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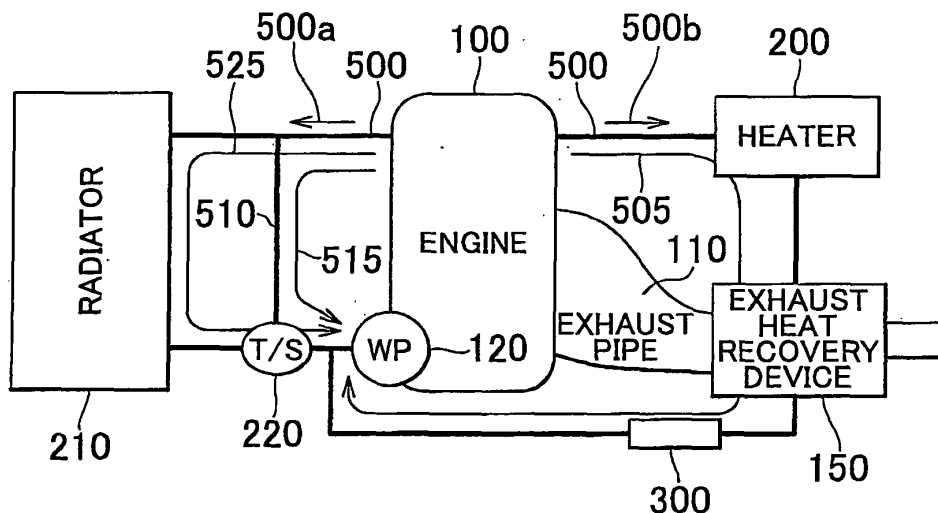
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(57) A flow control mechanism (300) is disposed downstream of an exhaust heat recovery device (150) on a cooling water circuit (500b) between the exhaust heat recovery device (150) and a water pump (120). The flow control mechanism (300) controls a flow rate of cooling water in accordance with a cooling water temperature around the flow control mechanism (300). When the cooling water temperature is low, the flow control mechanism

(300) does not limit the flow rate of the cooling water to perform exhaust heat recovery. When the cooling water temperature is increased, the flow control mechanism (300) limits the flow rate of the cooling water to stop the exhaust heat recovery. Further, the flow control mechanism (300) again increases the flow rate of the cooling water when the cooling water temperature is increased to around the boiling point of the cooling water while the exhaust heat recovery is stopped.

FIG. 5



Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to a cooling apparatus for an internal combustion engine in which heat is recovered by an exhaust heat recovery device provided in an exhaust pipe.

2. Description of the Related Art

[0002] A configuration is available in which an exhaust heat recovery apparatus is incorporated into a cooling system of an engine in order to use exhaust heat discharged from the internal combustion engine as a heat source for a heating device (e.g. a heater core using engine cooling water as a heat source).

[0003] For example, Japanese Patent Application Publication No. 2006-283711 (JP-A-2006-283711) describes an exhaust heat recovery apparatus and its control method. The exhaust heat recovery apparatus is provided in an exhaust pipe of an internal combustion engine, the exhaust pipe including an exhaust heat recovery passage with which heat is recovered by the exhaust gas recovery apparatus from exhaust gas discharged from the internal combustion engine, and an exhaust bypass passage by which the exhaust heat recovery passage is bypassed. The exhaust pipe is provided with a flow control valve to adjust a proportion of a flow rate of exhaust gas that flows through the heat recovery passage to a flow rate of exhaust gas that flows through the exhaust heat bypass passage.

[0004] In JP-A-2006-283711, the opening degree of the flow control valve is variably controlled in accordance with a temperature of coolant water and the flow rate of exhaust gas determined based on the operating condition of the internal combustion engine, or a physical quantity that correlates to the flow rate of exhaust gas. Thus, when the exhaust heat recovery apparatus described in JP-A-2006-283711 is used, it is possible to improve heating performance by utilizing the exhaust heat without worsening fuel economy and exhaust emission of the internal combustion engine.

[0005] Further, Japanese Patent Application Publication No. 2006-250524 (JP-A-2006-250524) describes a multiple-pipe heat recovery device for recovering heat from the exhaust gas discharged from the internal combustion engine. The multiple-pipe heat recovery device includes an annular passage through which the exhaust gas flows when heat exchange is performed, and a bypass passage that penetrates the multiple-pipe heat recovery device at the center thereof. The multiple-pipe heat recovery device also includes a valve body that is opened and closed in accordance with a pressure of the exhaust gas, thereby selectively switching between the annular passage and the bypass passage.

[0006] However, according to JP-A-2006-283711 and JP-A-2006-250524, exhaust heat recovery is stopped (this condition may be simply referred to as a "non-recovery mode") by switching the passages of the exhaust gas in the exhaust heat recovery device. However, the flow rate of cooling water flowing through the exhaust heat recovery device is not reduced even when the exhaust heat recovery is stopped. Note that, although the exhaust gas flows through the bypass passage in the exhaust heat recovery device, and thereby the amount of heat exchanged between the engine cooling water and exhaust gas is reduced when the exhaust heat recovery is stopped, it is practically difficult to completely reduce the amount of heat recovered in the exhaust heat recovery device to zero due to the mechanism of the exhaust heat recovery device.

[0007] Therefore, even when the engine is warm, and thereby the exhaust heat recovery through the heat recovery passage is not performed, the temperature of the engine cooling water may be further increased due to unnecessary heat recovery in the bypass passage of the exhaust heat recovery device through which a large amount of the engine cooling water flows. Thus, improvement of heat radiation performance (e.g., increase in the capacity) of a heat radiation mechanism (for example, a radiator) may be required in order to reduce the temperature of the engine cooling water when the engine is warm, which may result in increase in size of the heat radiation mechanism.

SUMMARY OF THE INVENTION

[0008] The invention provides a cooling apparatus for an internal combustion engine in which the size of a heat radiation mechanism is reduced by preventing coolant temperature from increasing when an internal combustion engine is warm, that is, when exhaust heat recovery is not performed.

[0009] A cooling apparatus for an internal combustion engine according to an aspect of the invention includes: a coolant pump for circulating a coolant in the internal combustion engine; coolant piping; a heat radiation mechanism that radiates heat from a coolant; a load mechanism; an exhaust heat recovery device; and a flow control means.

[0010] The coolant piping is arranged in a manner such that an operation of the coolant pump produces a first coolant circuit and a second coolant circuit that are arranged in a parallel manner. The heat radiation mechanism is disposed on the first coolant circuit. The load mechanism is disposed on the second coolant circuit and is operated using heat carried by the coolant. The exhaust heat recovery device is disposed in an exhaust pipe of the internal combustion engine and performs heat exchange between the coolant flowing through the second coolant circuit and exhaust gas discharged from the internal combustion engine. The flow control means controls a flow rate of the coolant in accordance with a tem-

perature of the coolant in a disposition portion at which the flow control means is disposed, the flow control means being disposed downstream of the exhaust heat recovery device on the second coolant circuit.

[0011] In the cooling apparatus according to the aforementioned aspect of the invention, whether exhaust heat recovery is performed can be controlled by controlling the flow rate of the coolant that flows through the exhaust heat recovery device in accordance with the temperature of the coolant that flows through the exhaust heat recovery device. Therefore, when the exhaust heat recovery is not performed, the flow rate of the coolant that flows through the exhaust heat recovery device is reduced, and therefore the temperature of the coolant can be prevented from increasing due to unnecessary heat exchange performed in the exhaust heat recovery device. Consequently, it is possible to reduce the level of the heat radiation performance of the heat radiation mechanism required when the internal combustion engine is warm, that is, when the exhaust heat recovery is not performed, which makes it possible to reduce the size of the heat radiation mechanism.

