
ELECTRIC WP
DRIVE CONTROL
BRUSHLESS SENSORLESS MOTOR
1a
6
FSV
PUMP SPEED INFORMATION
5
THERMOSTAT
9b

FIG. 2

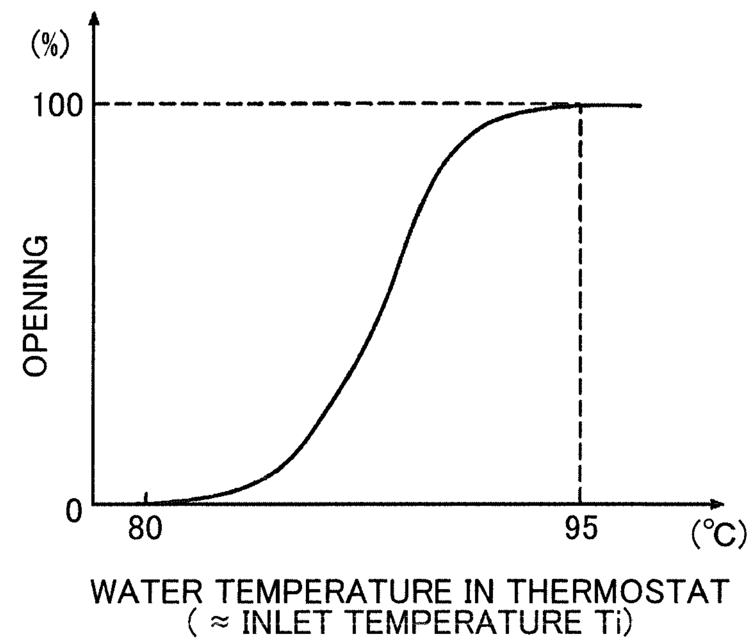

(%)
100
OPENING
0
80
95
(°C)
WATER TEMPERATURE IN THERMOSTAT
(≈ INLET TEMPERATURE Ti)

FIG. 3

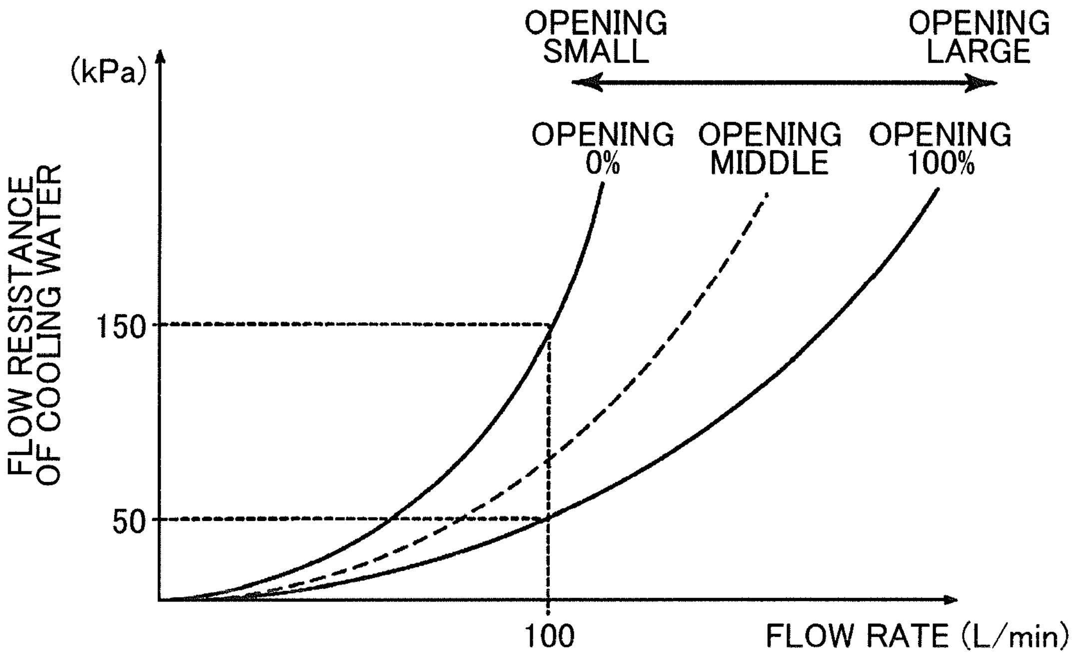

OPENING SMALL
OPENING LARGE
(kPa)
OPENING 0%
OPENING MIDDLE
OPENING 100%
FLOW RESISTANCE OF COOLING WATER
150
50
100
FLOW RATE (L/min)

