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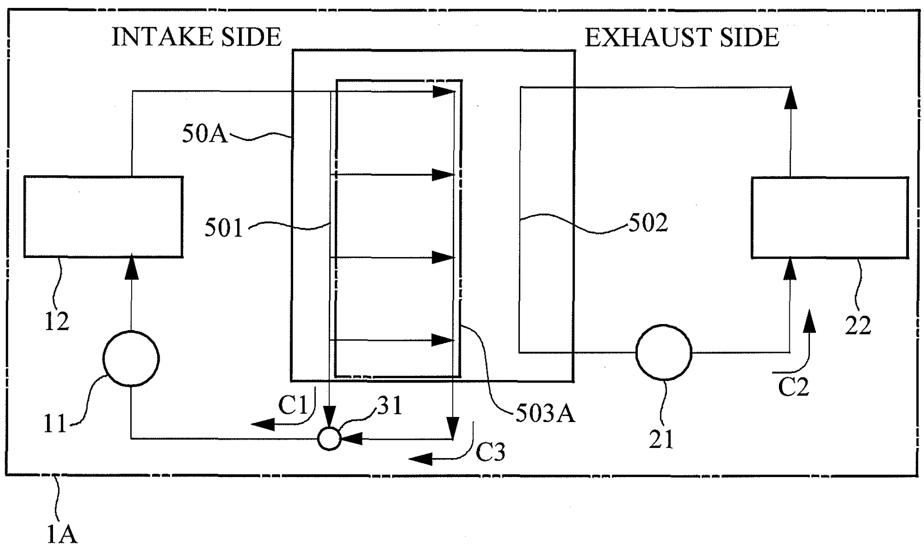
(54) COOLING DEVICE FOR ENGINE

(57) A cooling device 1A includes an engine 50A provided with W/Js 501, 502, and 503A, and a first control valve 31. The W/J 501 is provided at an intake side in a cylinder block 51A. The W/J 502 is provided at an exhaust side in the cylinder block 51A. The W/J 503A diverges from a given position of the W/J 501. Also, the W/J 503A is provided toward the exhaust side through the intake side of the cylinder head 52A. The first control valve 31 makes the coolant flowing state changeable between a state where the coolant is caused to flow in the W/J 501 and a state where the coolant is caused to flow in the W/Js 501 and 503A.

FIG. 1



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Description

[TECHNICAL FIELD]

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

[BACKGROUND ART]

[0002] An engine is generally cooled by a coolant. Also, there is known a cylinder head having a high heat load. Patent Document 1 discloses a cooling device for a multi-cylindered engine where the cylinder block is prevented from being excessively cooled while the cooling performance of the cylinder block is improved.

[PRIOR ART DOCUMENT]

[PATENT DOCUMENT]

[0003]

[Patent Document 1] Japanese Patent Application Publication No. 08-177483

[SUMMARY OF THE INVENTION]

[PROBLEMS TO BE SOLVED BY THE INVENTION]

[0004] The engine is cooled for suppressing, for example, the generation of knocking. When the engine is cooled down more than necessary, a cooling loss will be increased, resulting in a decrease in the heat efficiency

[0005] Thus, the present invention has been made in view of the above circumstances and has an object to provide a cooling device for an engine satisfying both a reduction in cooling loss and anti- knocking performance.

[MEANS FOR SOLVING THE PROBLEMS]

[0006] The present invention is an engine cooling device including: an engine including a cylinder block, a cylinder head, an intake side cooling medium passage, an exhaust side cooling medium passage, and a divergent cooling medium passage; and a first state change portion; wherein the intake side cooling medium passage is provided at an intake side in the cylinder block, and is provided in such a direction as to arrange a plurality of bores provided in the cylinder block, the exhaust side cooling medium passage is provided at an exhaust side in the cylinder block, is independent of the intake side cooling medium passage, and is provided in such a direction as to arrange the plurality of the bores, the divergent cooling medium passage diverges from a given position of the intake side cooling medium passage, is provided from the intake side cooling medium passage toward the exhaust side of the cylinder head through the intake side of the cylinder head, and is provided at the exhaust side in such a direction as to arrange the plurality of the bores, and the first state change portion makes a cooling medium flowing state changeable between a state where the cooling medium is caused to flow in the intake side cooling medium passage and a state where the cooling medium is caused to flow in the intake side cooling medium passage and the divergent cooling medium passage, selected from the intake side cooling medium passage and the divergent cooling medium passage.

[0007] Preferably, the present invention further includes a first flow control portion including the first state change portion, causing the cooling medium to flow in the intake side cooling medium passage and the exhaust side cooling medium passage when an engine driving state is in a low speed and a high load, and causing the cooling medium to flow in the intake side cooling medium passage selected from the intake side cooling medium passage and the divergent cooling medium passage.

[0008] Preferably, the present invention further includes a second flow control portion including the first state change portion, prohibiting the cooling medium from flowing in the intake side cooling medium passage and the exhaust side cooling medium passage when the engine driving state is in a low load.

[0009] Preferably, the present invention further includes: a heat exchanger transferring heat between air and the cooling medium caused to flow in the exhaust side cooling medium passage; a heat accumulator storing the cooling medium caused to flow in the exhaust side cooling medium passage, and keeping heat of the cooling medium; a second state change portion making the cooling medium flowing state changeable between a state where the cooling medium is caused to flow in the heat exchanger and the a state where the cooling medium is caused to flow in the heat accumulator selected from the heat exchanger and the heat accumulator; and a third flow control portion including the second state change portion, causing the cooling medium to flow in the exhaust side cooling medium passage when the engine driving state is in a cold driving or in an engine starting, and causing the cooling medium to flow in the heat accumulator, selected from the heat exchanger and the heat accumulator.

[0010] Preferably, the present invention further includes a high heat conductive portion provided at a portion between adjacent bores selected from the plurality of the bores, exposed from a deck surface of the cylinder block, and having a heat conductivity higher than a base material of the cylinder block.

[0011] Preferably, in the present invention, the high heat conductive portion includes a channel portion and a high heat conductive material, the channel portion is provided at the portion between the adjacent bores selected from the plurality of the bores of the cylinder block, opens toward the deck surface, and has a given depth, and a material is supplied to the channel portion and is melted by a laser beam, whereby the high heat conductive material is provided at the channel portion so as to be exposed at the deck surface and has a heat conductivity higher than the base material of the cylinder block.

[EFFECTS OF THE INVENTION]

[0012] According to the present invention, both a reduction in the cooling loss and the anti-knocking performance can be satisfied.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0013]

FIG. 1 is a schematic view of a cooling device for an engine according to a first embodiment;
FIG. 2 is a schematic view of the engine according to the first embodiment;
FIG. 3 is a view of each water jacket;
FIG. 4 is a view of intake side and exhaust side water jackets;
FIG. 5 is a view of a divergent water jacket;
FIG. 6 is a schematic view of an ECU;
FIG. 7 is a view of divisions of an engine driving state;
FIG. 8 is a view of a first flow manner of a coolant;
FIG. 9 is a view of a second flow manner of the coolant;
FIG. 10 is a view of a third flow manner of the coolant;
FIG. 11 is a flowchart of a first operation;
FIG. 12 is a view of a heat transfer coefficient and a surface area ratio of the combustion chamber in response to a crank angle;
FIG. 13 is a schematic view of a cooling device for the engine according to a second embodiment;
FIG. 14 is a view of a fourth flow manner of the coolant;
FIG. 15 is a flow chart of a second operation;
FIG. 16 is a vertical sectional view of an engine according to a third embodiment;
FIG. 17 is a top view of a cylinder block according to the third embodiment;
FIG. 18 is an enlarged view around a first high heat conductive portion illustrated in FIG. 16;
FIG. 19 is a view of a first example of a second high heat conductive portion;
FIG. 20 is a view of a second example of the second high heat conductive portion;
FIG. 21 is an enlarged view around a third high heat conductive portion illustrated in FIG. 16;
FIG. 22 is a schematic view of a method for forming a high heat conductive material;
FIG. 23 is a view of a first variation of the cooling device for the engine; and
FIG. 24 is a view of a second variation of the cooling device for the engine.

[MODES FOR CARRYING OUT THE INVENTION]

[0014] Embodiments according to the present invention will be described with reference to the drawings.

[First Embodiment]

[0015] FIG. 1 is a schematic view of a cooling device for an engine (hereinafter, referred to as cooling device). A cooling device 1A is mounted on a vehicle not illustrated. The cooling device 1A includes: a first water pump (hereinafter, referred to as W/P) 11; a first radiator 12; a second W/P 21; a second radiator 22; a first control valve 31; and an engine 50A.

[0016] The W/Ps 11 and 21 are cooling medium pressure feeding portions, and pressure-feed a coolant as a cooling medium. The W/Ps 11 and 21 are variableness W/Ps changing a flow rate of the coolant to be pressure-fed. The W/Ps 11 and 21 pressure-feed the coolant, thereby causing the coolant to flow in the engine 50A. The radiators 12 and 22 are heat exchangers, and transfer heat between air and the coolant caused to flow in the engine 50A.

[0017] The engine 50A is provided with an intake side water jacket (hereinafter referred to as W/J) 501 and an exhaust side W/J 502. In response to this, specifically, the first W/P 11 causes the coolant to flow in the intake side W/J 501. On the other hand, the second W/P 21 causes the coolant to flow in the exhaust side W/J 502. Also, the first radiator 12 transfers heat between air and the coolant caused to flow in the intake side W/J 501. On the other hand, the second radiator 22 transfers heat between air and the coolant caused to flow in the exhaust side W/J 502.

[0018] The cooling capacity of the second radiator 22 is set to be greater than that of the first radiator 12. Specifically, the capacity of the second radiator 22 is greater than that of the first radiator 12. For this reason, when the flow rates of the coolants are the same, the second radiator 22 transfers heat between air and the coolant caused to flow in the exhaust side W/J 502 such that the temperature of the coolant flowing in the exhaust side W/J 502 is lower than that of the coolant flowing in the intake side W/J 501.

[0019] The engine 50A is provided with a divergent W/J 503A in addition to the W/Js 501 and 502. The divergent W/J 503A diverges from the intake side W/J 501. The coolant flowing in the divergent W/J 503A joins the coolant flowing in the intake side W/J 501 again.

[0020] The first control valve 31 is provided at a joining point where the coolant flowing in the intake side W/J 501 joins the coolant flowing in the divergent W/J 503A. The first control valve 31 switches the coolant flowing state between the state where the coolant is caused to flow in the intake side W/J 501 selected from the W/Js 501 and 503A and the state where the coolant is caused to flow in the W/Js 501 and 503A. This makes the coolant flowing state changeable.

[0021] The cooling device 1A is formed with plural coolant circulation passages. For example, as the coolant circulation passage, there is a first circulation passage C1 in which the intake side W/J 501 is installed. After being discharged from the first W/P 11, the coolant flowing in the first circulation passage C1 flows the intake side W/J 501 through the first radiator 12. After flowing in the intake side W/J 501, the coolant returns to the first W/P 11 through the first control valve 31.

[0022] Also, as the coolant circulation passage, for example, there is a second circulation passage C2 in which the exhaust side W/J 502 is installed. After being discharged from the second W/P 21, the coolant flowing in the second circulation passage C2 flows the exhaust side W/J 502 through the second radiator 22. After flowing in the exhaust side W/J 502, the coolant retunes to the second W/P 21.

[0023] Also, as the coolant circulation passage, for example, there is a third circulation passage C3 in which divergent W/J 503A is installed. After being discharged from the first W/P 11, the coolant flowing in the third circulation passage C3 flows in the intake side W/J 501 through the first radiator 12. Subsequently, the coolant flows into the divergent W/J 503A from a partway of the intake side W/J 501. After flowing in the divergent W/J 503A, the coolant returns to the first W/P 11 through the first control valve 31.

[0024] Thus, the first control valve 31 is provided at, specifically, the joining point where the first circulation passage C1 and the third circulation passage C3 join together. For example, the first control valve 31 may be provided in the circulation passage C3 at a position of the downstream side of the engine 50A and the upstream side of the joining point where the circulation passage C3 and the first circulation passage C1 join together. In this case, for example, the first control valve 31 is switched between whether or not the flow rate of the coolant flowing in the divergent W/J 503A is zero, thereby changing the coolant flowing state.

[0025] For example, the flow of the coolant in the divergent W/J 503A is allowed or prohibited, in order to switch whether or not the flow rate of the coolant flowing in the divergent W/J 503A is zero. Further, for example, the flow rate of the coolant flowing in the divergent W/J 503A is changeable. The first control valve 31 corresponds to a first state change portion.

[0026] FIG. 2 is a schematic view of the engine 50A. The engine 50A is a spark-ignition internal combustion engine, and includes: a cylinder block 51 A; a cylinder head 52A; a piston 53; a head gasket 54A; an inlet valve 55; an exhaust valve 56; a spark plug 57.

[0027] Bores 51a are provided in the cylinder block 51A. The piston 53 is provided in the bore 51 a. The cylinder head 52A is provided in the cylinder block 51A through the head gasket 54A. Thus, the head gasket 54A is provided between the cylinder block 51A and the cylinder head 52A. The head gasket 54A has a high heat insulating property. In this regard, a board of the head gasket 54A is made of SUS, and a surface thereof is coated with a rubber (for example, NBR rubber) having a high heat insulating property. A wall portion of the bore 51a, the cylinder head 52A, and the piston 53 define a combustion chamber E.

[0028] The cylinder head 52A is formed with an intake port 52a for introducing intake air to the combustion chamber E and an exhaust port 52b for exhausting gas from the combustion chamber E. Also, the intake valve 55 for opening and closing the intake port 52a and the exhaust valve 56 for opening and closing the exhaust port 52b are provided. The spark plug 57 is provided in the cylinder head 52A to face an upper center of the combustion chamber E.

[0029] The intake side W/J 501 and the exhaust side W/J 502 are provided in the cylinder block 51A. The intake side W/J 501 is provided in the cylinder block 51A at the intake side. The exhaust side W/J 502 is provided in the cylinder block 51A at the exhaust side. The W/Js 501 and 502 are provided adjacently to the wall portion of the bore 51a.