[0012] The flow control means may be designed so that, when the temperature of the coolant is within a first temperature range which is below a first predetermined temperature, the flow rate of the coolant is not limited by the flow control means. Further, the flow control means may be designed so that, when the temperature of the coolant is within a second temperature range which is between the first predetermined temperature and a second predetermined temperature inclusive, the flow rate of the coolant is reduced, and when the temperature of the coolant is within a third temperature range which is above the second predetermined temperature, the flow rate of the coolant is increased compared to the flow rate corresponding to the second temperature range.

[0013] The flow control means may include a thermal deformation member that expands and contracts in accordance with the temperature of the coolant and movable means that is displaced as the thermal deformation member expands or contracts. The flow control means may open and close a coolant passage on the second coolant circuit by the thermal deformation member and the movable means.

[0014] The movable means may be provided with a flow limiting means that closes the coolant passage when the movable means is displaced within a predetermined range.

[0015] The flow limiting means may be provided with at least one penetration hole through which a predetermined amount of the coolant is passed even when the coolant passage is closed.

[0016] The thermal deformation member may contain a wax material or may be made of a shape-memory alloy.

[0017] Alternatively, the flow control means may include: a temperature detection device for detecting the temperature of the coolant; a flow control valve whose opening degree is controlled based on an electric signal;

and a control means. Further, the control means may generate the electric signal to control the opening degree of the flow control valve in accordance with the detected temperature of the coolant.

[0018] The exhaust heat recovery device and the flow control means may be disposed in series on the second coolant circuit, and the load mechanism may be disposed in parallel to the exhaust heat recovery device and the flow control means.

[0019] The cooling apparatus for an internal combustion engine may include a first exhaust passage on which the heat exchange is performed between the coolant and the exhaust gas; a second exhaust passage by which the first exhaust passage is bypassed; and an exhaust control valve that controls a proportion of a flow rate of exhaust gas that flows through the first exhaust passage with respect to a flow rate of the exhaust gas that flows through a second exhaust passage. Further, the exhaust control valve may be controlled so that the exhaust gas mainly flows through the second exhaust passage when the temperature of the coolant is in a temperature range in which the flow rate of the coolant is limited by the flow control means.

[0020] Further, the load mechanism may be a heater.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The foregoing and further features and advantages of the invention will become apparent from the following description of example embodiments with reference to the accompanying drawings, wherein like numerals are used to represent like elements and wherein:

FIG. 1 schematically shows an overall configuration of a cooling apparatus for an internal combustion engine as a comparative example;

FIG. 2 shows an exhaust passage established when exhaust heat recovery is not performed;

FIG. 3 shows an exhaust passage established when exhaust heat recovery is not performed;

FIG. 4 is a graph illustrating the amount of heat recovered in the cooling apparatus for an internal combustion engine shown in FIG. 1;

FIG. 5 schematically shows an overall configuration of a cooling apparatus for an internal combustion engine according to a first embodiment of the invention;

FIG. 6 schematically shows a configuration of a flow control mechanism shown in FIG 5;

FIG. 7 is a timing chart showing how the flow control mechanism controls a flow rate of cooling water in accordance with a temperature of the cooling water; FIG. 8 is a graph showing expansion characteristics of a wax shown in FIG. 5;

FIGS. 9A to 9C schematically show how the flow control mechanism is operated in accordance with the cooling water temperature;

FIG. 10 is a graph showing an amount of heat re-

covered in the cooling apparatus for an internal combustion engine according to the first embodiment; FIG. 11 schematically shows a modification example of the flow control mechanism shown in FIG. 5; FIG. 12 schematically shows an overall configuration of a cooling apparatus for an internal combustion engine according to a second embodiment of the invention; FIG. 13 schematically shows an overall configuration of a cooling apparatus for an internal combustion engine according to a third embodiment of the invention; FIG. 14 is a graph illustrating the amount of heat recovered in the cooling apparatus for an internal combustion engine according to the third embodiment; and FIG. 15 schematically shows an overall configuration of a cooling apparatus for an internal combustion engine according to a fourth embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[0022] Embodiments of the invention will be described in detail below with reference to the attached drawings. The same or equivalent elements in the drawings will be denoted by the same reference numerals, and in principle the description thereof will not be repeated.

[0023] FIG. 1 schematically shows an overall structure of a cooling apparatus for an internal combustion engine, which is a comparative example of a cooling apparatus for an internal combustion engine according to the embodiments of the invention.

[0024] Referring to FIG. 1, an engine 100 is an internal combustion engine including a cooling passage (not shown) through which a coolant flows. Water is typically used as the coolant for the engine 100, and therefore the coolant will also be referred to as "engine cooling water" or simply referred to as "cooling water". It should be noted that the coolant is not limited to water, and any suitable fluid or gas can be used as the coolant as appropriate.

[0025] The engine 100 includes a water pump 120 for circulating the coolant in the cooling apparatus. The water pump 120 may be an electric pump, or may be a mechanical pump driven by the rotational force of the engine 100. Note that, the water pump 120 may be regarded as a "coolant pump" according to the invention. In cooling water piping 500, the operation of the water pump 120 produces a cooling water circuit 500a for leading, to a radiator 210, the cooling water that is discharged from the engine 100, and a cooling water circuit 500b for leading the cooling water to a heater 200, the circuits being arranged in a parallel manner.

[0026] A thermostat 220 is provided on the cooling water circuit 500a. The thermostat 220 is a thermal valve that is opened and closed in accordance with a temperature of cooling water in a portion at which the thermostat 220 is disposed. When the thermostat 220 is closed (that

is, when the engine is cold), a cooling water path 515 extending from a cooling water outlet of the engine 100 to the water pump 120, in which the radiator 210 is bypassed by means of a bypass pipe 510. On the other hand, when the cooling water temperature is increased and the thermostat 220 is opened (that is, when the engine is warm), the cooling water flowing through the cooling water circuit 500a circulates through a cooling water path 525 without flowing through the bypass pipe 510, the cooling water path 525 extending from the cooling water outlet of the engine 100 to the water pump 120 through the radiator 210. The radiator 210 includes a heat radiation mechanism (not shown), and the cooling water circulating through the cooling water circuit 500a is cooled through heat exchange performed by the heat radiation mechanism (for example, by means of air cooling). Therefore, in order to increase the amount of heat radiation, that is, in order to achieve the desired heat radiation performance, it is necessary to secure a large heat radiation area.

[0027] The cooling water circuit 500a is configured so that the cooling water is circulated through the cooling water path 515 when the thermostat 220 is closed, and the cooling water is circulated through the cooling water path 525 when the thermostat 220 is opened.

[0028] The cooling water circuit 500b includes a cooling water path 505 extending from the cooling water outlet of the engine 100 to the water pump 120 via the heater 200 and an exhaust heat recovery device 150. The heater 200 is provided so as to function as a heat exchanger for air heating, and performs the heating using the cooling water flowing through the cooling water circuit 500b as a heat source. In other words, the cooling water is circulated by the water pump 120 through the cooling water circuit 500b, and the circulated cooling water (heated water) heats the air through heat exchange between the air and the heated cooling water. The heated air is sent out into a vehicle compartment using a fan (not shown).

[0029] The heater 200 is operated using heat carried by the cooling water, and may be regarded as a "load mechanism" according to the invention. The load mechanism is not limited to the heater 200, and an additional load mechanism may be provided on the cooling water circuit 500b in addition to the heater 200.

[0030] The exhaust heat recovery device 150 is provided in an exhaust pipe 110 of the engine 100, and exhaust heat is recovered in the exhaust heat recovery device 150 through heat exchange between the cooling water which flows through the cooling water circuit 500b and exhaust gas discharged from the engine 100. The exhaust heat recovery device 150 includes an exhaust control valve 160 that functions as a switching mechanism to switch between an exhaust heat recovery mode (in which exhaust heat is recovered) and a non-recovery mode (in which exhaust heat is not recovered). The exhaust heat recovery device 150 also includes a thermal actuator 170 for opening and closing the exhaust control valve 160.