FIG. 4

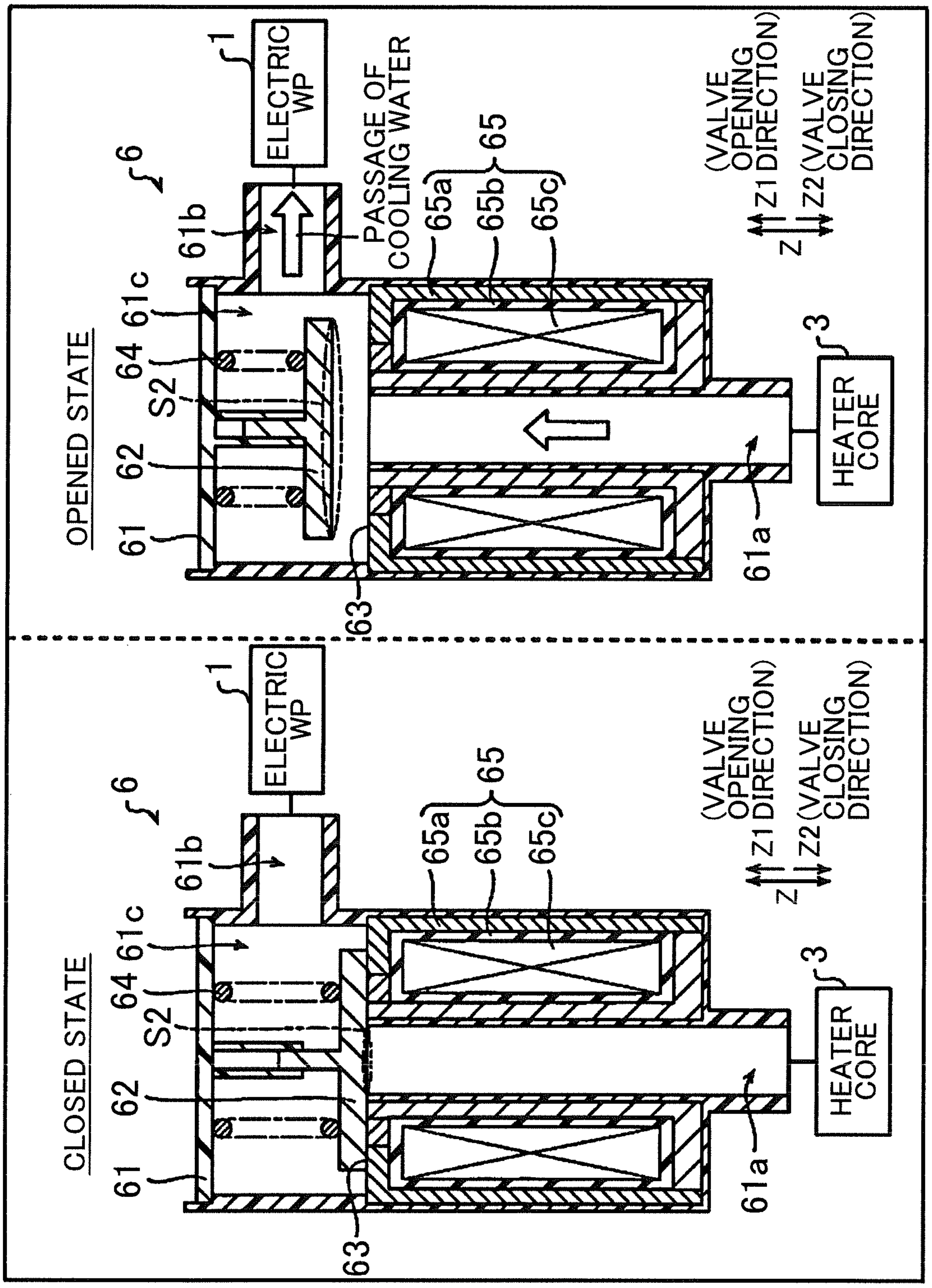