[0030] Partial W/Js 503aa to 503ad are provided in the cylinder head 52A. The partial W/Js 503aa, 503ab, and 503ac are provided around the intake port 52a, an exhaust port 52ab, and the spark plug 57, respectively. Also, the partial W/Js 503ad are provided for cooling a portion between the intake valve 55 and the exhaust valve 56, and another portion.

[0031] FIG. 3 is a view of the W/Js 501, 502, and 503A. FIG. 4 is a view of the W/Js 501 and 502. FIG. 5 is a view of the divergent W/J 503A. FIG. 3 is a perspective view of the engine 50A and illustrates the W/Js 501, 502, and 503A. FIG. 4 is a top view of the cylinder block 51A and illustrates the W/Js 501 and 502. FIG. 5 is a perspective view of an inner structure of the cylinder head 52A and schematically illustrates the divergent W/J 503A.

[0032] Plural bores 51a (herein, four) are provided in the cylinder block 51A. Plural bores 51a are arranged in series. The intake side W/J 501 is provided in such a direction as to arrange plural bores 51a. An intake side inlet portion 51b which introduces the coolant into the intake side W/J 501 is provided in the cylinder block 51A at a front side of the engine 50A, that is, at an opposite side of where the engine 50A produces an output. Moreover, an intake side outlet portion 51c which discharges the coolant from the intake side W/J 501 is provided at a rear side of the engine 50A. The intake side W/J 501 causes the coolant to flow from the front side to the rear side of the engine 50A.

[0033] The exhaust side W/J 502 is provided independently of the intake side W/J 501. Also, the exhaust side W/J 502 is provided in such a direction as to arrange the plural bores 51 a. An exhaust side inlet portion 51d which introduces the coolant into the exhaust side W/J 502 is provided in the cylinder block 51A at the front side of the engine 50A. Also, an exhaust side outlet portion 51e which discharges the coolant from the exhaust side W/J 502 is provided at the rear side of the engine 50A. The exhaust side W/J 502 causes the coolant to flow from the front side to the rear side of the engine 50A.

[0034] The W/Js 501 and 502 open toward a deck surface D of the cylinder block 51A. That is, the cylinder block 51A is an open deck type of the cylinder block. The intake side W/J 501 corresponds to an intake side cooling medium passage, and the exhaust side W/J 502 corresponds to an exhaust side cooling medium passage.

[0035] The divergent W/J 503A diverges from a given position of the intake side W/J 501, and is provided to extend from the intake side W/J 501 toward the exhaust side of the cylinder head 52A through the intake side of the cylinder head 52A. Further, the divergent W/J 503A is provided in the cylinder head 52A at the exhaust side in such a direction as to arrange the plural bores 51 a.

[0036] A given position is set to correspond to the bore 51a. For this reason, the divergent W/J 503A is provided with the plural (herein, four) partial W/Js 503a which are diverged to respectively correspond to the bores 51a. The partial W/Js 503a cause the coolant to flow from the intake side toward the exhaust side of the cylinder head 52A. That is, the coolant is caused to flow in the lateral direction crossing the front-rear direction of the engine 50A.

[0037] The partial W/J 503a is provided to extend from the intake side toward the exhaust side, and defines, for example, the above mentioned partial W/Js 503aa to 503ad so as to cool each portion of the cylinder head 52A. The divergent W/J 503A is provided at the exhaust side of the cylinder head 52A and extends in such a direction as to arrange the plural bores 51a so as to join the W/J 503a. The divergent W/J 503A corresponds to a divergent cooling medium passage.

[0038] FIG. 6 is a schematic view of an ECU 70A. The cooling device 1A is further equipped with the ECU 70A. The ECU 70A is an electronic control unit, and includes a microcomputer equipped with a CPU 71, a ROM 72, a RAM 73, and the like, and input-output circuits 75 and 76. These parts are connected to each other via a bus 74.

[0039] The ECU 70A is electrically connected with various sensors or switches such as a crank corner sensor 81 for detecting the rotational number of the engine 50A, an air flow meter 82 for measuring the amount of intake air of the engine 50A, an accelerator opening sensor 83 for detecting the degree of an accelerator opening, and a water temperature sensor 84 for detecting the temperature of the coolant. Also, the ECU 70A is electrically connected with various control objects such as the W/Ps 11 and 21, and the first control valve 31. The ECU 70A detects the load of the engine 50A based on the outputs of the air flow meter 82 and the accelerator opening sensor 83.

[0040] The ROM 72 stores map data or programs about various kinds of processing performed by the CPU 71. The CPU 71 processes based on a program stored in the ROM 72 and uses a temporary memory area of the RAM 73 if necessary, whereby the ECU 70A functions as various portions such as a control portion, a determination portion, a detecting portion, and a calculating portion.

[0041] For example, the ECU 70A functions as a control portion for controlling the flow of the coolant in the W/Js 501, 502, and 503A in response to the engine driving state (the driving state of the engine 50A). The control portion controls the W/Ps 11 and 21, and the first control valve 31 to control the flow of the coolant.

[0042] FIG. 7 is a view of divisions of the engine driving state. As illustrated in FIG. 7, the engine driving state is classified into six divisions D1 to D6, in response to the number of the rotation of the engine 50, the load thereof, the cold driving, and the engine starting. In control of the control portion, the control portion sets requirements to be satisfied in each of the divisions D 1 to D6 and control indications for satisfying the set requirements, as will be described below in detail.

[0043] Firstly, when the engine driving state is an idle state corresponding to the division D1, two requirements are set for improving a combustion speed depending on an increase in the intake air temperature, and for increasing an exhaust gas temperature to activate an exhaust gas purifying catalyst. In response to this, two control indications are set for increasing the temperatures of the intake port 52a and the upper portion of the wall portion of the bore 51a, and for increasing the temperature of the exhaust port 52b.

[0044] Further, when the engine driving state is in a low load corresponding to the division D2, two requirements are set for improving the heat efficiency (reducing the cooling loss), and for improving the combustion speed by increasing the intake air temperature. In response to this, two control indications are set for the insulation of the cylinder head 52A, and for an increase in the temperatures of the intake port 52a and the upper portion of the wall portion of the bore 51a.

[0045] Further, when the engine driving state is in a low rotation and high load corresponding to the division D3, the requirements are set for reducing the knocking and for improving the heat efficiency (reducing the cooling loss) . In response to this, there are set two control indications for cooling the intake port 52a and the upper portion of the wall portion of the bore 51a and for insulating the cylinder head 52A.

[0046] Further, when the engine driving state is in a high rotation and high load corresponding to the division D4, two requirements are set for ensuring reliability and reducing the knocking. In response to this, two control indications are set for cooling the periphery of the spark plug 57, the portion between the intake and exhaust valves 55 and 56, and the exhaust port 52b, and for cooling the intake port 52a.

[0047] Also, in a cold driving corresponding to the division D5, two requirements are set for accelerating warm- up of the engine and improving the combustion speed depending on an increase in the intake air temperature. In response to this, two control indications are set for accelerating the heat transfer of the cylinder head

52A and for increasing the temperatures of the intake port 52a and the upper portion of the wall portion of the bore 51a.

[0048] Also, in an engine startup corresponding to the division D6, two requirements are set for improving the ignition property and for promoting the fuel vaporization. In response to this, two control indications are set for increasing the temperature of the intake port 52a, and for increasing the temperatures of the periphery of the spark plug 57 and the upper portion of the wall portion of the bore 51a.

[0049] In this regard, the control portion of the cooling device 1A is achieved to perform the following controls. FIG. 8 is a view of a first flow manner of the coolant. FIG. 9 is a view of a second flow manner of the coolant.

FIG. 10 is a view of a third flow manner of the coolant. In FIGs. 8, 9, and 10, broken lines indicate a state where the coolant does not flow, and heavy lines indicate a state where the coolant flows.

[0050] As illustrated in FIG. 8, the control portion prohibits the coolant from flowing in the W/Js 501 and 502, when the engine driving state is in the idle state corresponding to the division D1, the low load corresponding to the division D2, the cold driving corresponding to the division D5, or the engine starting corresponding to the division D6. Specifically, the W/Ps 11 and 21 are controlled to stop.

[0051] As illustrated in FIG. 9, the control portion causes the coolant to flow in the W/Js 501 and 502 and in the intake side W/Js 501 selected from the W/Js 501 and 503A, when the engine driving state is in the low rotation and high load corresponding to the division D3. Specifically, the W/Ps 11 and 21 are controlled to drive, and the first control valve 31 is controlled to cause the coolant to flow in the intake side W/J 501 selected from the W/Js 501 and 503A.

[0052] As illustrated in FIG. 10, the control portion causes the coolant to flow in the W/Js 501 and 502 and in the W/Js 501 and 503A selected from the W/Js 501 and 503A, when the engine driving state is in the high rotation and high load corresponding to the division D4. Specifically, the W/Ps 11 and 21 are controlled to drive, and the first control valve 31 is controlled to cause the coolant to flow in the W/Js 501 and 503A selected from the W/Js 501 and 503A.

[0053] The control portion may cause the coolant to flow in the W/Js 501 and 502, and may further cause the coolant to flow in the W/Js 501 and 503A or the divergent W/J 503A selected from the W/Js 501 and 503A as need, when the engine driving state is in the low rotation and high load corresponding to the division D3. In this case, for example, the coolant can be caused to arbitrarily flow in the divergent W/J 503A in order to prevent the coolant from boiling.

[0054] In response to the engine driving state, the control portion and the W/Ps 11 and 12, and the control portion and the first control valve 31 define different flow control portions. In this regard, a first flow control portion corresponds to the W/Ps 11 and 12, the first control valve 31, and a portion, of the control portion, performing the above control when the engine driving state is in the low rotational and high load. Also, a second flow control portion corresponds to the W/Ps 11 and 12, the first control valve 31, and a portion, of the control portion, performing the above control when the engine driving state is in the low load.

[0055] Next, a description will be given of a first operation of the ECU 70A with reference to a flowchart illustrated in FIG. 11. The ECU 70A determines whether or not the engine 50A has just started up (step S1) . If a positive determination is made, the ECU 70A stops the W/Ps 11 and 21 (step S21A) . Accordingly, this flowchart is temporarily finished. On the other hand, if a negative determination is made, the ECU 70A determines whether or not the engine 50A is in the cold driving (step S2) . Whether or not the engine 50A is in the cold driving is determined, for example, in response to a determination whether or not the coolant temperature is equal to or less a given value (for example, 75 degrees Celsius) . If a positive determination is made in step S2, the processing proceeds to step S21A.

[0056] If a negative determination is made in step S2, the ECU 70A detects the rotational number and the load of the engine 50A (step S11). Subsequently, the ECU 70A determines the division corresponding to the detected rotational number and load (from step S12 to S14). Specifically, when the division corresponds to the division D1, the processing continues to step S21A from the positive determination in S12. When the division corresponds to the division D2, the processing continues to step S21A from the positive determination in S13.

[0057] When the division corresponds to the division D3, the processing continues to step S31 from the positive determination in S 14. In this case, the ECU 70A drives the W/Ps 11 and 21, and then controls the first control valve 31 to cause the coolant to flow in the intake side W/J 501 selected from the W/Js 501 and 503A. This flowchart is temporarily finished after step S31.

[0058] When the division corresponds to the division D4, the processing continues to step S11 from the negative determination in S 14. In this case, the ECU 70A drives the W/Ps 11 and 21, and then controls the first control valve 31 to cause the coolant to flow in the W/Js 501 and 503A selected from the W/Js 501 and 503A. This flowchart is temporarily finished after step S41.

[0059] Next, the effect of the cooling device 1A will be described. FIG. 12 is a view of a heat transfer coefficient and a surface area ratio of the combustion chamber E in response to a crank angle. As illustrated in FIG. 12, the heat transfer coefficient rises around the top dead center in the compression stroke. The surface area ratio between the cylinder head 52A and the piston 53 rises around the top dead center in the compression stroke. It is thus understood that the temperature of the cylinder head 52A greatly influences the cooling loss.

[0060] On the other hand, knocking depends on the compression end temperature. It is recognized that the surface area ratio of the wall portion of the bore 51 a is great in the intake compression stroke influencing the compression end temperature. It is thus understood that the temperature of the wall portion of the bore 51 a greatly influences knocking.

[0061] In response to this, the cooling device 1A can cause the coolant to flow in the W/Js 501 and 502. Therefore, the wall portion of the bore 51a can be cooled. For this reason, the cooling device 1A can suppress the knocking. Further, the cooling device 1A can switch the coolant flowing state so as to cause the coolant to flow in the intake side W/J 501 selected from the W/Js 501 and 503A. This can reduce the cooling loss generated in the cylinder head 52A. For this reason, the cooling device 1A can ensure both the anti-knocking property and a reduction in the cooling loss.

[0062] In this regard, the cooling device 1A controls the flow of the coolant as follows. That is, when the engine driving state is in the low rotation and high load, the coolant is caused to flow in the W/Js 501 and 502, and in the intake side W/J 501 selected from the W/Js 501 and 503A. Therefore, when the engine driving state is in the low rotation and high load, the coolant is caused not to flow in the divergent W/J 503A, thereby reducing the cooling loss and suppressing the knocking.

[0063] Also, when the engine driving state is in the low load, the coolant is prohibited from flowing in the W/Js 501 and 502. This can increase the temperatures of intake air and exhaust gas while reducing the cooling loss. Also, when the engine driving state is in the idle state, the cold driving, or the engine starting, the temperatures of intake air and exhaust gas can be increased in the same manner. This can achieve the improvement in combustion, the activation of the exhaust gas purifying catalyst, and the maintenance of the active temperature thereof. This can result in suppressing the deterioration of fuel consumption and exhaust emission.

[0064] Also, when the engine driving state is in the high rotation and high load, the coolant is caused to flow in the W/Js 501 and 502, and in the W/Js 501 and 503A selected from the W/Js 501 and 503A. This can ensure reliability and suppress the knocking. Further, for example, the exhaust gas temperature is reduced, thereby reducing the heat load applied to the exhaust gas purifying catalyst.