[0031] The thermal actuator 170 is provided on the cooling water circuit 500b near the exhaust heat recovery device 150, and opens and closes the exhaust control valve 160 in accordance with the cooling water temperature in a portion at which the thermal actuator 170 is disposed. The thermal actuator 170 may be formed using a thermostat and a shape-memory alloy, for example. When the cooling water temperature is lower than a predetermined threshold temperature, the thermal actuator 170 closes the exhaust control valve 160 (that is, the exhaust heat recovery is performed). When the cooling water temperature is equal to or higher than the predetermined threshold temperature, the thermal actuator 170 opens the exhaust control valve 160 (that is, the exhaust heat recovery is not performed).

[0032] Referring to FIGS. 2 and 3, the following paragraphs will schematically describe the configuration of the exhaust heat recovery device 150, and also describe an exhaust passage established in the exhaust heat recovery mode and an exhaust passage established in the non-recovery mode.

[0033] Referring to FIG. 2, when the thermal actuator 170 closes the exhaust control valve 160, exhaust gas discharged from the engine 100 flows through a heat recovery passage 156 so that heat exchange is performed between the exhaust gas flowing through the heat recovery passage 156 and the coolant that flows in cooling water channels 152 included in the cooling water circuit 500b. In this way, when the exhaust control valve 160 is closed, it is possible to promptly increase the cooling water temperature using heat recovered from the exhaust gas through heat exchange between the exhaust gas and the cooling water that flows through the cooling water circuit 500b.

[0034] On the other hand, as shown in FIG. 3, when the thermal actuator 170 opens the exhaust control valve 160, the exhaust gas discharged from the engine 100 is discharged into the outside through a bypass passage 158 by which the heat recovery passage 156 shown in FIG. 2 is bypassed. When the exhaust control valve 160 is closed, the amount of exhaust gas involved in the heat exchange is reduced, and therefore the exhaust heat recovery from the exhaust gas as shown in FIG. 2 is not performed.

[0035] FIG. 4 is a chart illustrating the amount of heat recovered in the cooling apparatus for an internal combustion engine according to the comparative example. Referring to FIG. 4, the amount of heat recovered in the exhaust heat recovery device 150 is determined in accordance with the flow rates of the cooling water and exhaust gas involved in the heat exchange. When the exhaust control valve 160 is opened and the exhaust heat recovery is not performed (this condition may be sometimes referred to as "non-recovery mode"), the bypass passage 158 is selected, so that the amount of exhaust gas involved in the heat exchange is reduced, which results in reduction in the amount of heat recovered when the flow rate is the same.

[0036] However, it is difficult to completely stop the heat exchange performed in the exhaust heat recovery device 150, and therefore heat is still recovered to some extent even when the exhaust heat recovery is not performed. Therefore, even when the engine 100 is warm, that is, even when the exhaust heat recovery is not performed, the temperature of the entire cooling water circulating in the cooling apparatus is increased depending on the amount of heat recovered in the exhaust heat recovery device 150. This can increase the required heat radiation performance of the radiator 210 for reducing the cooling water temperature when the engine is warm, which can in turn result in increase in size of the radiator 210.

[0037] For this reason, the cooling apparatus for an internal combustion engine according to each embodiment of the invention described below includes a mechanism for suppressing increase in temperature of the cooling water circulating in the cooling apparatus when the engine 100 is warm, that is, when the exhaust heat recovery in the exhaust heat recovery device 150 is not performed.

[0038] FIG. 5 schematically shows an overall configuration of a cooling apparatus for an internal combustion engine according to a first embodiment of the invention.

[0039] In the cooling apparatus for an internal combustion engine according to the first embodiment, the exhaust control valve 160 and the accompanying thermal actuator 170 are omitted as compared to the cooling apparatus shown in FIG. 1. Thus, the exhaust gas discharged from the engine 100 always flows through the heat recovery passage 156 (shown in FIG. 2) in the exhaust heat recovery device 150.

[0040] Further, a flow control mechanism 300 is provided in a path of the cooling water from the exhaust heat recovery device 150 to the water pump 120. In other words, the flow control mechanism 300 is disposed downstream of the exhaust heat recovery device 150 on the cooling water circuit 500b. The flow control mechanism 300 controls the flow rate of the cooling water in accordance with the cooling water temperature in a portion of the cooling water circuit 500b at which the flow control mechanism 300 is disposed. Basically, when the cooling water temperature is low (that is, when the engine is cold), the flow rate of the cooling water is not limited by the flow control mechanism 300, and the exhaust heat recovery is performed. However, when the cooling water temperature is increased, the flow rate of the cooling water is limited by the flow control mechanism 300, and the exhaust heat recovery is not performed.

[0041] FIG. 6 schematically shows the flow control mechanism 300 shown in FIG. 5. Referring to FIG. 6, the flow control mechanism 300 includes a wax 310 that expands and contracts in accordance with the cooling water temperature, and a movable portion 320 that is displaced as the wax 310 expands or contracts. A flow limiter 330 is provided on the tip of the movable portion 320 so that the flow limiter 330 closes a coolant passage on the cool-

ing water circuit 500b when the movable portion 320 is positioned within a predetermined range of displacement. The flow limiter 330 is provided with a small hole 340 for temperature sensing, in order to allow a small amount of the cooling water to flow even when the coolant passage on the cooling water circuit 500b is closed. The member that expands and contracts in accordance with the cooling water temperature is not limited to the wax 310, and may be a material whose volume is changed in accordance with the ambient temperature, such as a shape-memory alloy. Note that, the wax 310 may be regarded as a "thermal deformation member" according to the invention.

[0042] FIG. 7 shows how the flow control mechanism 300 is operated in accordance with the cooling water temperature. Further, FIG. 8 shows expansion characteristics of the wax 310. As shown in FIG. 8, the wax 310 has expansion characteristics such that the wax 310 does not expand in a temperature range below T_0 ; the wax 310 gradually expands in a temperature range from T_0 to T_3 ; and expansion of the wax 310 reaches its maximum when temperature reaches T_3 .

[0043] Therefore, as shown in FIG. 7, the flow control mechanism 300 does not limit the flow rate of the cooling water in the temperature range where the cooling water temperature T_w is below T_0 . In other words, in the temperature range where the cooling water temperature T_w is below T_0 as shown in FIG. 9A, the wax 310 is under a contracted state. Therefore, the flow limiter 330 does not reach a flow-limiting portion 502 in the cooling water circuit 500b, and the flow-limiting portion 502 remains open so that the cooling water flows therein without limitation. In this temperature range (i.e., $T_w < T_0$), the exhaust heat recovery mode is established in which a sufficient amount of the cooling water is allowed to flow through the exhaust heat recovery device 150 and exhaust heat recovery is performed.

[0044] Referring again to FIG. 7, when the cooling water temperature T_w is within a temperature range from T_0 to T_1 , the wax 310 expands as the cooling water temperature increases, and the flow limiter 330 gradually closes the flow-limiting portion 502, thereby gradually limiting the flow rate of the cooling water. Further, when the cooling water temperature T_w is within a temperature range from T_1 to T_2 , the flow limiter 330 reaches a point at which the flow-limiting portion 502 is closed as the movable portion 320 is further displaced by the further expansion of the wax 310, as shown in FIG. 9B. Thus, the flow rate of the cooling water flowing through the exhaust heat recovery device 150 is reduced, and the non-recovery mode is established in which the exhaust heat recovery is not performed.