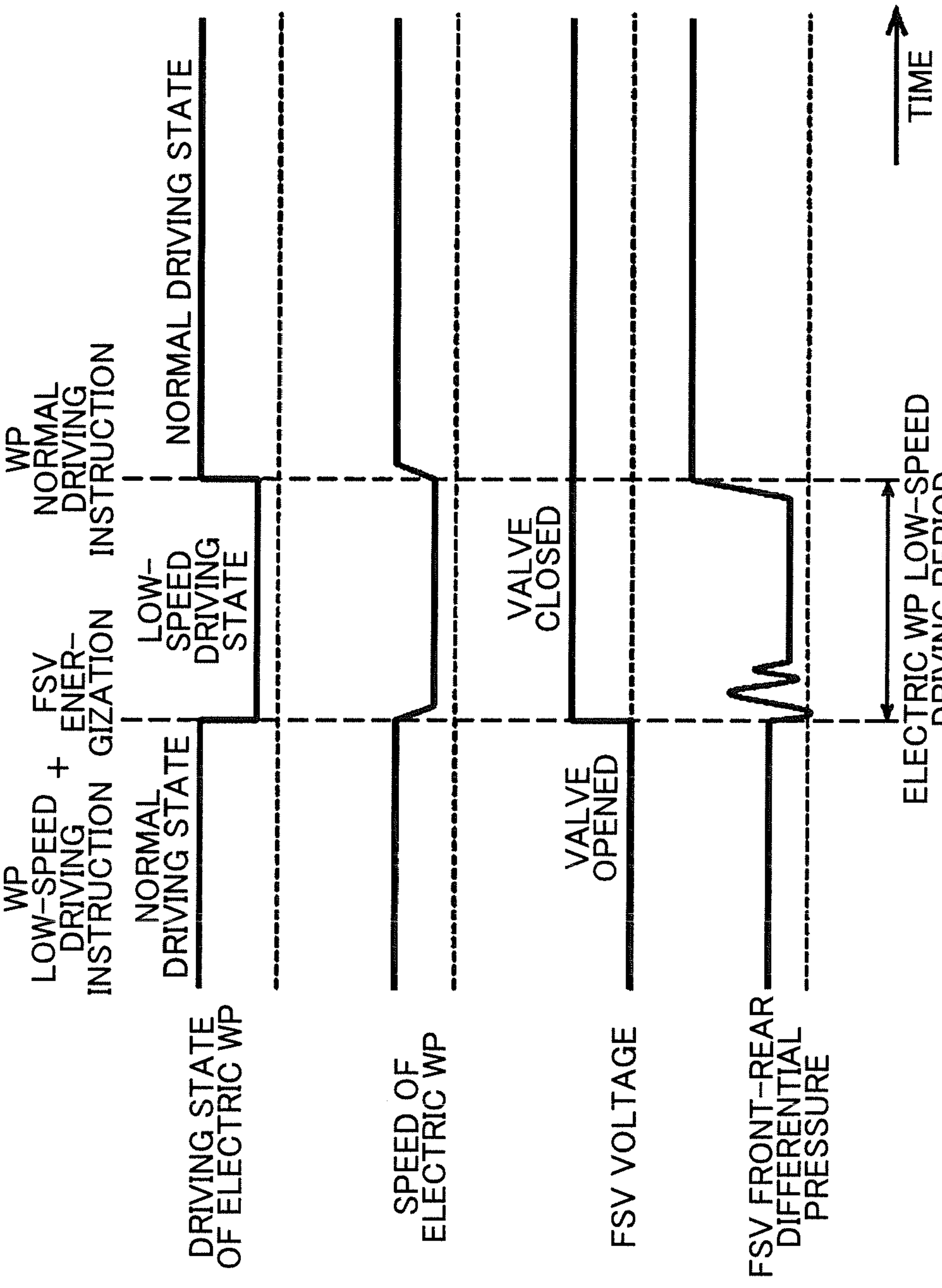