[0065] In such a way, the cooling device 1A which controls the flow of the coolant can improve the heat efficiency mainly in the low rotation and high load state. On the other hand, the cooling device 1A can also establish the driving of the engine 50A in another driving state. Thus, the heat efficiency can be improved not only in the specific driving state but also in the whole usual driving state of the engine 50A.

[0066] Incidentally, the exhaust side of the wall portion of the bore 51 a corresponds to a portion hit by the intake air that has flowed into the combustion chamber E. Also, the above portion tends to have a high temperature in light of the exhaust gas. For this reason, the temperature of the exhaust side of the wall portion of the bore 51a influences on the knocking more than that of the intake side thereof.

[0067] Correspondingly, the cooling device 1A can cause the temperature of the coolant flowing in the exhaust side W/J 501 to be lower than that of the coolant flowing in the intake side W/J 501 at the side of the second radiator 22, under the conditions where the flow rates of the coolant are the same. Therefore, the exhaust side of the wall portion of the bore 51a is effectively cooled, thereby suitably suppressing the knocking.

[0068] Also, the cooling device 1A is equipped with the head gasket 54A having the high heat insulating property, thereby suppressing the cooling of the cylinder head 52A in accordance with the cooling of the wall portion of the bore 51a. This can also result in reducing the cooling loss.

[0069] Further, the cooling device 1A causes the coolant to flow in the W/Js 501 and 502. Additionally, the cooling device 1A causes the coolant to further flow in the divergent W/J 503A, when the coolant is caused to flow in the intake side W/J 501 selected from the W/Js 501 and 503A. Therefore, the cooling loss can be reduced while the coolant is being cooled at minimum to prevent the coolant from boiling.

[Second Embodiment]

[0070] FIG. 13 is a schematic view of a cooling device 1B. The cooling device 1B is substantially the same as the cooling device 1A, except that the cooling device 1B is further equipped with a heat accumulator 25, a second control valve 32, and an ECU 70B instead of the ECU 70A. The ECU 70B is substantially the same as the ECU 70A, except that the ECU 70B is electrically connected to the second control valve 32 and a control portion is achieved as will be described later. Thus, an illustration of the ECU 70B is omitted.

[0071] The cooling device 1B is further formed with a fourth circulation passage C4 in which the heat accumulator 25 is installed. The coolant flowing in the fourth circulation passage C4 flows in the heat accumulator 25, after being discharged from the second W/P 21. Further, the coolant flows at the exhaust side through the second control valve 32, after flowing in the heat accumulator 25. The coolant returns to the second W/P 21, after flowing in the exhaust side W/J 502.

[0072] The heat accumulator 25 is provided to bypass the second radiator 22. The heat accumulator 25 stores the coolant flowing in the exhaust side W/J 502 and keeps heat of the coolant. After the coolant flows in the exhaust side W/J 502, the heat accumulator 25 stores the coolant before the coolant flows in the second radiator 22. The heat accumulator 25 can store the coolant and keep its heat, when the temperature of the coolant is at least higher than a normal temperature (for example, 25 degrees Celsius).

[0073] The second control valve 32 is provided in the point where the second circulation passage C2 and the fourth circulation passage C4 joins together. The second control valve 32 switches the coolant flowing state between a state where the coolant is caused to flow in the second radiator 22 and a state where the coolant is caused to flow in the heat accumulator 25, selected from the second radiator 22 and the heat accumulator 25. This makes the coolant flowing state changeable. For example, the second control valve 32 may switch between a connection state and a disconnection state of the heat accumulator 25, and may be built therein. The second control valve 32 corresponds to the second state change portion.

[0074] FIG. 14 is a view of a fourth flow manner of the coolant. In FIG. 14, broken lines indicate a state where the coolant does not flow, and heavy lines indicate a state where the coolant flows. As illustrated in FIG. 14, the control portion prohibits the coolant from flowing in the intake side W/J 501 selected from the W/Js 501 and 502, and causes the coolant to flow in the exhaust side W/J 502, when the engine driving state is in the cold driving or the engine starting. Specifically, the first W/P 11 is controlled to stop, and the second W/P 21 is controlled to drive.

[0075] Also, the control portion changes the coolant flowing state so as to cause the coolant to flow in the heat accumulator 25 selected from the second radiator 22 and the heat accumulator 25. Specifically, the second control valve 32 is controlled to cause the coolant to flow in the heat accumulator 25 selected from the second radiator 22 and the heat accumulator 25.

[0076] When the engine driving state is in the warm-up driving, the control portion changes the coolant flowing state so as to cause the coolant to flow in the second radiator 22 selected from the second radiator 22 and the heat accumulator 25. Specifically, the second control valve 32 is controlled to cause the coolant to flow in the second radiator 22 selected from the second radiator 22 and the heat accumulator 25. Except for these arrangements, the control portion is the same as the control portion of the ECU 70A. A third flow control portion corresponds to the W/Ps 11 and 12, the second control valve 32, and a portion, of the control portion, performs the above mentioned control when the engine driving state is in the cold driving or in the engine starting.

[0077] Next, a description will be given of an second operation of the ECU 70B with reference to a flowchart illustrated in FIG. 15. Herein, parts different from the flowchart illustrated in FIG. 11 will be explained herein. If positive determinations are made in steps S1 and S2, the ECU 70B controls the first W/P 11 to stop and controls the second W/P 21 to drive. Further, the ECU 70B controls the second control valve 32 to cause the coolant to flow in the heat accumulator 25 selected from the second radiator 22 and the heat accumulator 25 (step S21B) . Therefore, the coolant that is stored and kept in the heat accumulator 25 at a previous engine driving is used. This flowchart is temporarily finished after step S21B.

[0078] If a negative determination is made in step S2, the engine driving state is determined to be in the warm-up driving. At this time, the ECU 70B controls the second control valve 32 to cause the coolant to flow in the second radiator 22 selected from the second radiator 22 and the heat accumulator 25 (step S3). Therefore, the second radiator 22 can be used in the warm-up driving. Simultaneously, the heat accumulator 25 can store the coolant having a temperature higher than an atmosphere temperature at least and keep heat of the coolant.

[0079] Next, the effect of the cooling device 1B will be explained. When the engine driving state is in the cold driving or the engine start- up, the cooling device 1B prohibits the coolant from flowing, and causes the coolant to flow in the exhaust side W/J 502. Moreover, the coolant is caused to flow in the exhaust side W/J 502, and the coolant is caused to flow in the heat accumulator 25 selected from the second radiator 22 and the heat accumulator 25.

[0080] For this reason, the cooling device 1B can suitably increase temperatures of intake air and exhaust gas, when the engine driving state is in the cold driving or the engine starting. Also, the fuel vaporization can be promoted, for example, when the fuel is directly injected into the cylinder. This can also suppress the oil dilution at the wall portion of the bore 51 a. Consequently, the driving of the engine 50A can be suitably established as compared with the cooling device 1A.

[Third Embodiment]

[0081] FIG. 16 is a vertical sectional view of an engine 50B. FIG. 16 is a view of the vertical section of the engine 50B in such a direction as to arrange the bores 51 a when viewed from the exhaust side. A cooling device 1C according to the present embodiment is substantially the same as the cooling device 1B, except that the cooling device 1C is equipped with the engine 50B instead of the engine 50A. Thus, a schematic illustration of the cooling device 1C is omitted. Additionally, the cooling device 1 A can be changed in the same manner.

[0082] The engine 50B is equipped with a cylinder block 51B instead of the cylinder block 51A. Further, a head gasket 54B is provided instead of the head gasket 54A. Furthermore, a cylinder head 52B is provided instead of the cylinder head 52A. Except for these arrangements, the engine 50B is substantially the same as the engine 50A.

[0083] The cylinder block 51B is substantially the same as the cylinder block 51 A, except that the cylinder block 51 B is further provided with a first high heat conductive portion 511. The first high heat conductive portion 511 is provided at a portion between the adjacent bores 51a (between the bores 51a) of the plural bores 51 a in the cylinder block 51 B. The first high heat conductive portion 511 is exposed from the deck surface D of the cylinder block 51B, and has a heat conductivity higher than a base material of the cylinder block 51B.

[0084] The head gasket 54B is substantially the same as the head gasket 54A, except that the head gasket 54B is further provided with a second high heat conductive portion 541. The second high heat conductive portion 541 is provided to correspond to the portion between the bores 51a. Specifically, the second high heat conductive portion 541 is provided to correspond to the first high heat conductive portion 511. The second high heat conductive portion 541 is exposed at the surface of the cylinder block 51 B side and the cylinder head 52B side. The second high heat conductive portion 541 has a heat conductivity higher than the other portions of the head gasket 54B. For example, copper, or copper compound metal can be applied to the second high heat conductive portion 541.

[0085] The cylinder head 52B is substantially the same as the cylinder head 52A, except that the cylinder head 52B is further provided with a third high heat conductive portion 521 and is further provided with a divergent W/J 503B instead of the divergent W/J 503A. The third high heat conductive portion 521 is provided to correspond to the portion between the bores 51a. Specifically, the third high heat conductive portion 521 is provided to correspond to the second high heat conductive portion 541. The third high heat conductive portion 521 is exposed at a surface facing the deck surface D of the cylinder block 51B, and has a heat conductivity higher than a base material of the cylinder head 52B.

[0086] The divergent W/J 503B is substantially the same as the divergent W/J 503A, except that the divergent W/J 503B is provided with a partial W/J 503b instead of the partial W/J 503a. The partial W/J 503b is substantially the same as the partial W/J 503a, except that the partial W/J 503b is provided to correspond to the portion between the bores 5 1 a, and both ends of the whole plural bores 51a. That is, the partial W/J 503b is substantially the same as the partial W/J 503a, except that a given position is set to correspond to the portion between the bores 5 1 a, and the both ends of the whole plural bores 51a.

[0087] In the partial W/J 503b, for example, a given position may be correspond to the bore 51 a, and the partial W/J 503b may be provided to extend from the intake side toward the exhaust side so as to cool a portion, of the cylinder head 52B, facing the portion between the bores 51a.

[0088] FIG. 17 is a top view of the cylinder block 51B. The first high heat conductive portion 511 has a given length along the direction from the intake side to the exhaust side. The given length is set so that the first high heat conductive portion 511 does not reach the W/Js 501 and 502. This restrict the heat which is transferred from the first high heat conductive portion 511 to the coolant flowing in the W/Js 501 and 502 to some extent. However, the present invention is not limited to these arrangements. For example, the given length may be set so that the first high heat conductive portion 511 reaches at least one of the W/Js 501 and 502.

[0089] FIG. 18 is an enlarged view around the first high heat conductive portion 511 illustrated in FIG. 16. Specifically, the first high heat conductive portion 511 is provided with a channel portion 511 a and a high heat conductive material 511b. The channel portion 511a is provided between the bores 51a, and opens toward the deck surface D. The channel portion 511 a has a given depth. The given depth can be set to correspond to the upper portion of the wall portion of the bore 51 a. The channel portion 511 a has a given length along the direction from the intake side to the exhaust side. The given length is described above.

[0090] The high heat conductive material 511b is provided within the channel portion 511a. A material is supplied to the channel portion 511a and is melted by a laser beam, thereby providing the high heat conductive material 511b. The high heat conductive material 511b is provided to be exposed at the deck surface D. Further, the high heat conductive material 511b is provided to fill the channel portion 511a. The high heat conductive material 511b has a heat conductivity higher than the base material of the cylinder block 51B.

[0091] FIG. 19 is a view of a first specific example of the second high heat conductive portion 541. (a) is a general view of the head gasket 54B, and (b) is an enlarged sectional view of the second high heat conductive portion 541. In this example, each of boards 54a is provided with holes at portions facing the first high heat conductive portion 511, and the boards 54a sandwich and hold the second high heat conductive portion 541 such that the second high heat conductive portion 541 is exposed from the hole at the surface. The second high heat conductive portion 541 is made of a high heat conduction member (for example, copper sheet).

[0092] FIG. 20 is a view of a specific example of the second high heat conductive portion 541. In this example, among a bead 54b provided to correspond to the wall portion of the bore 51a, a width of a portion of the bead 54b corresponding to the portion between the bores 51a is greater than that of another portion of the bead 54b. Further, the bead 54b is exposed at the surface of the portion facing the first high heat conductive portion 511. That is, it is not coated with a rubber having a high heat insulating property. The second high heat conductive portion 541 is defined by the portion where the bead 54b is exposed.

[0093] The second high heat conductive portion 541 has a given length along the direction from the intake side toward the exhaust side. The given length can be set to correspond to a given length of the first high heat conductive portion 511.

[0094] FIG. 21 is an enlarged view around the third high heat conductive portion 521 illustrated in FIG. 16. The third high heat conductive portion 521 is provided with a channel portion 521a and a high heat conductive material 521b. The channel portion 521a is provided at the portion, of the cylinder head 52B, facing the portion between the bores 51a, and opens at the surface facing the deck surface D. The channel portion 521a has a given depth and a given length along the direction from the intake side toward the exhaust side. The given depth is set not to reach the divergent W/J 503B. However, the present invention is not limited to these arrangements. The given depth may be set to reach the divergent W/J 503B. The given length can be set to correspond to the given length of the first high heat conductive portion 511.

[0095] The high heat conductive material 521b is provided within the channel portion 521a. A material is supplied to the channel portion 521a and is melted by a laser beam, thereby providing the high heat conductive material 521 b. The high heat conductive material 521 b is provided to be exposed at the deck surface D. Further, the high heat conductive material 521b is provided to fill the channel portion 521a. The high heat conductive material 521 b has a heat conductivity higher than that of the base material of the cylinder head 52B.

[0096] FIG. 22 is a schematic view of a method for forming the high heat conductive material 511b. A laser cladding device 90 is equipped with: a laser beam supply source 91; a condenser lens 92; a feeder 93; an oscillator 94;and a shield gas nozzle 95.

[0097] The laser beam supply source 91 generates laser beam. For example, the laser beam is a fiber laser or a CO_2 laser. The condenser lens 92 condenses the laser beam. The feeder 93 supplies materials to the channel portion 511 a. The oscillator 94 oscillates the laser beam, with a high period, irradiated from the laser beam supply source 91 through the condenser lens 92, to irradiate the leaser beam to the material supplied from the feeder 93. The shield gas nozzle 95 supplies a shield gas intercepting the material from outside air. For example, a shield gas is argon gas.