[0045] Note that, because the flow limiter 330 is provided with the small hole 340, the coolant passage on the cooling water circuit 500b is not completely closed, and a predetermined amount (e.g. small amount) of the cooling water continues to flow through the cooling water circuit 500b even when the cooling water temperature

T_w is within the aforementioned temperature range ($T_1 \leq T_w < T_2$). This allows the cooling water to circulate in the cooling apparatus to some extent, and therefore the wax 310 is allowed to expand and contract in accordance with the temperature of the cooling water circulating in the entire cooling apparatus. Note that, it is preferable that the "predetermined amount" of the cooling water be a minimum necessary amount that is enough for the wax 310 to behave according to the temperature of the circulating cooling water.

[0046] In a temperature range $T_w \geq T_2$, which is reached when the cooling water temperature further increases, the wax 310 further expands, and accordingly the movable portion 320 is further displaced, so that the flow limiter 330 gradually leaves the flow-limiting portion 502 and gradually opens the flow-limiting portion 502 (i.e., opens the cooling water circuit 500b), as shown in FIG. 9C. Then, when the cooling water temperature T_w reaches T_3 ($T_w = T_3$), the wax 310 expands to the maximum, and the flow-limiting portion 502 (i.e., the cooling water circuit 500b) is again opened at the flow-limiting portion 502. This allows the cooling water to flow without limitation of the flow rate.

[0047] Therefore, as shown in FIG. 7, when the cooling water temperature T_w is within the temperature range from T_2 to T_3 , the flow rate of the cooling water is increased compared to the flow rate when the cooling water temperature T_w is within the temperature range from T_1 to T_2 . Therefore, if the predetermined temperature T_2 is set based on the temperature at which local boiling of the cooling water can occur, such local boiling can be prevented from occurring by increasing the flow rate of the cooling water even when the cooling water temperature is excessively increased in the non-recovery mode. In other words, it is preferable to make a design so that, in the non-recovery mode, the flow control mechanism 300 operates to increase the flow rate of the cooling water when the cooling water temperature T_w is within a range ($T_2 < T_w < T_3$) indicated at 400 in FIG. 7.

[0048] The flow rate control of the cooling water in accordance with the cooling water temperature, which is shown in FIG. 7, can be achieved by designing the arrangement and size of the movable portion 320 and the flow limiter 330 in the flow control mechanism 300, and the flow-limiting portion 502, etc. to match the expansion characteristics of the wax 310 shown in FIG. 8.

[0049] In the cooling apparatus for an internal combustion engine according to the first embodiment, in the non-recovery mode, the amount of heat recovered in the exhaust heat recovery device 150 can be reduced by reducing the flow rate of the cooling water flowing through the exhaust heat recovery device 150, as shown in FIG. 10, so that the temperature of the cooling water circulating in the cooling apparatus is prevented from increasing. This makes it possible to reduce the requirement for heat radiation performance of the radiator 210 and reduce the size of the radiator 210. Further, it is possible to increase the flow rate of the cooling water again when the cooling

water temperature is excessively increased in the non-recovery mode in which the flow rate of the cooling water is reduced. Thus, it is possible to reliably prevent local boiling of the cooling water.

[0050] In the cooling device for an internal combustion engine according to the first embodiment, the configuration of the flow control mechanism 300 shown in FIG. 6 may be modified as shown in FIG. 11. In the modification example shown in FIG. 11, the wax 310 is attached to a fixing portion 350 through the movable portion 320. In this configuration, when the wax 310 expands, the flow-limiting portion 502 is closed by the expanded wax 310. This configuration makes it possible to control the flow rate of the cooling water with higher accuracy in accordance with the cooling water temperature, because the heat-sensitivity is improved. Note that, even though it is not shown in the drawing, the wax 310 in the modification example may be provided with the small hole 340 for temperature sensing, similar to the configuration shown in FIG. 6.

[0051] In the first embodiment, FIGS. 6 and 11 show the examples of the mechanical configuration of the flow control mechanism 300. However, the configuration of the flow control mechanism 300 is not limited to these example mechanical configurations, and any selected configuration may be employed, such as a configuration employing a combination of a rotary valve/a butterfly valve and a wax/a shape-memory alloy, as long as the control characteristics shown in FIG. 7 can be achieved.

[0052] FIG. 12 schematically shows an overall configuration of a cooling apparatus for an internal combustion engine according to a second embodiment of the invention.

[0053] Referring to FIG. 12, the cooling apparatus for an internal combustion engine according to the second embodiment includes the cooling water circuit 500b on which the heater 200 is disposed in parallel to the exhaust heat recovery device 150 and the flow control mechanism 300.

[0054] This configuration eliminates the possibility of drastic reduction of the flow rate of the cooling water that flows through the heater 200, even when the flow rate of the coolant is reduced by the flow control mechanism 300 during a transition from the exhaust heat recovery mode to the non-recovery mode. As a result, it becomes easier to achieve desired performance of the heater 200. Further, this configuration makes it possible to obtain the necessary flow rate of the cooling water that flows through the heater 200, that is, the amount of heat that can be used by the heater 200 for heating the air, and therefore it becomes possible for the heater 200 to achieve desired heating performance, even in the non-recovery mode.

[0055] FIG. 13 is a block diagram showing a configuration of a cooling apparatus for an internal combustion engine according to a third embodiment of the invention.

[0056] Referring to FIG. 13, in the cooling apparatus for an internal combustion engine according to the third

embodiment, the exhaust control valve 160 and the thermal actuator 170, which are similarly provided in the configuration shown in FIG. 1, are further provided as compared to the configuration of the cooling apparatus for an internal combustion engine according to the first embodiment (shown in FIG. 5).

[0057] In other words, in the cooling apparatus for an internal combustion engine according to the third embodiment, it is possible to perform both of the control methods described above, in one of which the flow rate of the cooling water that flows through the exhaust heat recovery device 150 is controlled by the flow control mechanism 300, and in the other of which the switching of the exhaust gas passage in the exhaust heat recovery device 150 is controlled.

[0058] Consequently, as shown in FIG. 14, the amount of heat recovered in the exhaust heat recovery device 150 can be significantly reduced in the non-recovery mode by reducing the flow rate of the cooling water that flows through the exhaust heat recovery device 150 and the amount of the exhaust gas involved in the heat exchange between the cooling water and the exhaust gas. This makes it possible to suppress the temperature increase of the entire circulating cooling water, thereby further reducing the requirement for heat radiation performance of the radiator 210.

[0059] FIG. 15 is a block diagram showing a cooling apparatus for an internal combustion engine according to a fourth embodiment of the invention.

[0060] In the cooling apparatus for an internal combustion engine according to the fourth embodiment, the flow control mechanism 300, which is employed in the first embodiment and other embodiments, is electronically controlled.

[0061] In place of the mechanical flow-control mechanism 300 as shown in FIGS. 6 and 11, a flow control mechanism 600, which can adjust an opening degree of a valve based on electric signals, is provided in the cooling apparatus for an internal combustion engine according to the fourth embodiment.

[0062] The flow control mechanism 600 includes: a flow control valve 360 whose opening degree can be controlled based on the electric signals; a temperature sensor 370 provided at a position at which the flow control mechanism 300 is disposed in the first to third embodiments; and an electronic control unit (ECU) 380 that controls the opening degree of the flow control valve 360 in accordance with the cooling water temperature detected by the temperature sensor 370.

[0063] The electronic control unit 380 outputs control signals for adjusting the opening degree of the flow control valve 360 so that the control of the flow rate of the cooling water, shown in FIG. 7, is performed based on the cooling water temperature detected by the temperature sensor 370. In other words, the flow control mechanism used in the embodiments according to the invention may be realized in the form in which the flow control valve 360 is electrically controlled as shown in FIG. 15.