OPENED STATE
CLOSED STATE
ELECTRIC WP
PASSAGE OF COOLING WATER
HEATER CORE
1
3
6
61
61a
61b
61c
62
63
64
S2
65
65a
65b
65c
Z
Z1 (VALVE OPENING DIRECTION)
Z2 (VALVE CLOSING DIRECTION)

FIG. 5


DRIVING STATE OF ELECTRIC WP
SPEED OF ELECTRIC WP
FSV VOLTAGE
FSV FRONT-REAR DIFFERENTIAL PRESSURE
WP LOW-SPEED DRIVING INSTRUCTION + FSV ENERGIZATION
WP NORMAL DRIVING INSTRUCTION
NORMAL DRIVING STATE
LOW-SPEED DRIVING STATE
NORMAL DRIVING STATE
VALVE OPENED
VALVE CLOSED
ELECTRIC WP LOW-SPEED DRIVING PERIOD
TIME

F I G . 6

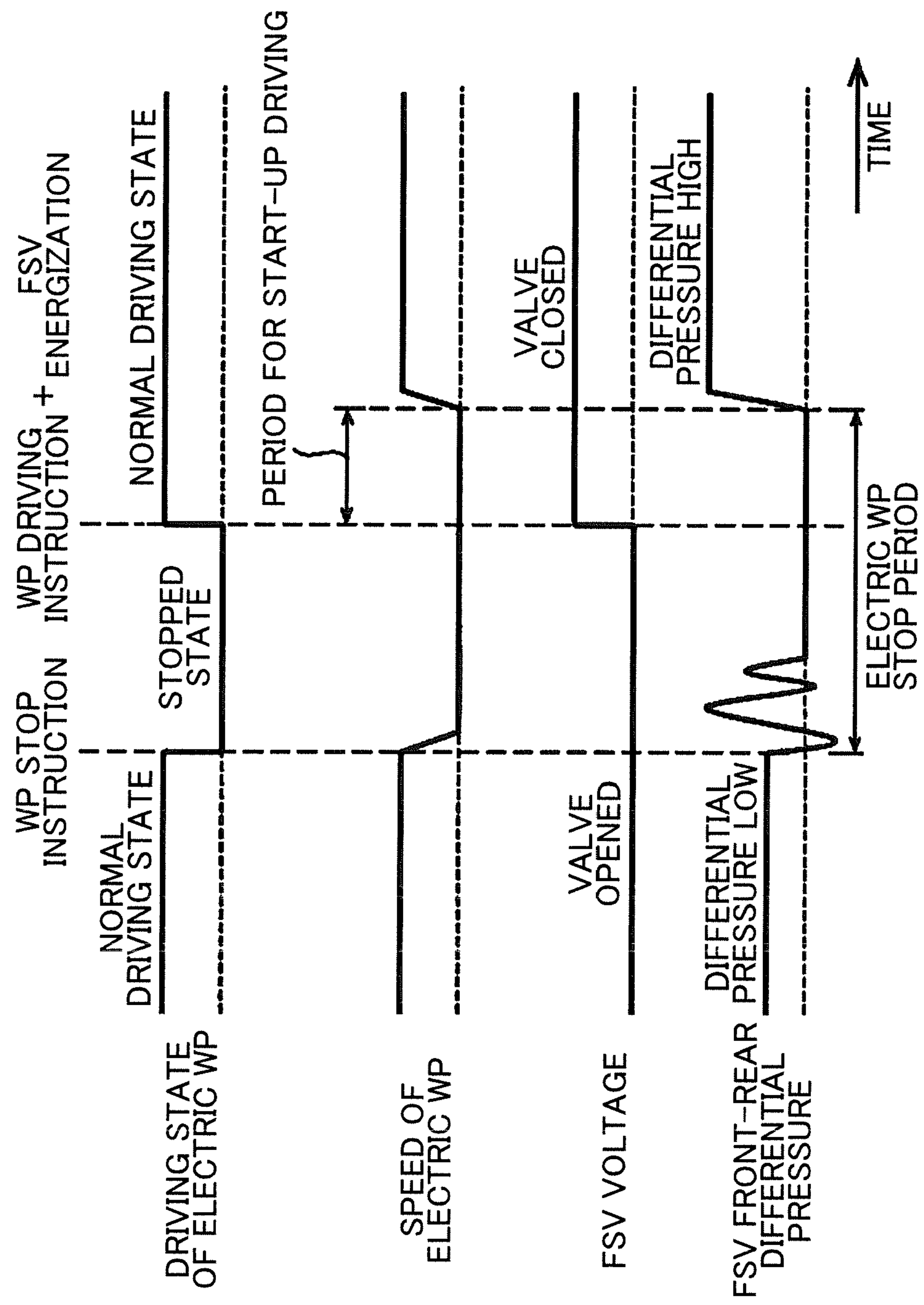

DRIVING STATE OF ELECTRIC WP
SPEED OF ELECTRIC WP
FSV VOLTAGE
FSV FRONT-REAR DIFFERENTIAL PRESSURE
NORMAL DRIVING STATE
WP STOP INSTRUCTION
STOPPED STATE
WP DRIVING INSTRUCTION + FSV ENERGIZATION
NORMAL DRIVING STATE
PERIOD FOR START-UP DRIVING
VALVE OPENED
VALVE CLOSED
DIFFERENTIAL PRESSURE LOW
DIFFERENTIAL PRESSURE HIGH
ELECTRIC WP STOP PERIOD
TIME