[0098] The laser cladding device 90 melts the material supplied to the channel portion 511a with the laser beam to overlay (clad) the material, thereby providing the high heat conductive material 511b. The material employs metal powders having a heat conductivity higher than the base material of the cylinder block 51B. This enables the heat conductivity of the high heat conductive material 511b to be higher than that of the base material of the cylinder block 51B. For example, the base material of the cylinder block 51B is an aluminum die-casting, and is made of, for example, copper powders. For example, the material may be alloy powders such as copper alloy, or metal powders mixed with plural types of metal powders.

[0099] When the high heat conductive material 511b is provided at the channel portion 511a, the cylinder block 51B is moved arbitrarily. This can change the position where the material is supplied and the position where the laser beam is irradiated. For example, the high heat conductive material 511b can be provided by use of a coaxial nozzle which can supply the material and irradiate the laser beam. In this case, the coaxial nozzle is moved appropriately, thereby changing the position where the material is supplied and the position where the laser beam is irradiated.

[0100] The high heat conductive material 521b can be provided in the same manner as the high heat conductive material 511b. In this case, the material employs metal powders having a heat conductivity higher than the base material of the cylinder head 52B. For example, as for the cylinder head 52B, the base material is an aluminum die-casting, and the material is the same as the high heat conductive material 511b.

[0101] Next, the effect of the cooling device 1C will be described. Herein, as to the upper portion of the wall portion of the bore 51a, in particular, the portion between the adjacent bores 51a tends to have a high temperature due to the influence of the combustion. Correspondingly, the cooling device 1C having the first high heat conductive portion 511 can promote the heat transfer from the portion between the bores 51a. The heat transfer can be promoted without especially increasing the heat transfer from the cylinder head 52B to the cylinder block 51B.

[0102] For this reason, as compared with the cooling device 1B, the cooling device 1C having the first high heat conductive portion 511 can suppress an increase in the cooling loss and further suppress the knocking. Also, the given depth of the first high heat conductive portion 511 is set to correspond to the upper portion of the wall portion of the bore 51a, thereby suitably promoting the heat transfer from the portion between the bores 51a.

[0103] Further, the portion, between the adjacent bores 51a, of the upper portion of the wall portion of the bore 51a tends to have a temperature higher than the portion, of the cylinder head 52B, facing the portion between the bores 51 a. Correspondingly, the cooling device 1C having the second high heat conductive portion 541 can promote the heat transfer from the portion between the bores 51a to the cylinder head 52B. Accordingly, the cooling device 1C having the second high heat conductive portion 541 can suppress the knocking in addition to an increase in the cooling loss, as compared with the cooling device 1B.

[0104] In this regard, the head gasket 54B can suppress the heat transfer from the cylinder head 52B to the cylinder block 51 B at another portion other than the second high heat conductive portion 541. Thus, the cooling device 1C having the head gasket 54B can suppress an increase in the cooling loss, and suitably suppress the knocking.

[0105] Also, the cooling device 1C having both the high heat conductive portions 511 and 541 can further suitably promote the heat transfer from the portion between the bores 51a to the cylinder head 52B. This can result in suppressing the knocking in addition to an increase in the cooling loss, as compared with a case of providing any one of the high heat conductive portions 511 and 541. It is also suitable to promote the heat transfer in such a manner, when the given length of the first high heat conductive portion 511 is set not to reach the W/Js 501 and 502.

[0106] Also, the cooling device 1C equipped with the second high heat conductive portion 541 selected from the high heat conductive portions 511 and 541, and the third high heat conductive portion 521 can promote the heat transfer from the third high heat conduction portion 521. That is, the heat transfer from the third high heat conductive portion 521 can be made improved. This can further promote the heat transfer to the cylinder head 52B from the portion between the bores 51a in a more suitable manner than a case without the third high heat conductive portion 521. This can result in suppressing the knocking in addition to the cooling loss, as compared with the case without the third high heat conductive portion 521.

[0107] Also, the cooling device 1C having the high heat conductive portions 511, 521, and 541 can promote the heat transfer in a suitable manner, as compared with a case without the first high heat conductive portion 511. This can result in suppressing the knocking in addition to the cooling loss, as compared with a case without the first high heat conductive portion 511.

[0108] Also, in the cooling device 1C, the first high heat conductive portion 511 is equipped with the channel portion 511 a and the high heat conductive material 511b. In providing the high heat conductive material 511b within the channel portion 511 a, the material is supplied to the channel portion 511 a and is melted by the laser beam. For this reason, the cooling device 1C can improve the adhesion between the channel portion 511 a and the high heat conductive material 511b. This can result in promoting the heat transfer from the portion between the bores 51 a in a suitable manner. Further, the high heat conductive material 511b is provided to fill the channel portion 511a, thereby suitably promoting the heat transfer. This also applies to the third high heat conductive portion 521.

[0109] Also, the cooling device 1C having the divergent W/J 503B can ensure the flow rate higher than a case where the coolant is caused to flow from the front side to the rear side of the engine 50B. This can improve the ability to cool the portion, of the cylinder head 52B, facing the portion between the bores 51a. For this reason, the cooling device 1C having the divergent W/J 503B is equipped with, for example, at least the second high heat conductive portion 541 selected from the high heat conductive portions 511, 521, and 541, thereby suitably promoting the heat transfer from the portion between the bores 51a to the cylinder head 52B.

[0110] While the exemplary embodiments of the present invention have been illustrated in detail, the present invention is not limited to the above-mentioned embodiments, and other embodiments, variations and modifications may be made without departing from the scope of the present invention.

[0111] For example, the case of providing the W/Ps 11 and 12 has been described in the above mentioned embodiments. However, the present invention is not limited to these arrangements. For example, the cooling device may have a common cooling medium pressure feeding portion that pressure-feeds a cooling medium to both an intake side cooling medium passage and an exhaust side cooling medium passage. As a variation of the cooling device 1A, FIG. 23 illustrates a cooling device 1A' having a third W/P 13 corresponding to the common cooling medium pressure feeding passage. This case has an advantage of a cost lower than the case where the W/Ps 11 and 12 are respectively provided in the W/Js 501 and 502. In such a way, each flow control portion can have, for example, the third W/P 13 instead of the W/Ps 11 and 12.

[0112] Further, the case of providing the radiators 12 and 22 has been described in the above embodiments. However, the present invention is not limited to these arrangements. The cooling device may have a common heat exchanger that has a common cooling medium inlet portion and first and second cooling medium outlet portions at such positions that the flowing distances of the coolant medium are different from each other. As a variation of the cooling device 1A', FIG. 24 illustrates a cooling device 1A" having a third radiator 23 corresponding to a common heat exchanger.

[0113] In this case, the coolant flowing distance passing through a first coolant outlet portion 23a is relatively short, and the coolant flowing distance passing through a second coolant outlet portion 23b is relatively long, selected from the first coolant outlet portion 23a and the second coolant outlet portion 23b. The coolant outlet portion 23a can be connected to the intake side W/J 501, and the coolant outlet portion 23b can be connected to the exhaust side W/J 502. The cooling device 1A" having the third radiator 23 has an advantage of a cost lower the case where the radiators 12 and 22 are respectively provided in the W/Js 501 and 502.

[0114] Additionally, a mechanical W/P may be employed as the cooling medium pressure feeding portion that pressure- feeds the cooling medium to the intake side cooling medium passage or the exhaust side cooling medium passage. This case is further provided with: a bypass pipe that bypasses the intake side cooling medium passage or the exhaust side cooling medium passage; and a bypass control valve that controls the cooling medium flowing in the bypass pipe. This can allow the cooling medium to flow in the intake side cooling medium passage or the exhaust side cooling medium passage, or prohibit the coolant medium from flowing therein. Further, this can change the flow rate. Thus, for example, each flow control portion can be provided with the third W/P 13 as the mechanical W/P, the above bypass pipe, and the bypass control valve, instead of the W/Ps 11 and 12.

[DESCRIPTION OF LETTERS OR NUMERALS]

[0115]

Cooling device	1A, 1A', 1A", 1B, 1C
First W/P	11
Second W/P	21

(continued)

First control valve	31
Second control valve	32
Engine	50A, 50B
Intake side W/J	501
Exhaust side W/J	502
Divergent W/J	503A, 503B
Cylinder block	51A, 51B
Cylinder head	52A, 52B
ECU	70A, 70B

Claims

1. An engine cooling device comprising:

an engine including a cylinder block, a cylinder head, an intake side cooling medium passage, an exhaust side cooling medium passage, and a divergent cooling medium passage; and
a first state change portion;
wherein the intake side cooling medium passage is provided at an intake side in the cylinder block, and is provided in such a direction as to arrange a plurality of bores provided in the cylinder block,
the exhaust side cooling medium passage is provided at an exhaust side in the cylinder block, is independent of the intake side cooling medium passage, and is provided in such a direction as to arrange the plurality of the bores,
the divergent cooling medium passage diverges from a given position of the intake side cooling medium passage, is provided from the intake side cooling medium passage toward the exhaust side of the cylinder head through the intake side of the cylinder head, and is provided at the exhaust side in such a direction as to arrange the plurality of the bores, and
the first state change portion makes a cooling medium flowing state changeable between a state where the cooling medium is caused to flow in the intake side cooling medium passage and a state where the cooling medium is caused to flow in the intake side cooling medium passage and the divergent cooling medium passage, selected from the intake side cooling medium passage and the divergent cooling medium passage.

2. The engine cooling device of claim 1, further comprising a first flow control portion including the first state change portion, causing the cooling medium to flow in the intake side cooling medium passage and the exhaust side cooling medium passage when an engine driving state is in a low speed and a high load, and causing the cooling medium to flow in the intake side cooling medium passage selected from the intake side cooling medium passage and the divergent cooling medium passage.

3. The engine cooling device of claim 1 or 2, further comprising a second flow control portion including the first state change portion, prohibiting the cooling medium from flowing in the intake side cooling medium passage and the exhaust side cooling medium passage when the engine driving state is in a low load.

4. The engine cooling device of any one of claims 1 to 3, further comprising:

a heat exchanger transferring heat between air and the cooling medium caused to flow in the exhaust side cooling medium passage;
a heat accumulator storing the cooling medium caused to flow in the exhaust side cooling medium passage, and keeping heat of the cooling medium;
a second state change portion making the cooling medium flowing state changeable between a state where the cooling medium is caused to flow in the heat exchanger and the a state where the cooling medium is caused to flow in the heat accumulator selected from the heat exchanger and the heat accumulator; and
a third flow control portion including the second state change portion, causing the cooling medium to flow in the exhaust side cooling medium passage when the engine driving state is in a cold driving or in an engine starting, and causing the cooling medium to flow in the heat accumulator, selected from the heat exchanger and the heat accumulator.

5. The engine cooling device of any one of claims 1 to 4, further comprising a high heat conductive portion provided at a portion between adjacent bores selected from the plurality of the bores, exposed from a deck surface of the cylinder block, and having a heat conductivity higher than a base material of the cylinder block.

6. The engine cooling device of claim 5, wherein
the high heat conductive portion includes a channel portion and a high heat conductive material,
the channel portion is provided at the portion between the adjacent bores selected from the plurality of the bores of the cylinder block, opens toward the deck surface, and has a given depth, and
a material is supplied to the channel portion and is melted by a laser beam, whereby the high heat conductive material is provided at the channel portion so as to be exposed at the deck surface and has a

heat conductivity higher than the base material of the cylinder block.