[0064] While the invention has been described with reference to example embodiments thereof, it is to be understood that the invention is not limited to the described embodiments or constructions. To the contrary, the invention is intended to cover various modifications and equivalent arrangements. In addition, while the various elements of the example embodiments are shown in various combinations and configurations, other combinations and configurations, including more, less or only a single element, are also within the spirit and scope of the invention.

Claims

1. A cooling apparatus for an internal combustion engine (100), including: a coolant pump (120) for circulating a coolant in the internal combustion engine (100); coolant piping (500) provided in a manner such that an operation of the coolant pump (120) produces a first coolant circuit and a second coolant circuit (500a, 500b) that are arranged in a parallel manner; a heat radiation mechanism (210) that is disposed on the first coolant circuit (500a) and radiates heat from the coolant; a load mechanism (200) that is disposed on the second coolant circuit (500b) and is operated using heat carried by the coolant; an exhaust heat recovery device (150) that is disposed in an exhaust pipe (110) of the internal combustion engine (100) and performs heat exchange between the coolant flowing through the second coolant circuit (500b) and exhaust gas discharged from the internal combustion engine (100), the cooling apparatus **characterized by** comprising:

flow control means (300; 600) for controlling a flow rate of the coolant in accordance with a temperature (T_w) of the coolant which flows into the flow control means (300; 600), the flow control means (300; 600) being disposed downstream of the exhaust heat recovery device (150) on the second coolant circuit (500b).

2. The cooling apparatus according to claim 1, wherein:

when the temperature (T_w) of the coolant is within a first temperature range which is below a first predetermined temperature (T_1), the flow rate of the coolant is not limited by the flow control means (300; 600);

when the temperature (T_w) of the coolant is within a second temperature range which is between the first predetermined temperature (T_1) and a second predetermined temperature (T_2) inclusive, the flow control means (300; 600) reduces the flow rate of the coolant; and

when the temperature (T_w) of the coolant is within a third temperature range which is above the

second predetermined temperature (T_2), the flow control means (300; 600) increases the flow rate of the coolant compared to the flow rate of the coolant in the second temperature range.

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

the flow control means (300) includes a thermal deformation member (310) that expands and contracts in accordance with the temperature (T_w) of the coolant and movable means (320) that is displaced as the thermal deformation member (310) expands and contracts; and the flow control means (300) opens and closes a coolant passage on the second coolant circuit (500b) by the thermal deformation member (310) and the movable means (320).

4. The cooling apparatus according to claim 3, wherein the movable means (320) is provided with flow limiting means (330) that closes the coolant passage when the movable means (320) is displaced within a predetermined range.

5. The cooling apparatus according to claim 4, wherein the flow limiting means (330) is provided with at least one penetration hole (340) through which a predetermined amount of the coolant is passed even when the coolant passage is closed.

6. The cooling apparatus according to any one of claims 3 to 5, wherein the thermal deformation member (310) contains a wax material.

7. The cooling apparatus according to any one of claims 3 to 5, wherein the thermal deformation member (310) is made of a shape-memory alloy.

8. The cooling apparatus according to claim 1 or 2, wherein the flow control means (600) includes: a temperature detection device (370) for detecting the temperature (T_w) of the coolant; a flow control valve (360) whose opening degree is controlled based on an electric signal; and control means (380) for generating the electric signal to control the opening degree of the flow control valve (360) in accordance with the detected temperature (T_w) of the coolant.

9. The cooling apparatus according to any one of claims 1 to 8, wherein:

the exhaust heat recovery device (150) and the flow control means (300; 600) are disposed in series on the second coolant circuit (500b); and the load mechanism (200) is disposed in parallel to the exhaust heat recovery device (150) and the flow control means (300; 600).

10. The cooling apparatus according to any one of claims 1 to 9, wherein:

the exhaust heat recovery device (150) includes: a first exhaust passage (156) on which the heat exchange is performed between the coolant and the exhaust gas; a second exhaust passage (158) by which the first exhaust passage (156) is bypassed; and an exhaust control valve (160) that controls a proportion of a flow rate of exhaust gas that flows through the first exhaust passage (156) with respect to a flow rate of the exhaust gas that flows through a second exhaust passage (158); and the exhaust control valve (160) is controlled so that the exhaust gas mainly flows through the second exhaust passage (158) when the temperature (T_w) of the coolant is in a temperature range in which the flow rate of the coolant is limited by the flow control means (300; 600).