FIG. 7

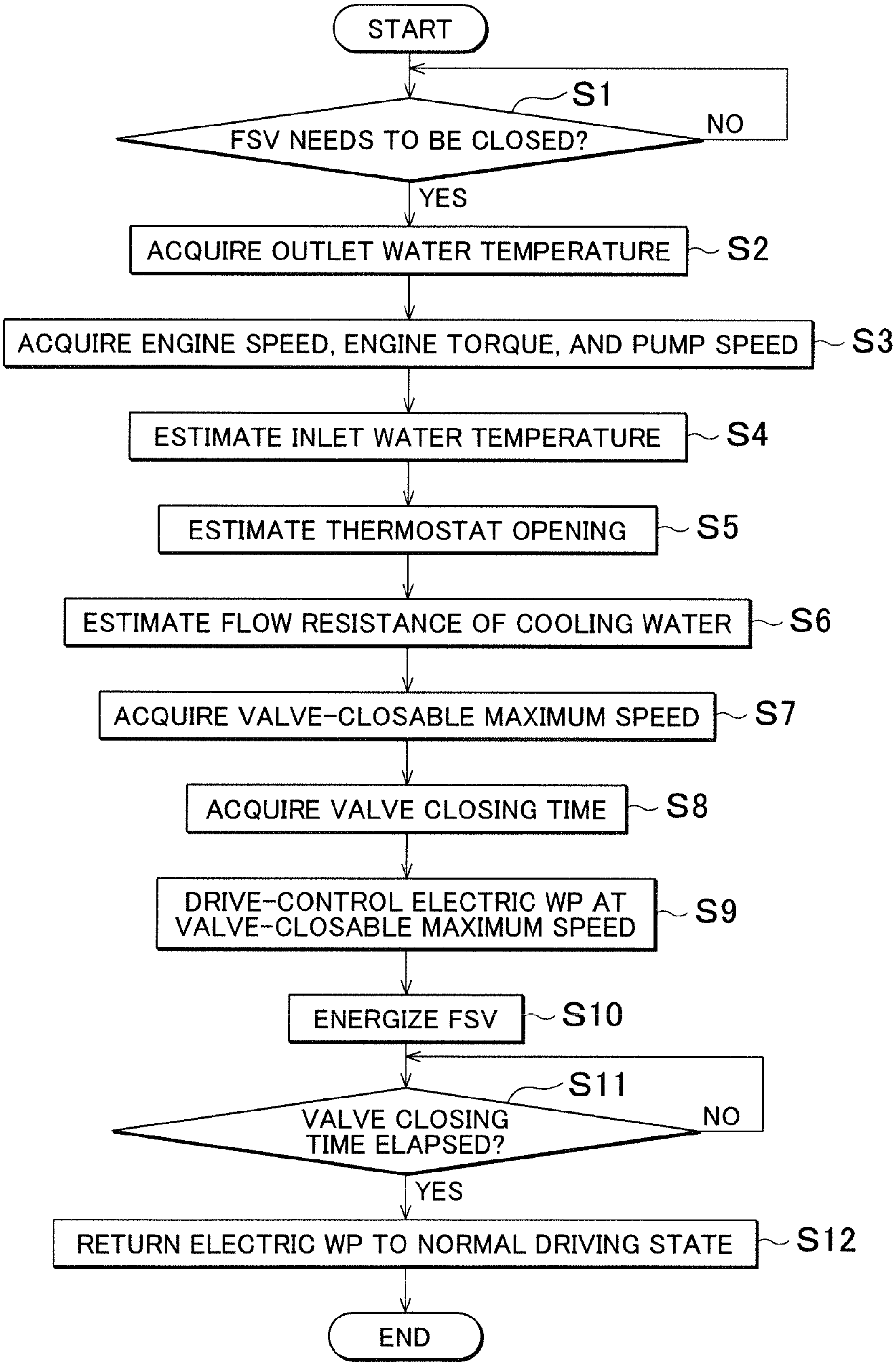