FIG. 1

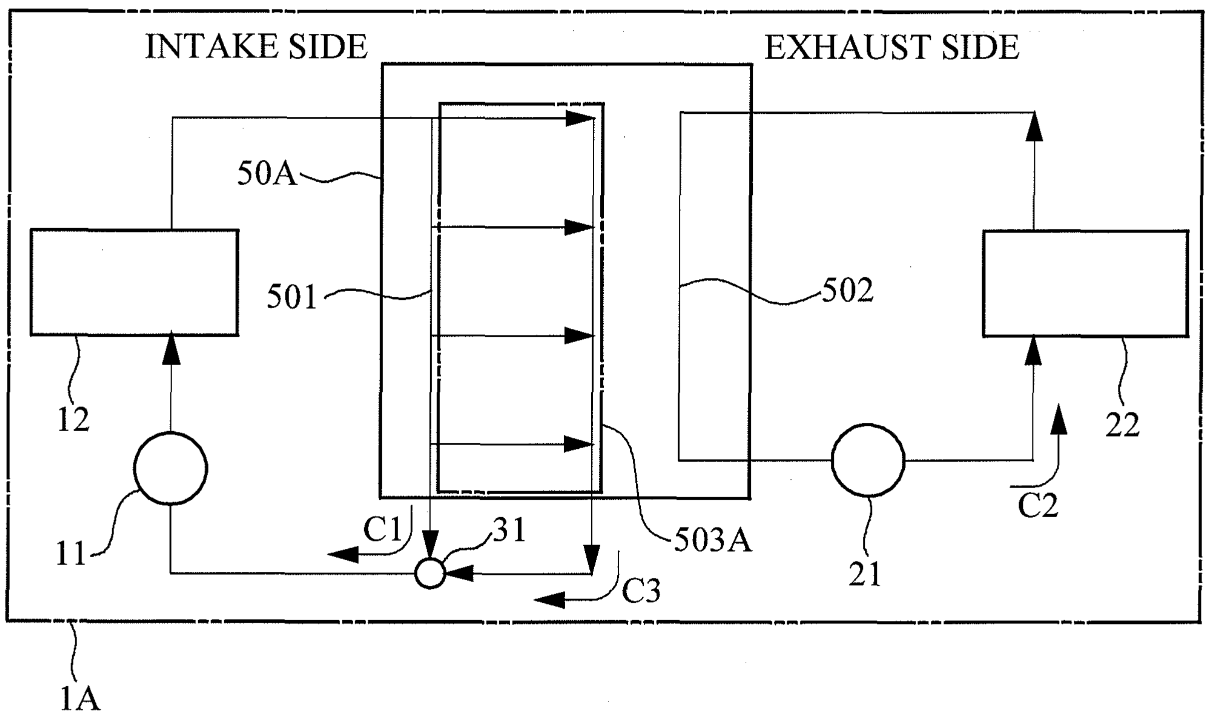

INTAKE SIDE
EXHAUST SIDE
50A
501
502
503A
12
11
31
C1
C3
C2
21
22
1A

FIG. 2

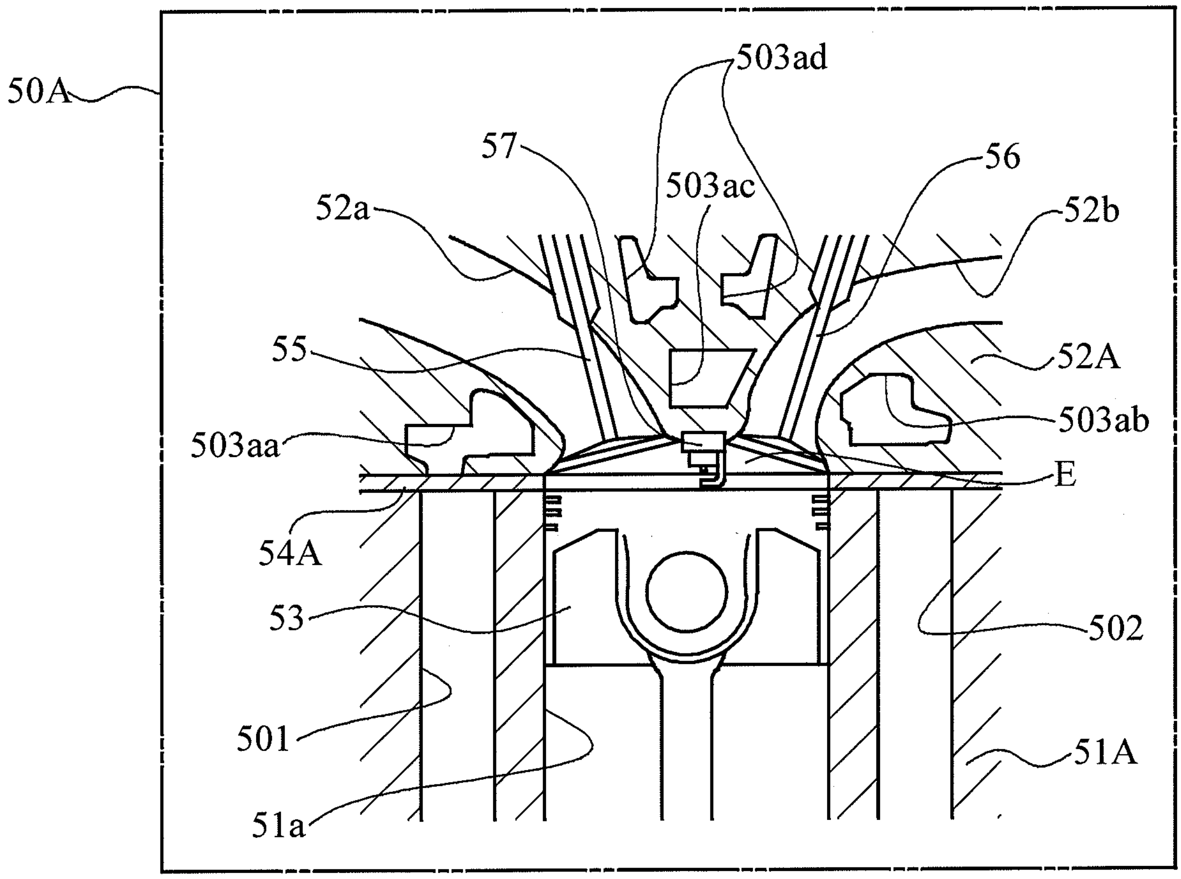

50A
503ad
57
56
503ac
52a
52b
55
52A
503ab
503aa
E
54A
53
502
501
51A
51a

FIG. 3

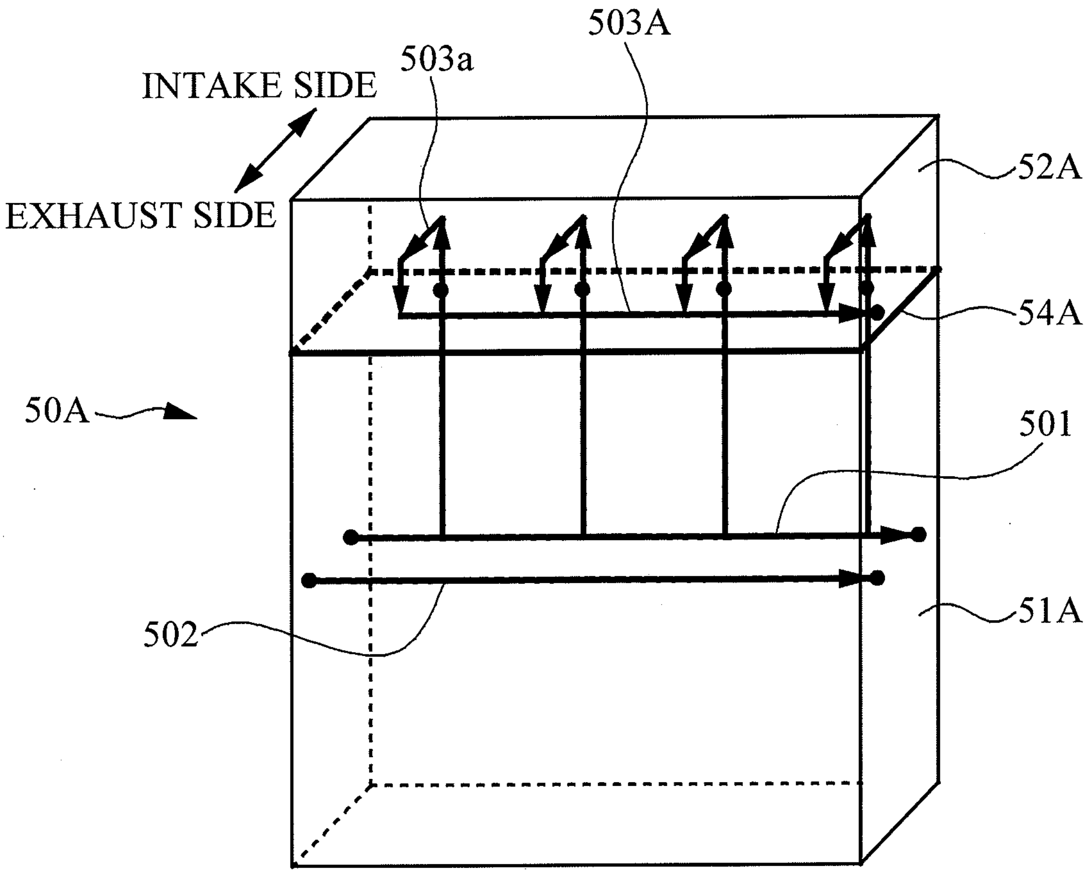


FIG. 4

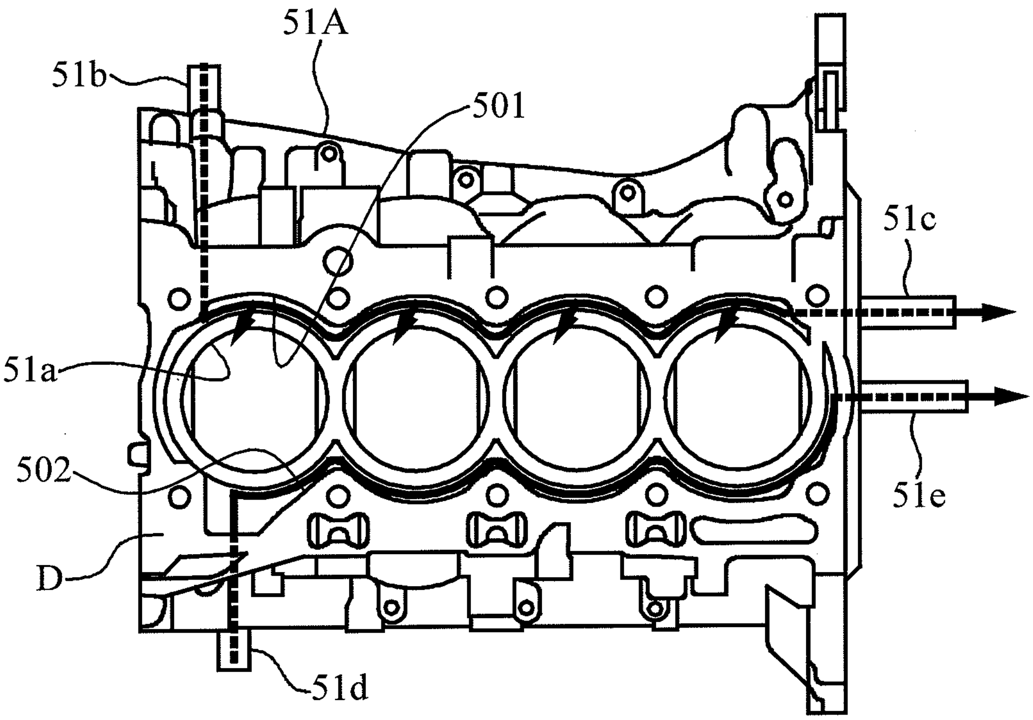


FIG. 5

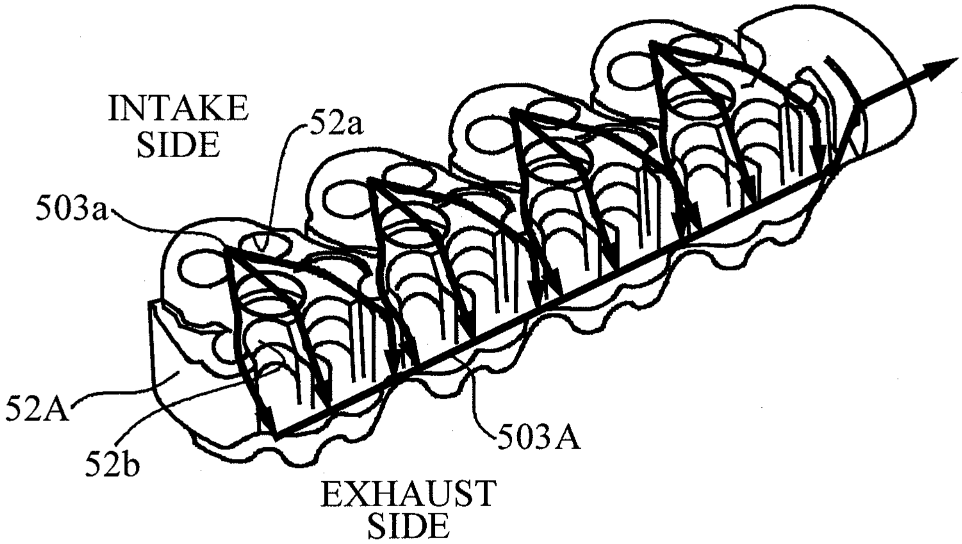


FIG. 6

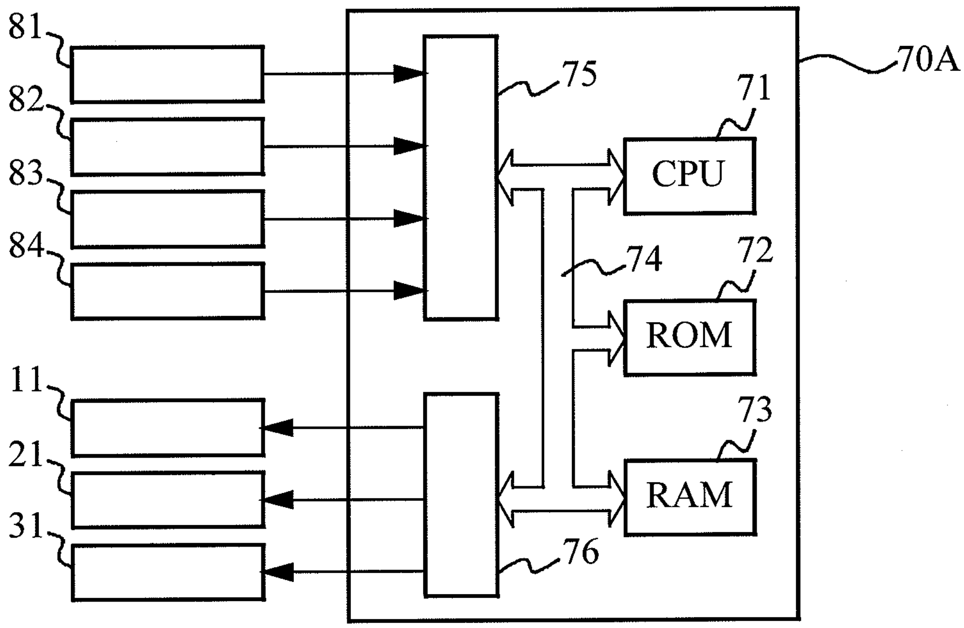


FIG. 7

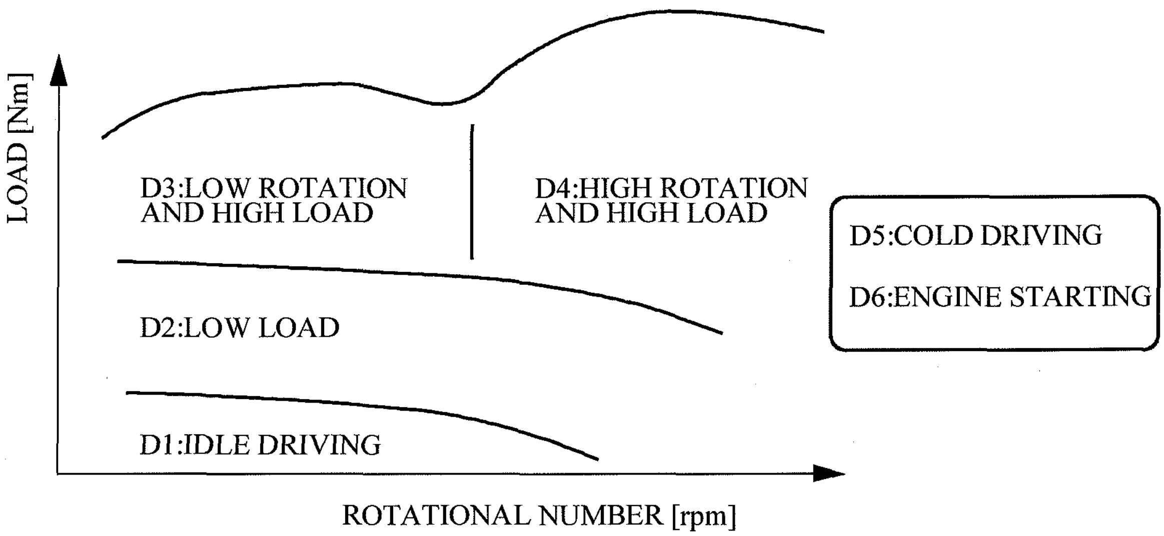

LOAD [Nm]
D3:LOW ROTATION AND HIGH LOAD
D4:HIGH ROTATION AND HIGH LOAD
D5:COLD DRIVING
D6:ENGINE STARTING
D2:LOW LOAD
D1:IDLE DRIVING
ROTATIONAL NUMBER [rpm]