11. The cooling apparatus according to any one of claims 1 to 10, wherein the load mechanism (200) is a heater.

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FIG. 1

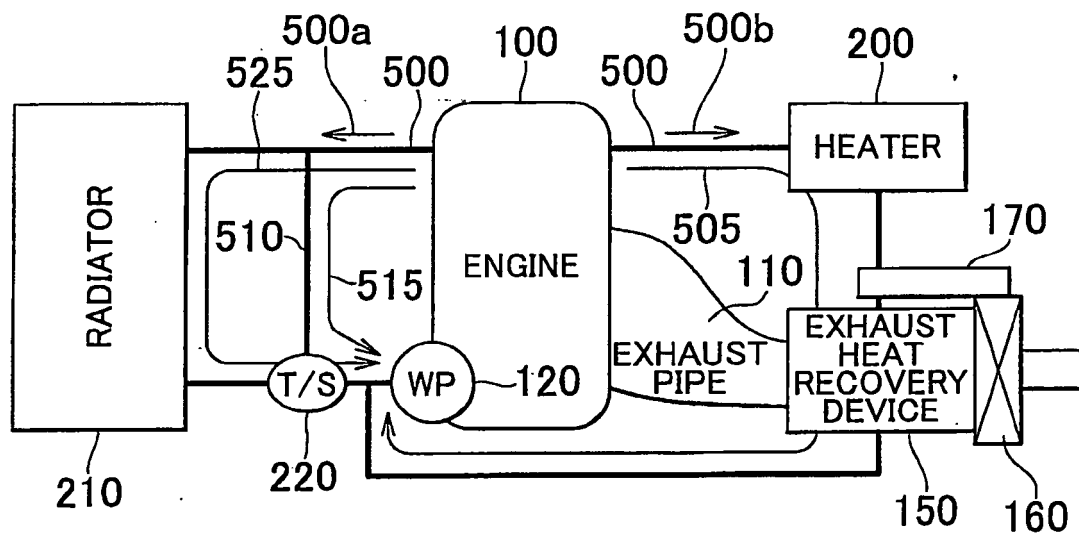


FIG. 2

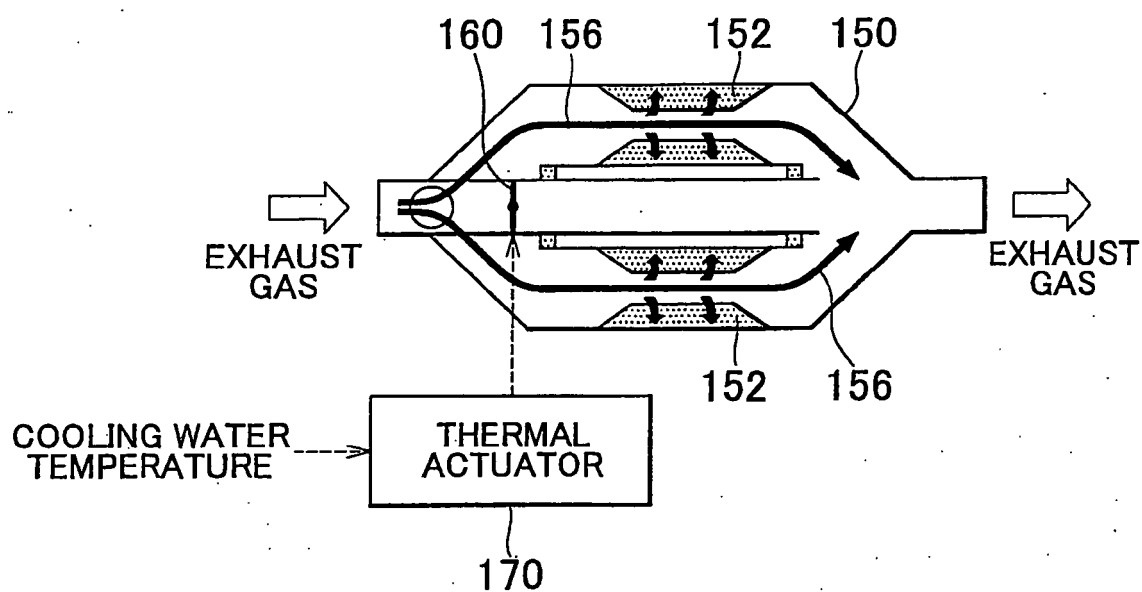


FIG. 3

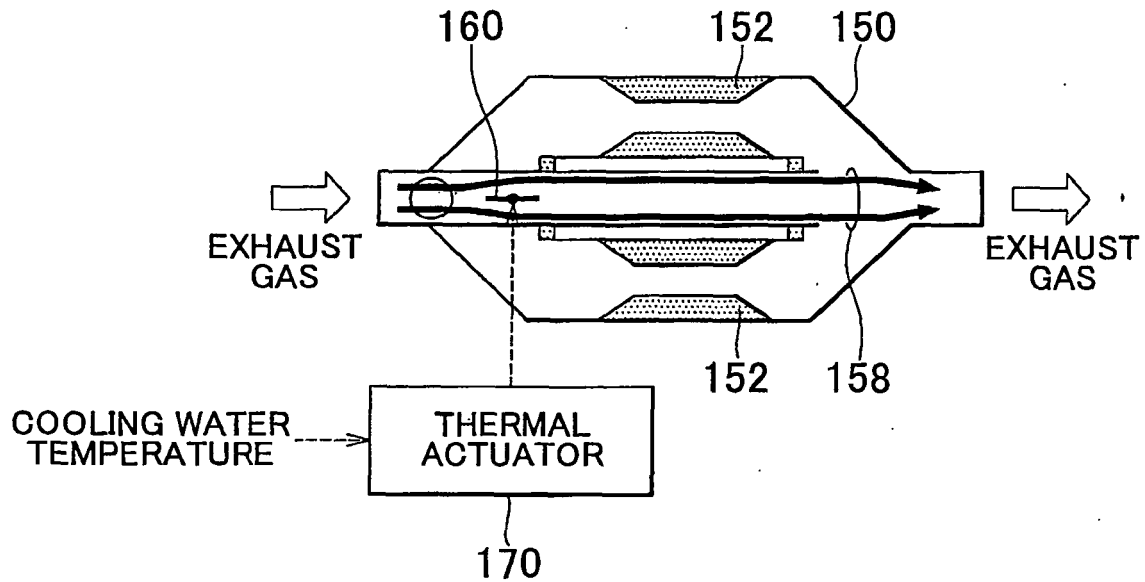


FIG. 4

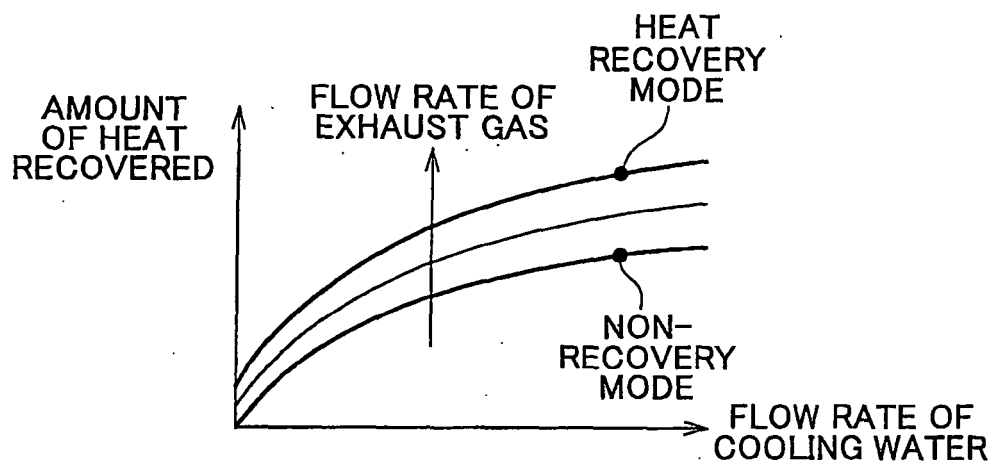


FIG. 5

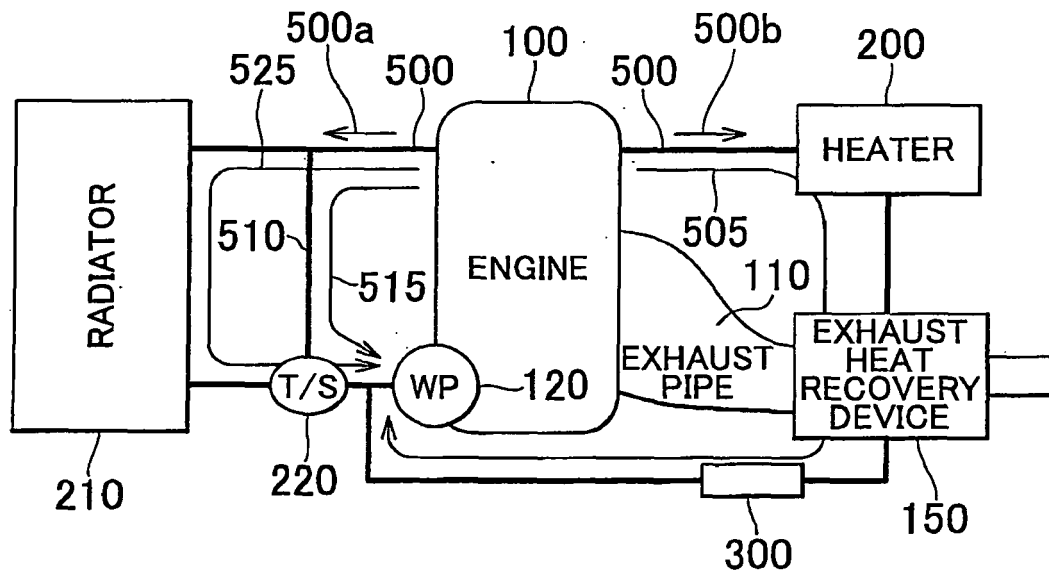