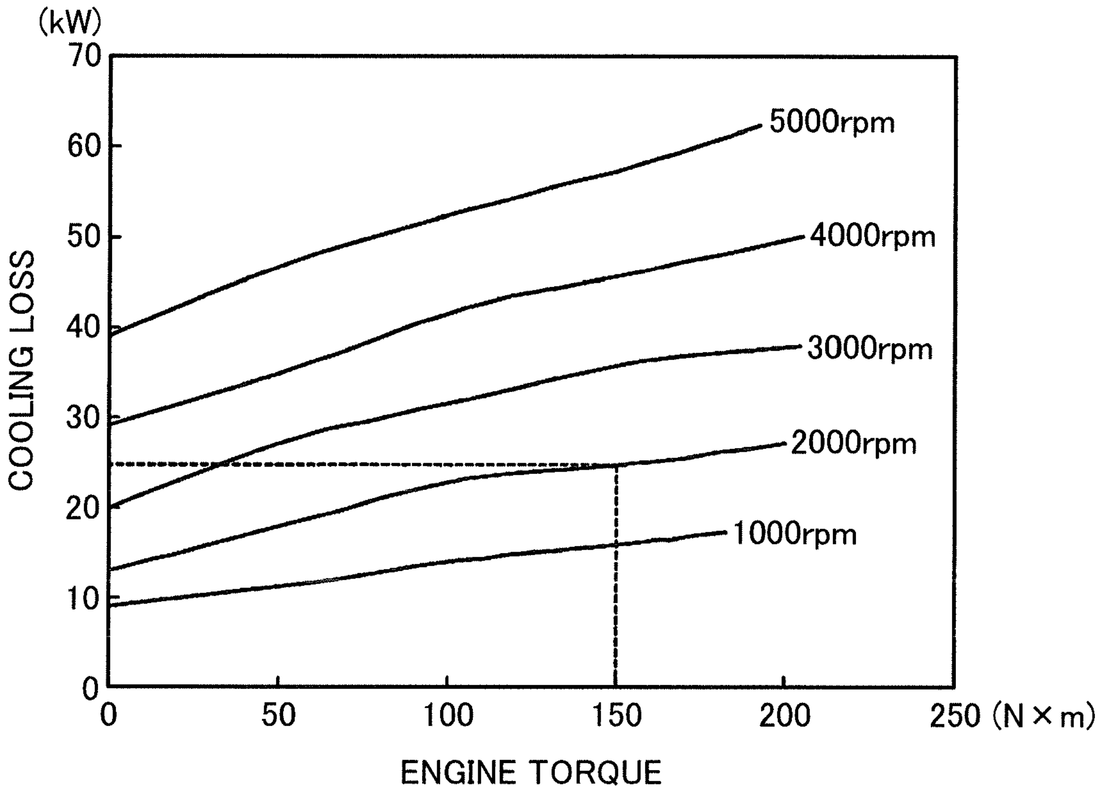