FIG. 8

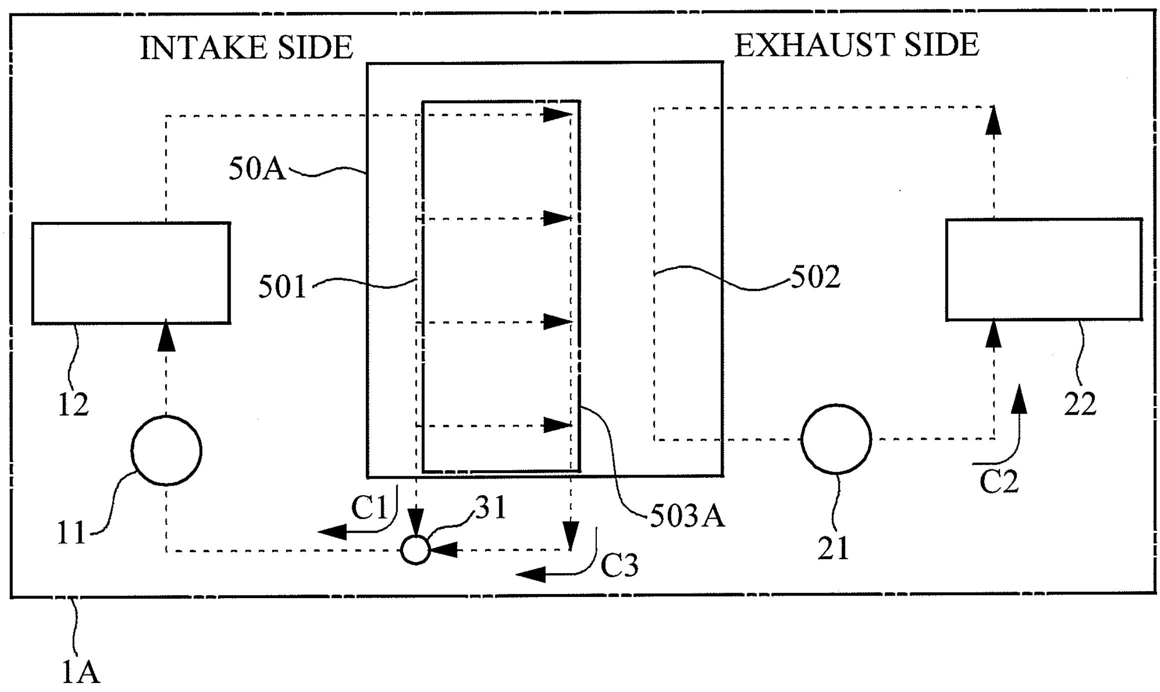

INTAKE SIDE
EXHAUST SIDE
50A
501
502
503A
12
11
22
21
31
C1
C2
C3
1A

FIG. 9

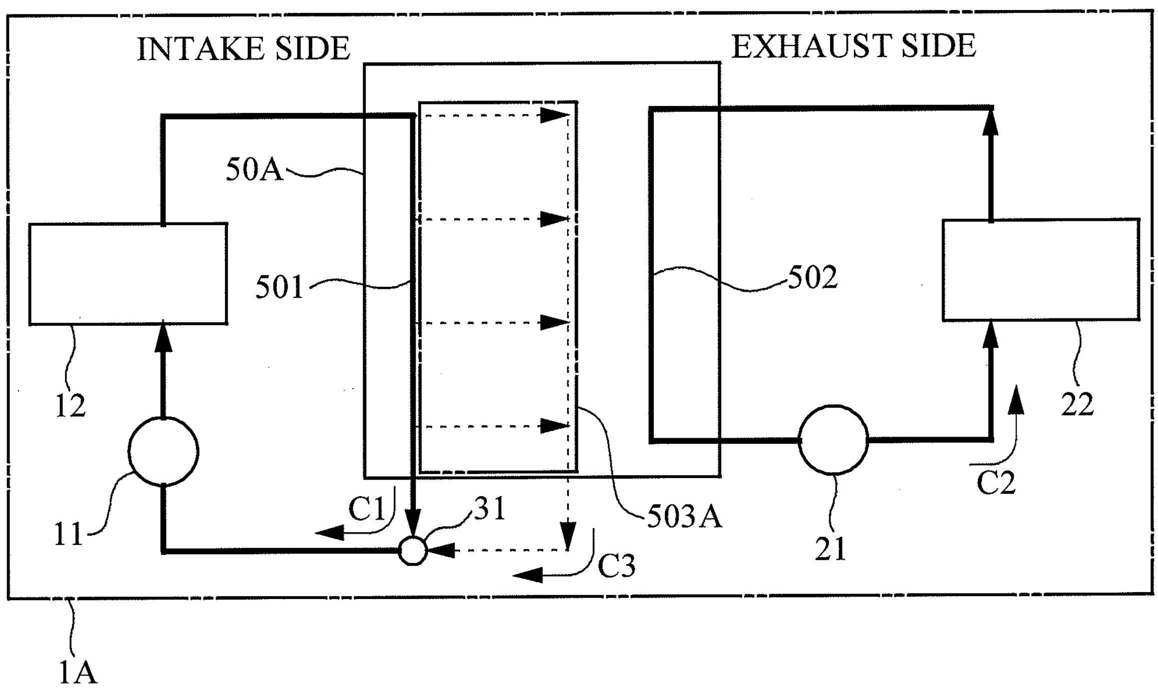

INTAKE SIDE
EXHAUST SIDE
50A
501
502
503A
12
11
31
C1
C3
21
22
C2
1A

FIG. 10

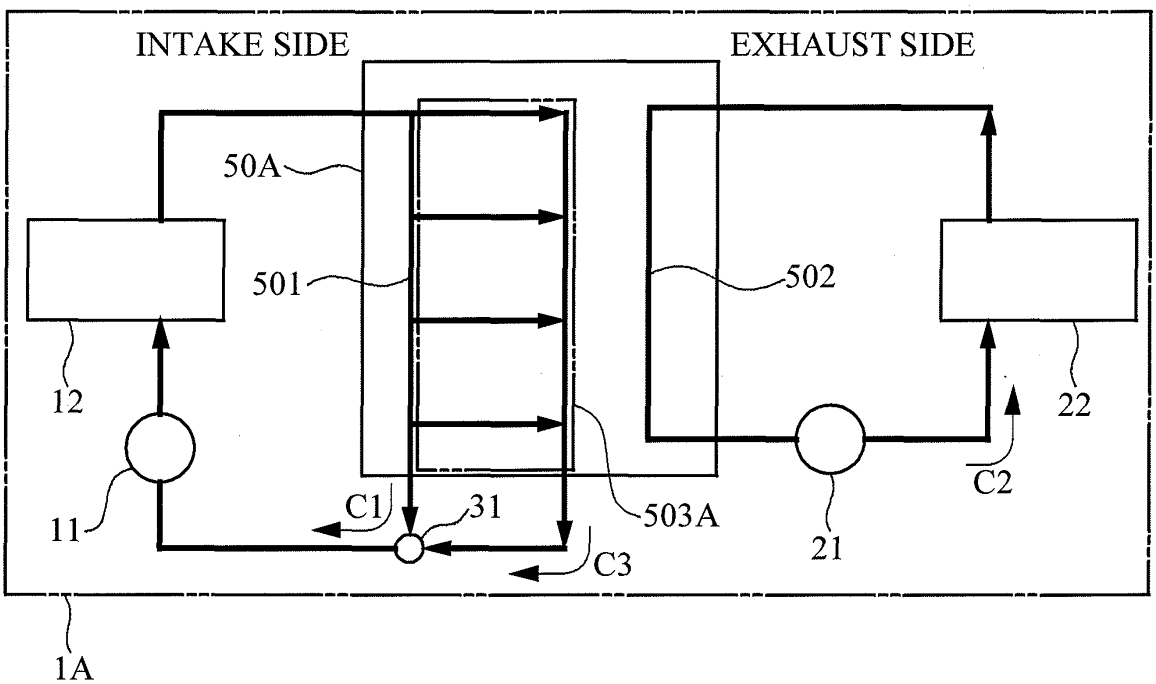

INTAKE SIDE
EXHAUST SIDE
50A
501
502
503A
12
11
31
C1
C3
21
22
C2
1A

FIG. 11

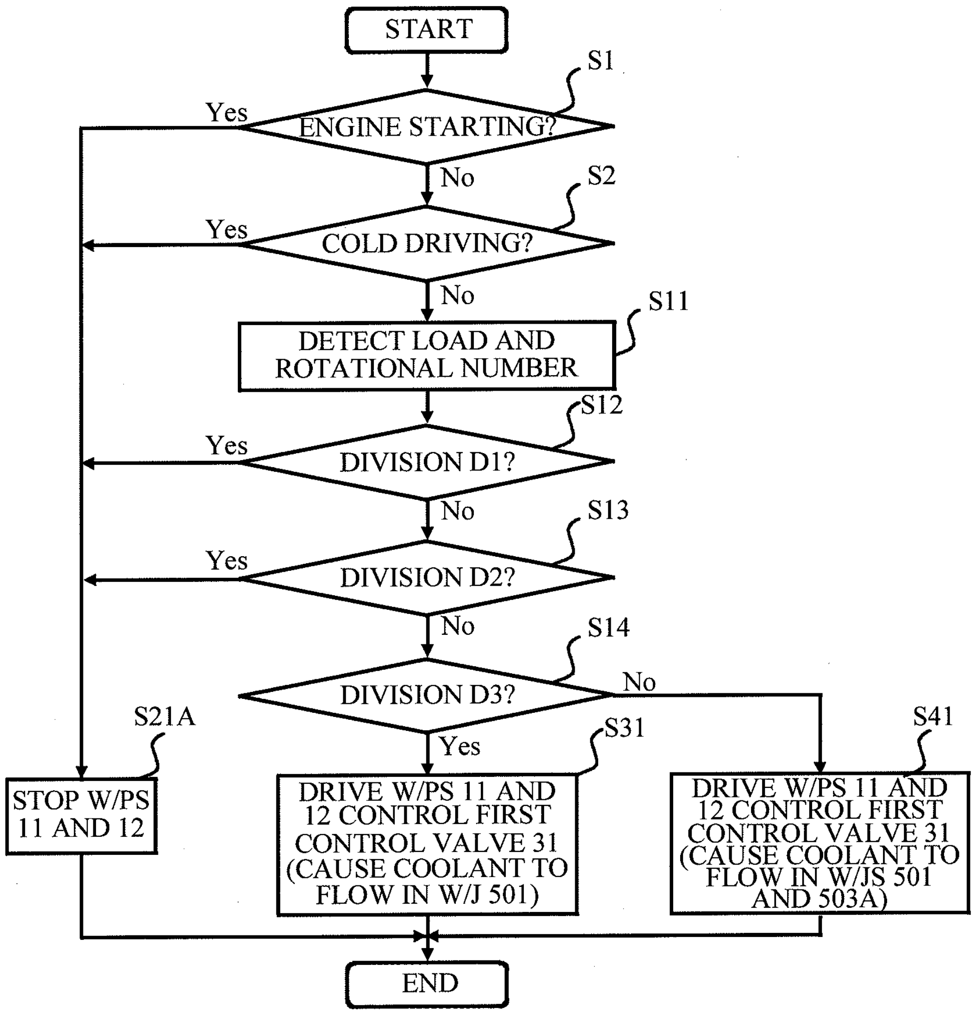

START
S1
Yes
ENGINE STARTING?
No
S2
Yes
COLD DRIVING?
No
S11
DETECT LOAD AND ROTATIONAL NUMBER
S12
Yes
DIVISION D1?
No
S13
Yes
DIVISION D2?
No
S14
DIVISION D3?
No
S21A
Yes
S31
S41
STOP W/PS 11 AND 12
DRIVE W/PS 11 AND 12 CONTROL FIRST CONTROL VALVE 31 (CAUSE COOLANT TO FLOW IN W/J 501)
DRIVE W/PS 11 AND 12 CONTROL FIRST CONTROL VALVE 31 (CAUSE COOLANT TO FLOW IN W/JS 501 AND 503A)
END