FIG. 6

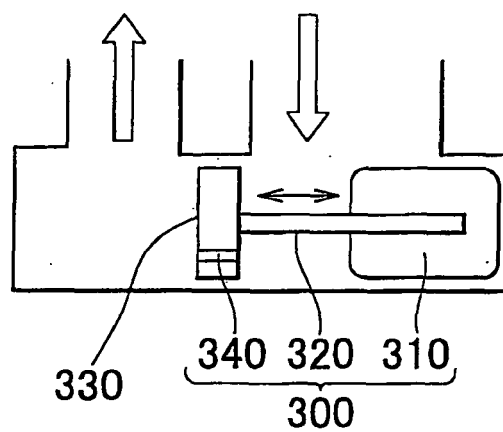


FIG. 7

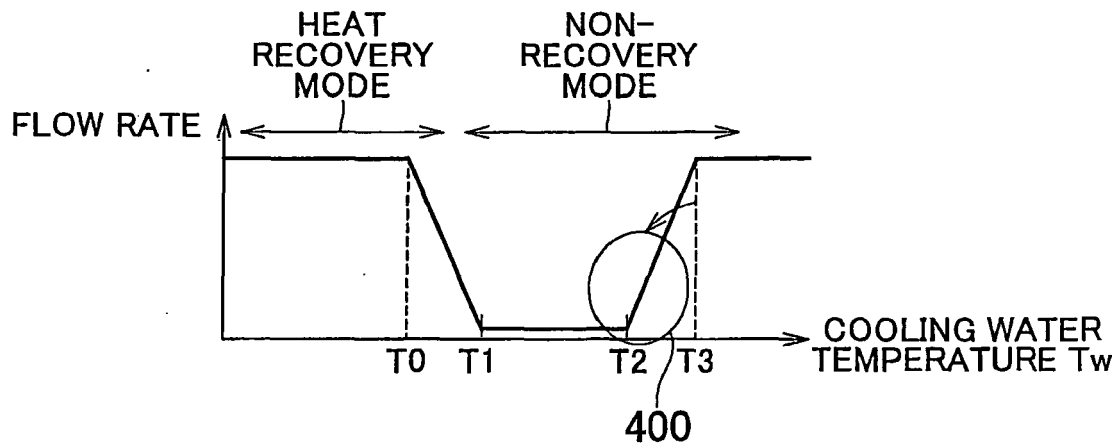


FIG. 8

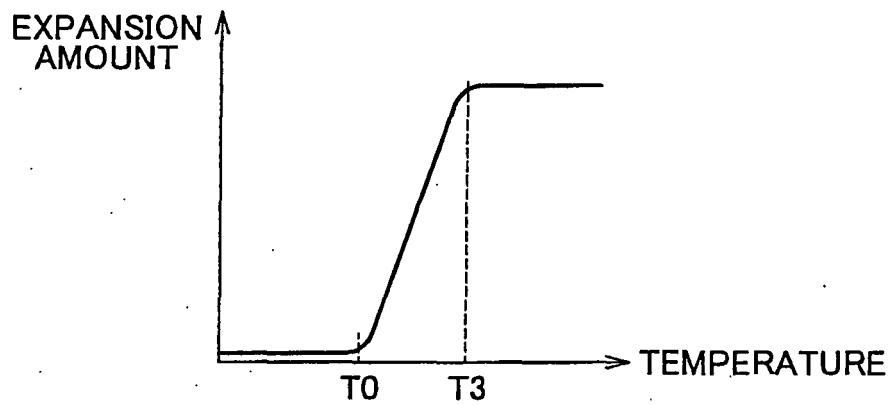


FIG. 9A

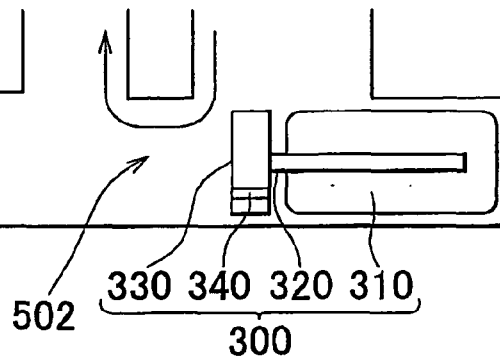


FIG. 9B

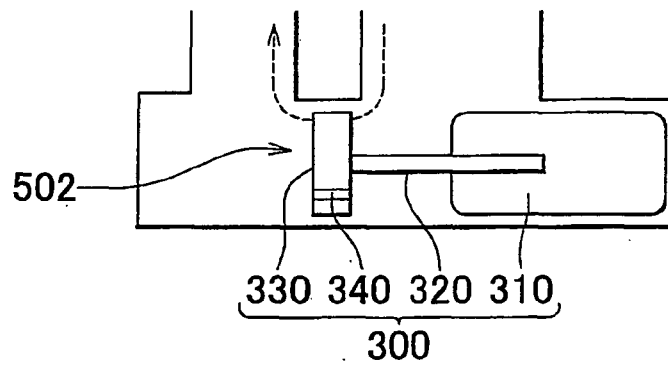


FIG. 9C

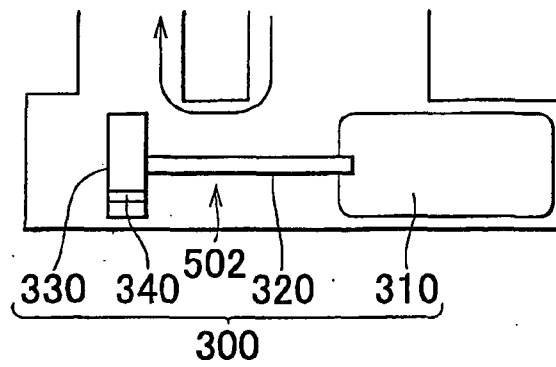


FIG. 10

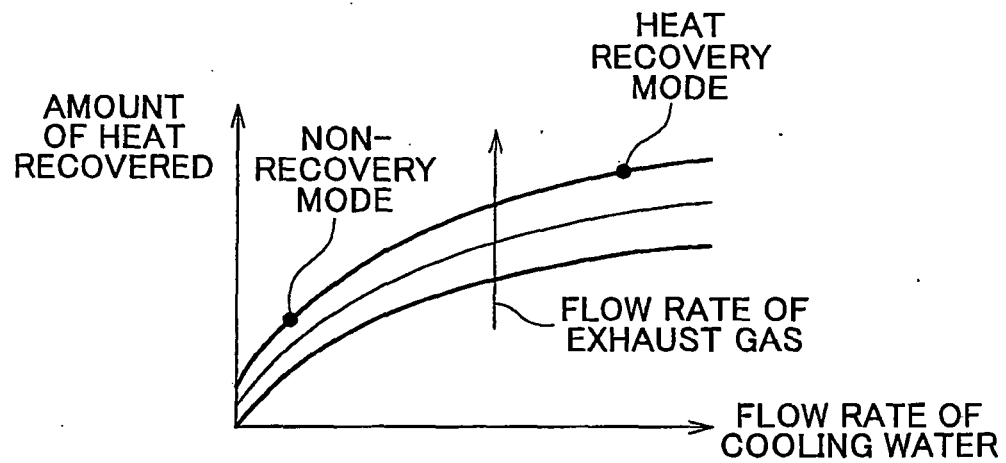


FIG. 11

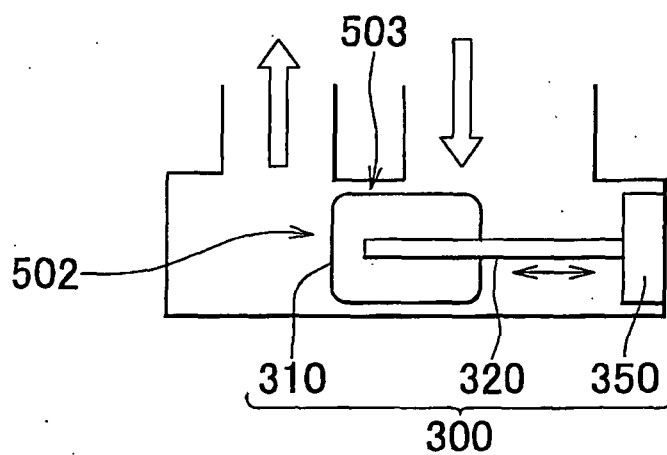