START
S1
FSV NEEDS TO BE CLOSED?
NO
YES
ACQUIRE OUTLET WATER TEMPERATURE
S2
ACQUIRE ENGINE SPEED, ENGINE TORQUE, AND PUMP SPEED
S3
ESTIMATE INLET WATER TEMPERATURE
S4
ESTIMATE THERMOSTAT OPENING
S5
ESTIMATE FLOW RESISTANCE OF COOLING WATER
S6
ACQUIRE VALVE-CLOSABLE MAXIMUM SPEED
S7
ACQUIRE VALVE CLOSING TIME
S8
DRIVE-CONTROL ELECTRIC WP AT VALVE-CLOSABLE MAXIMUM SPEED
S9
ENERGIZE FSV
S10
S11
VALVE CLOSING TIME ELAPSED?
NO
YES
RETURN ELECTRIC WP TO NORMAL DRIVING STATE
S12
END

FIG. 8


(kW)
70
60
50
40
30
20
10
0
COOLING LOSS
5000rpm
4000rpm
3000rpm
2000rpm
1000rpm
0
50
100
150
200
250 (N × m)
ENGINE TORQUE

F I G . 9

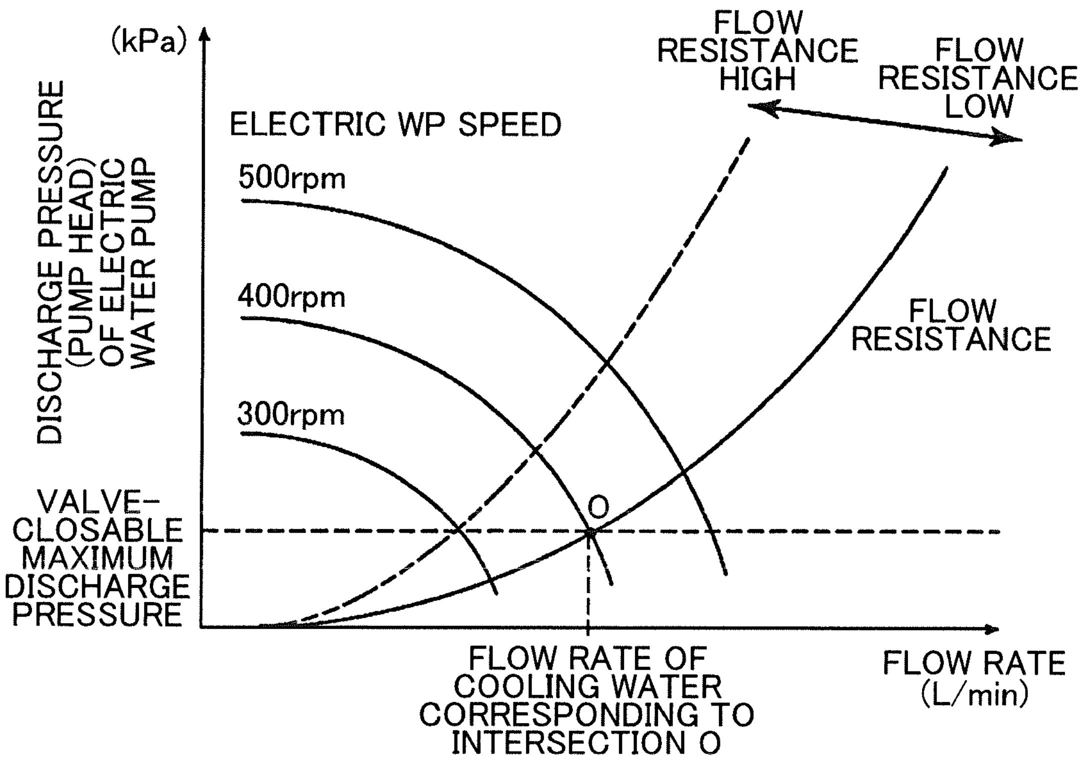
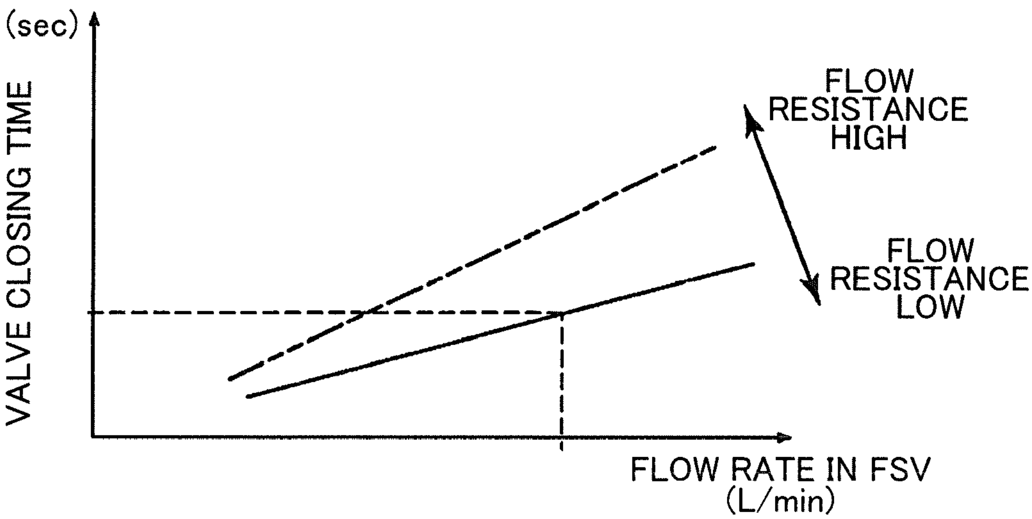

(kPa)
DISCHARGE PRESSURE (PUMP HEAD) OF ELECTRIC WATER PUMP
ELECTRIC WP SPEED
500rpm
400rpm
300rpm
FLOW RESISTANCE HIGH
FLOW RESISTANCE LOW
FLOW RESISTANCE
O
VALVE-CLOSABLE MAXIMUM DISCHARGE PRESSURE
FLOW RATE OF COOLING WATER CORRESPONDING TO INTERSECTION O
FLOW RATE (L/min)

FIG. 10


(sec)
VALVE CLOSING TIME
FLOW RESISTANCE HIGH
FLOW RESISTANCE LOW
FLOW RATE IN FSV (L/min)

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EUROPEAN SEARCH REPORT

Application Number
EP 16 18 2315

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	* abstract; figures 1,2,3 *	3-6	
X	US 2013/240174 A1 (MATSUSAKA MASANOBU [JP] ET AL) 19 September 2013 (2013-09-19) * paragraphs [0007], [0008], [0012], [0013], [0017], [0018]; figures 1,2a,2b *	1,2,6	
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F01P

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	25 November 2016	Luta, Dragos

CATEGORY OF CITED DOCUMENTS

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- JP 2013108398 A **[0002] [0003] [0004] [0005]**