FIG. 12

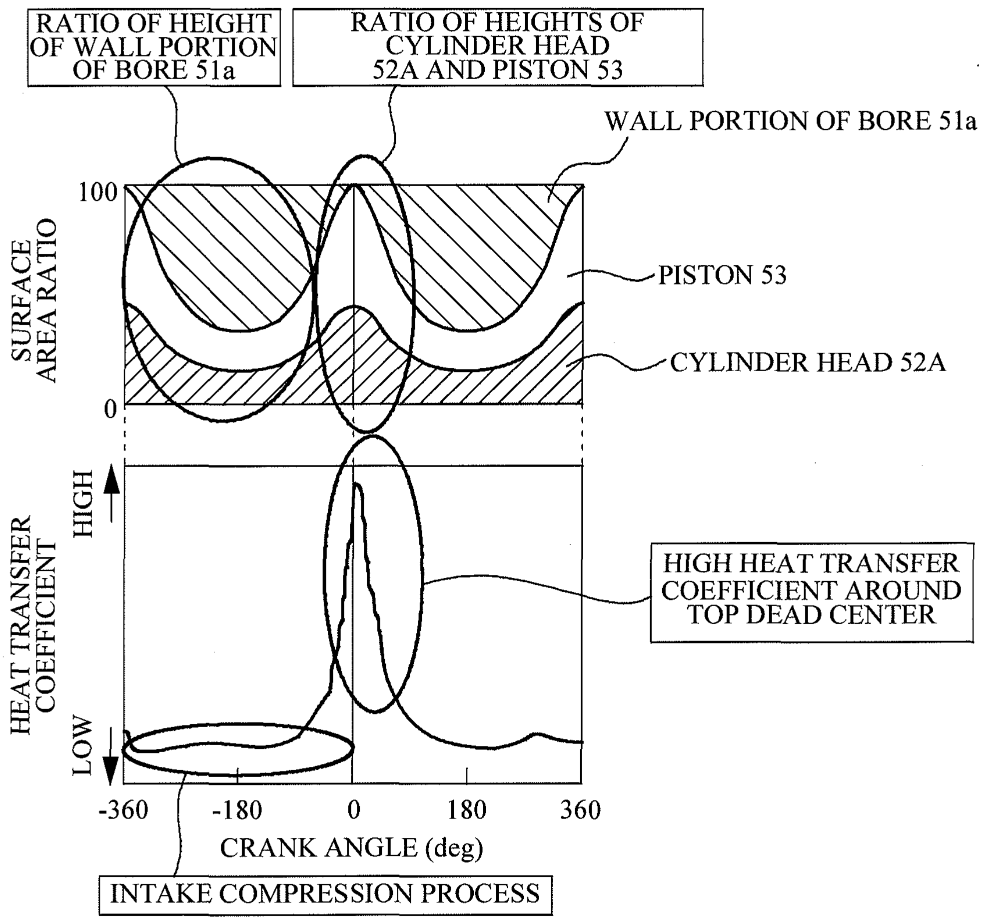

RATIO OF HEIGHT OF WALL PORTION OF BORE 51a
RATIO OF HEIGHTS OF CYLINDER HEAD 52A AND PISTON 53
WALL PORTION OF BORE 51a
100
SURFACE AREA RATIO
PISTON 53
CYLINDER HEAD 52A
0
HIGH
HEAT TRANSFER COEFFICIENT
LOW
HIGH HEAT TRANSFER COEFFICIENT AROUND TOP DEAD CENTER
-360
-180
0
180
360
CRANK ANGLE (deg)
INTAKE COMPRESSION PROCESS

FIG. 13

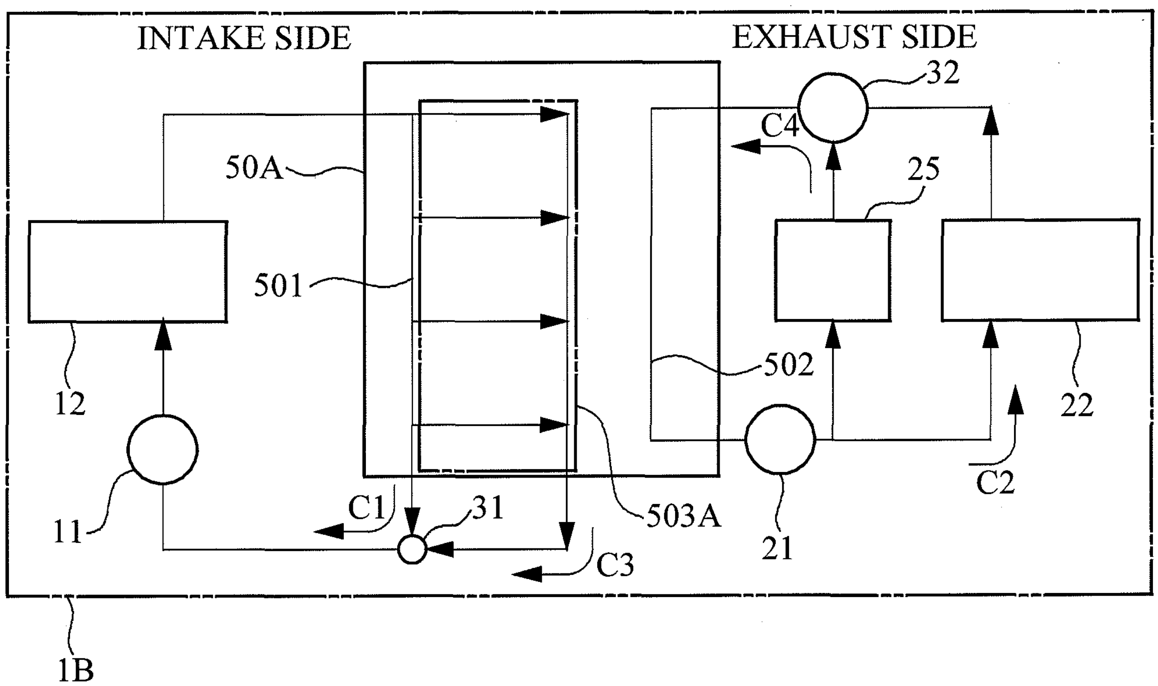

INTAKE SIDE
EXHAUST SIDE
32
C4
25
50A
501
502
12
22
503A
C2
11
C1
31
21
C3
1B

FIG. 14

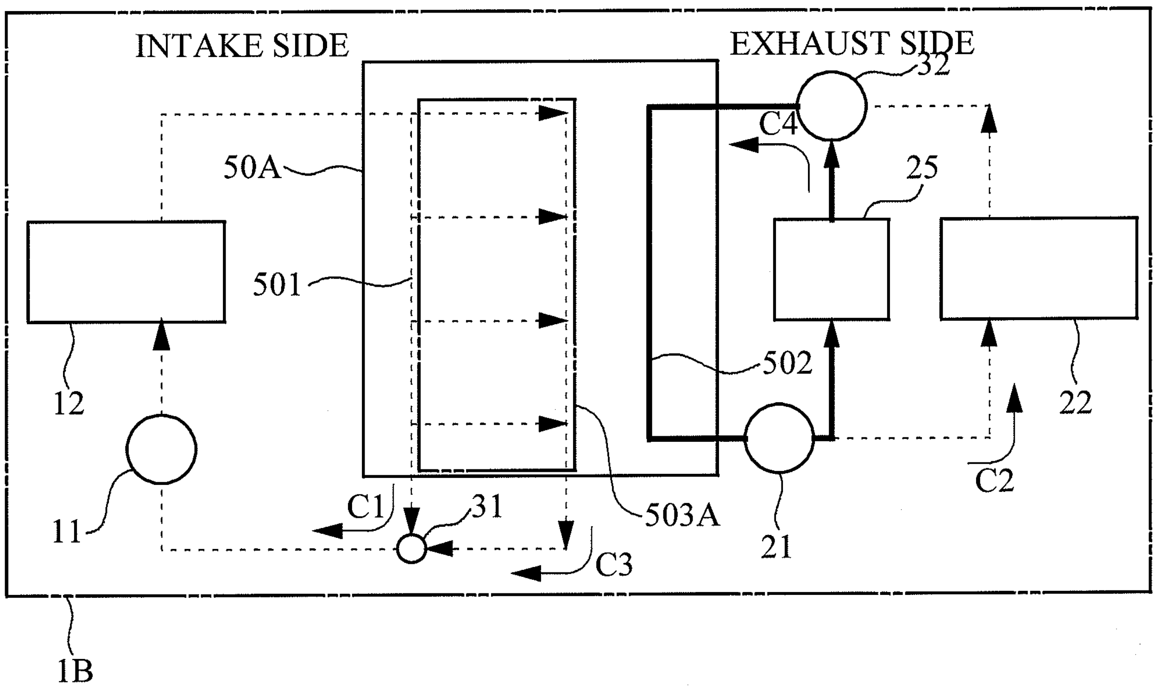
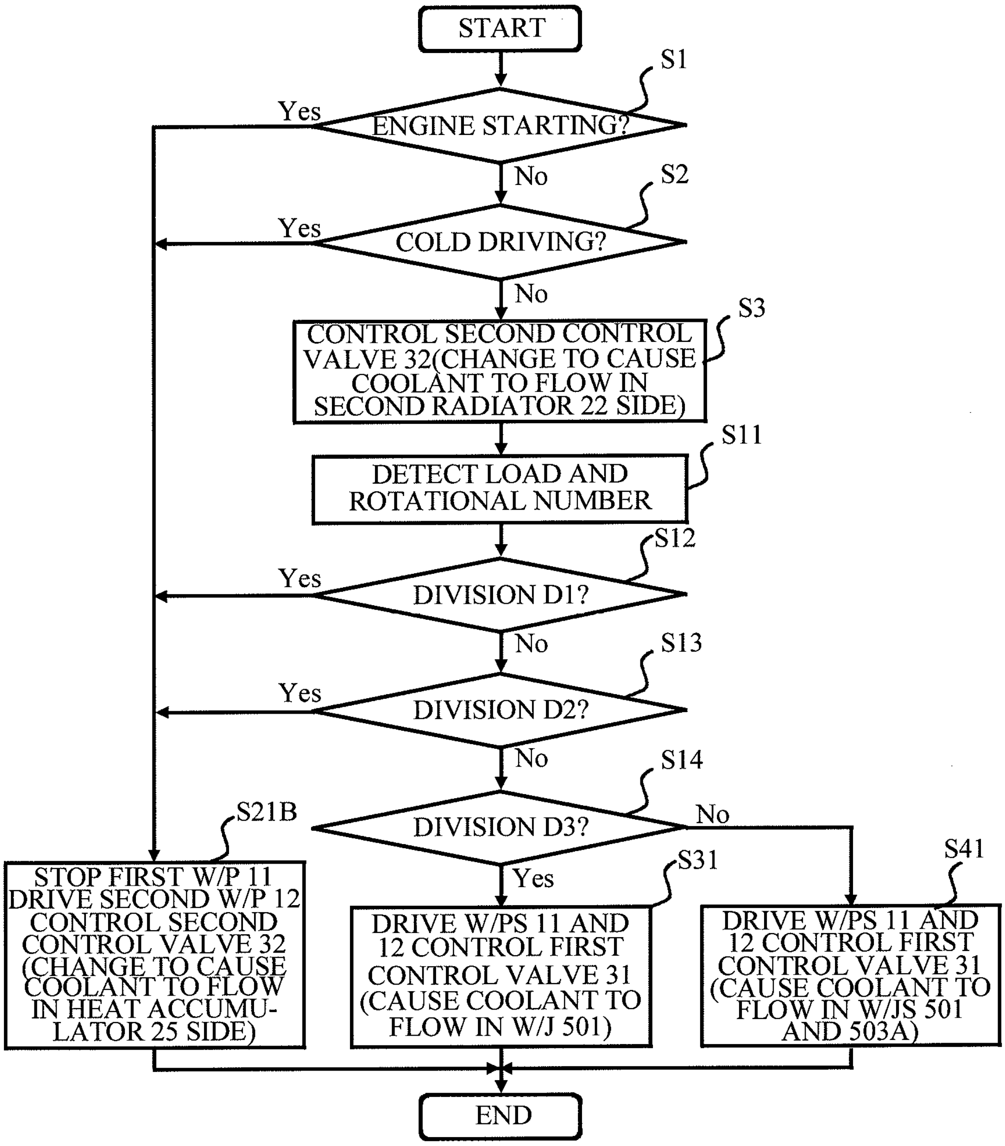

INTAKE SIDE
EXHAUST SIDE
32
C4
50A
25
501
502
12
22
C2
11
21
C1
31
503A
C3
1B

FIG. 15



START
S1
ENGINE STARTING?
Yes
No
S2
COLD DRIVING?
Yes
No
S3
CONTROL SECOND CONTROL VALVE 32(CHANGE TO CAUSE COOLANT TO FLOW IN SECOND RADIATOR 22 SIDE)
S11
DETECT LOAD AND ROTATIONAL NUMBER
S12
DIVISION D1?
Yes
No
S13
DIVISION D2?
Yes
No
S14
DIVISION D3?
No
Yes
S21B
STOP FIRST W/P 11 DRIVE SECOND W/P 12 CONTROL SECOND CONTROL VALVE 32 (CHANGE TO CAUSE COOLANT TO FLOW IN HEAT ACCUMU-LATOR 25 SIDE)
S31
DRIVE W/PS 11 AND 12 CONTROL FIRST CONTROL VALVE 31 (CAUSE COOLANT TO FLOW IN W/J 501)
S41
DRIVE W/PS 11 AND 12 CONTROL FIRST CONTROL VALVE 31 (CAUSE COOLANT TO FLOW IN W/JS 501 AND 503A)
END