FIG. 12

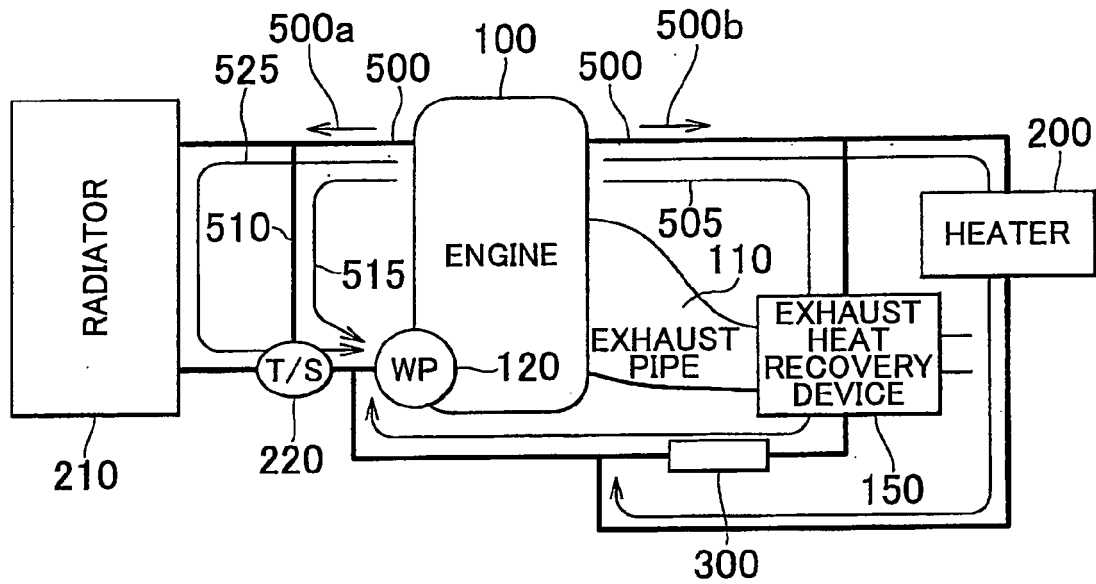


FIG. 13

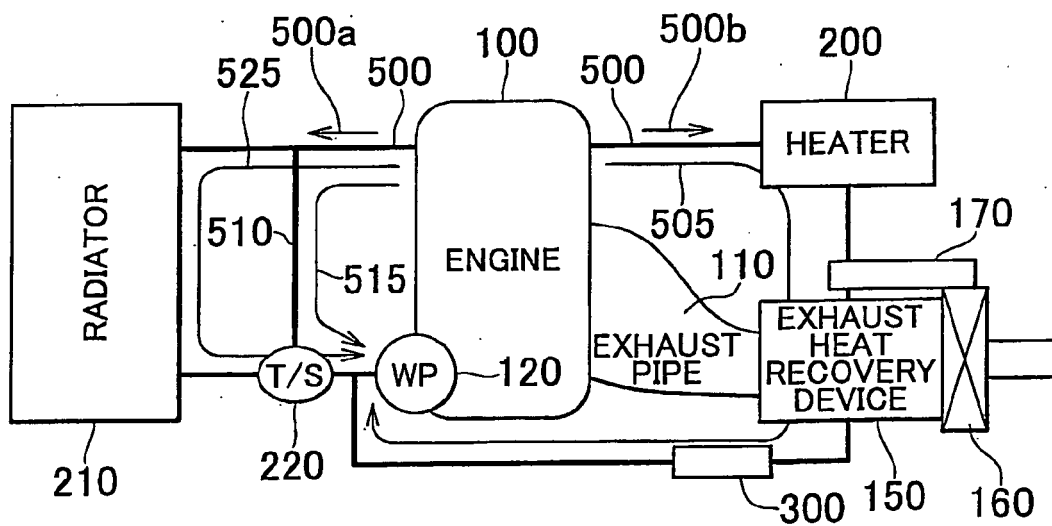


FIG. 14

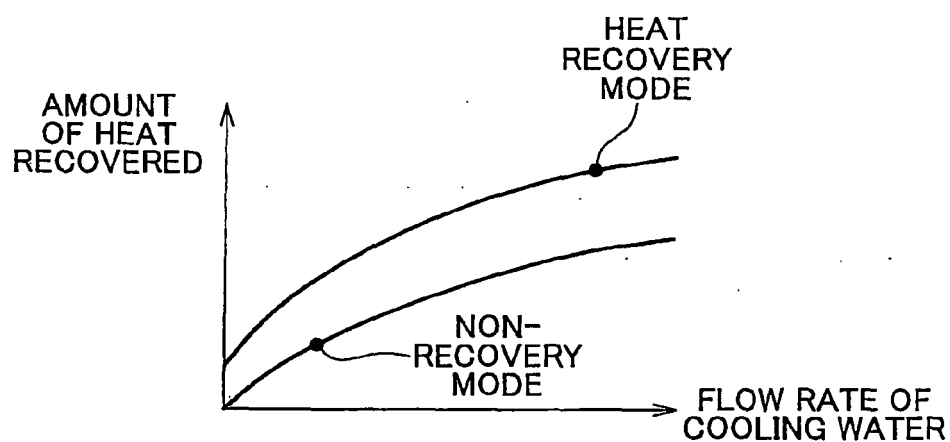
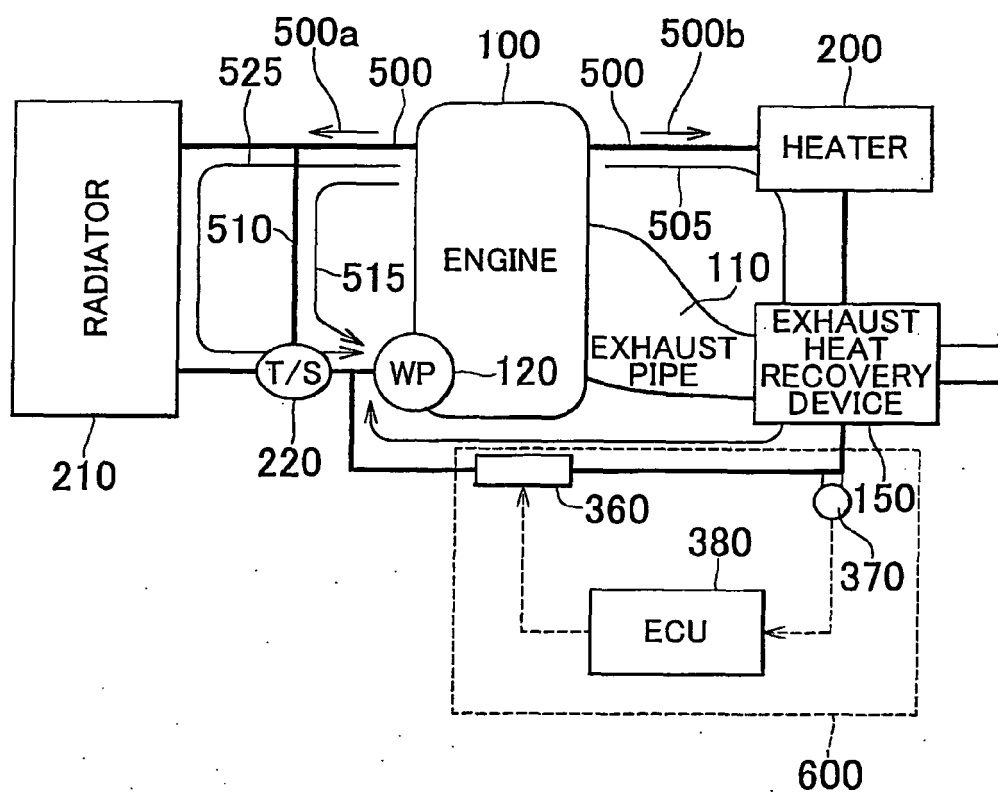


FIG. 15



REFERENCES CITED IN THE DESCRIPTION

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- JP 2006283711 A [0003] [0003] [0004] [0004]
[0006]
- JP 2006250524 A [0005] [0005] [0006]