FIG. 16

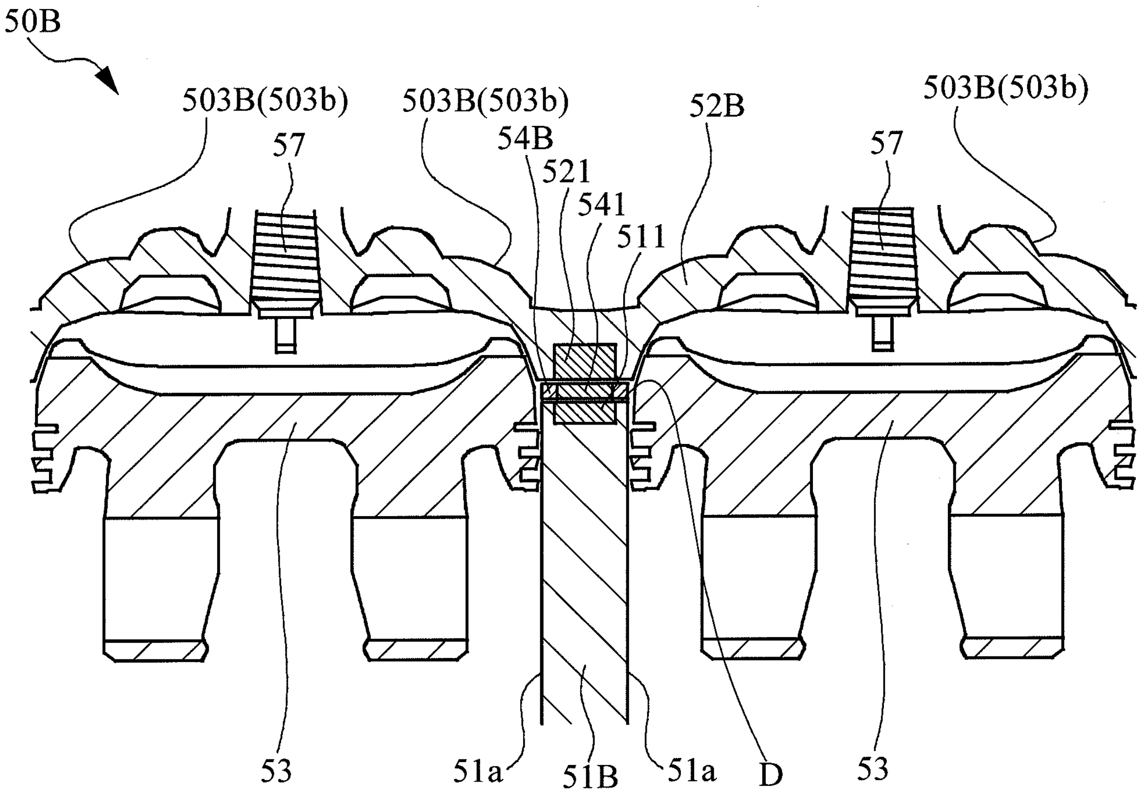

50B
503B(503b)
503B(503b)
52B
503B(503b)
57
54B
57
521
541
511
53
51a
51B
51a
D
53

FIG. 17

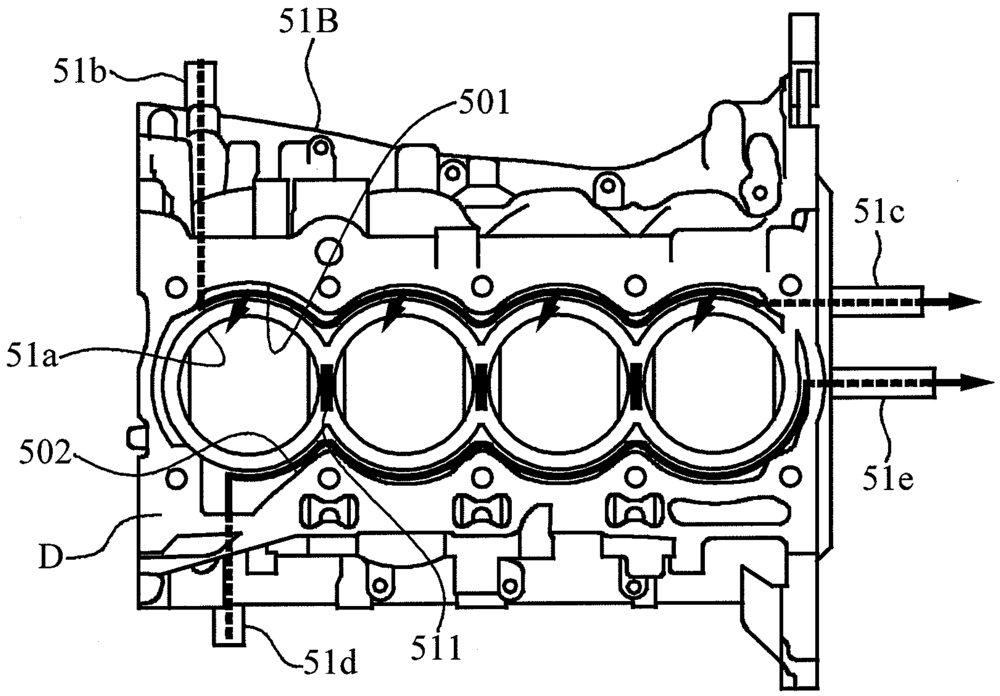


FIG. 18

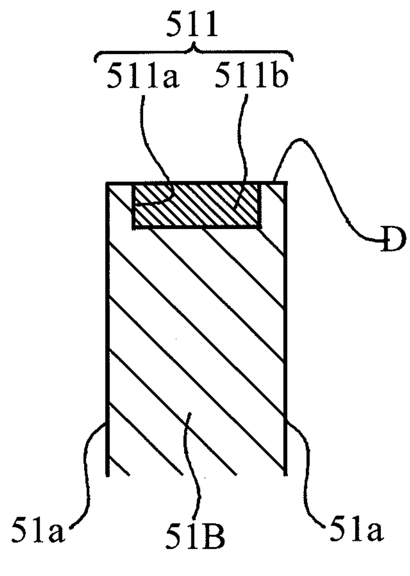


FIG. 19A

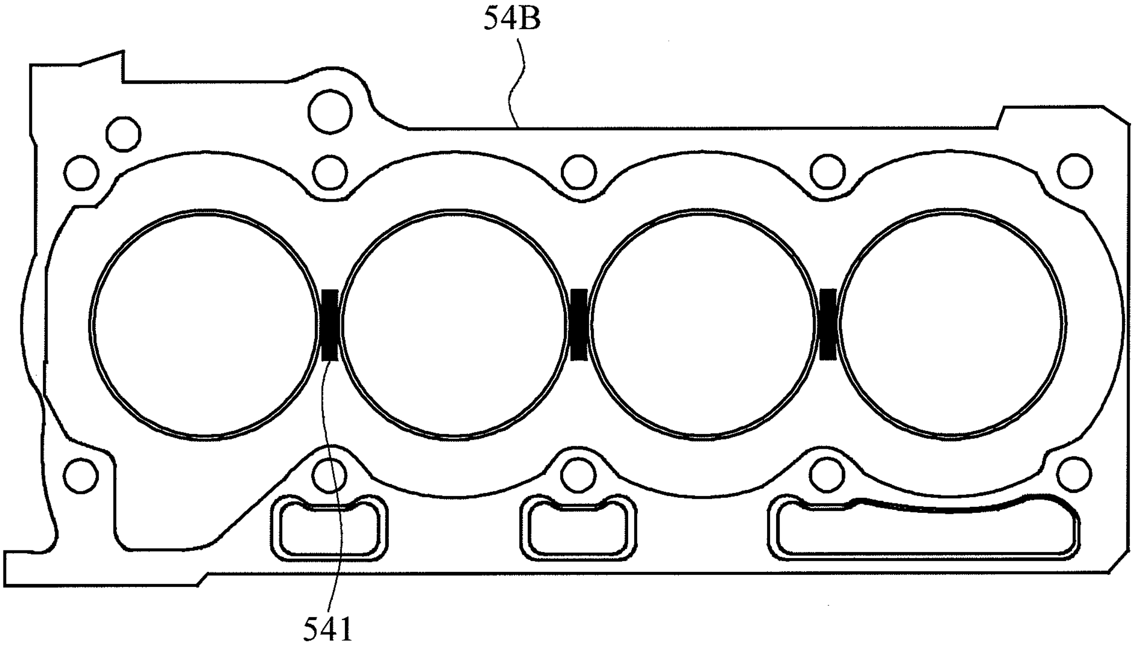


FIG. 19B

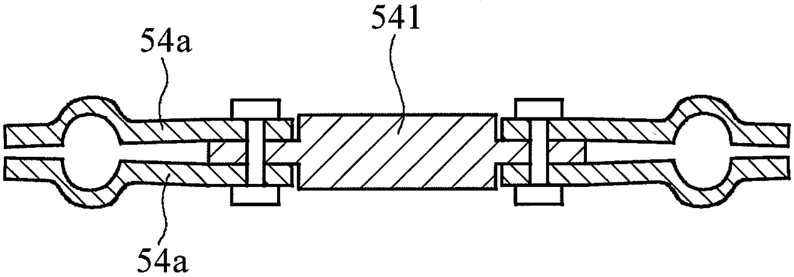


FIG. 20

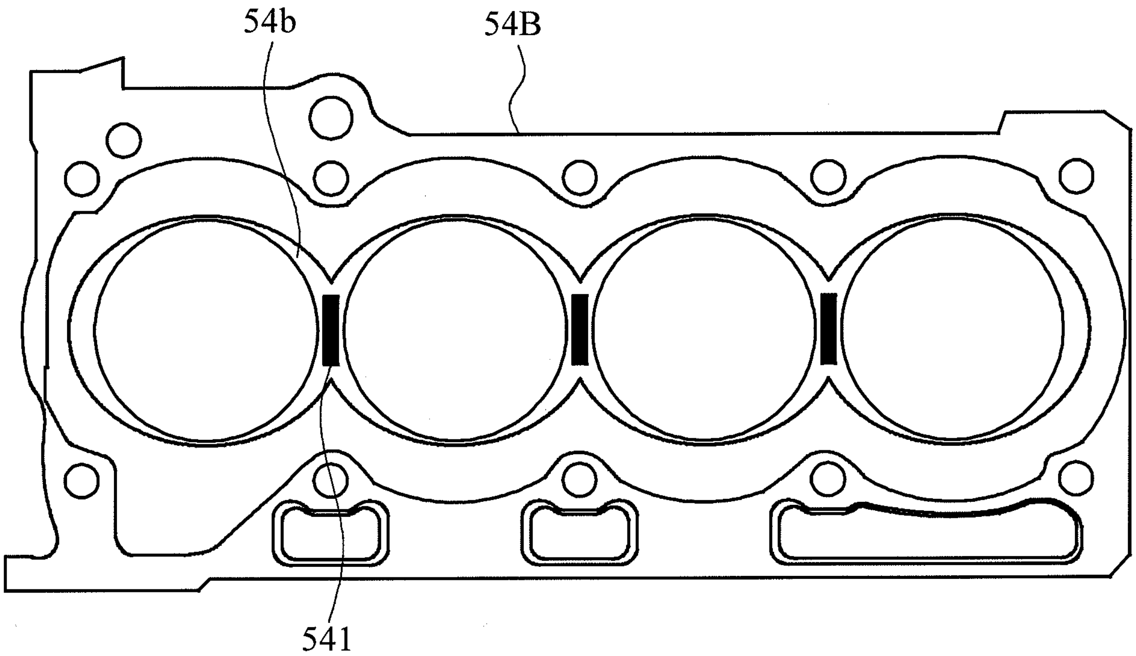


FIG. 21

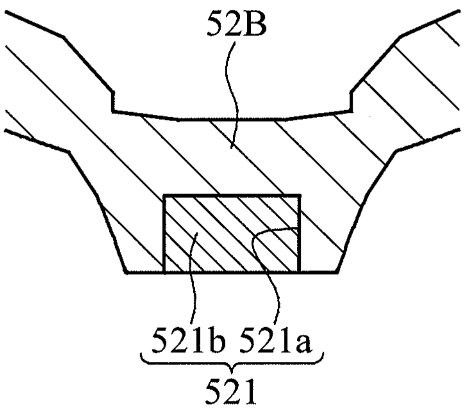


FIG. 22

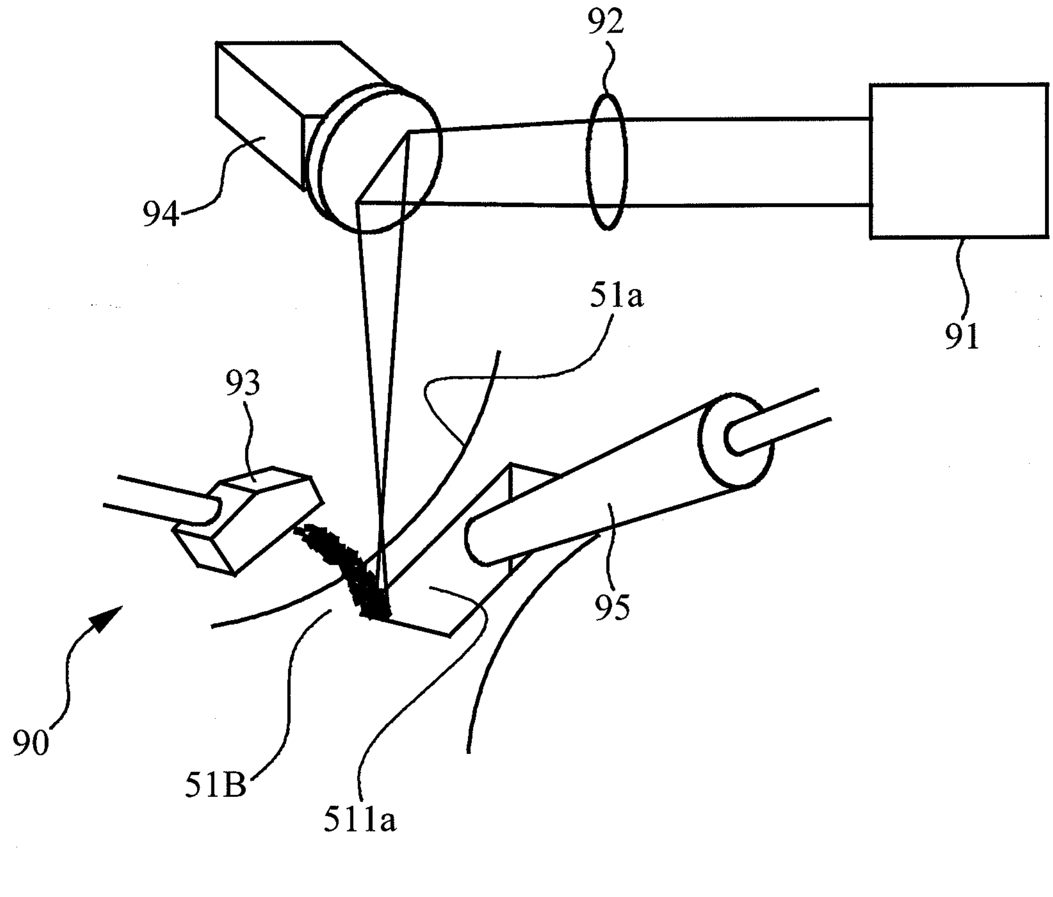


FIG. 23

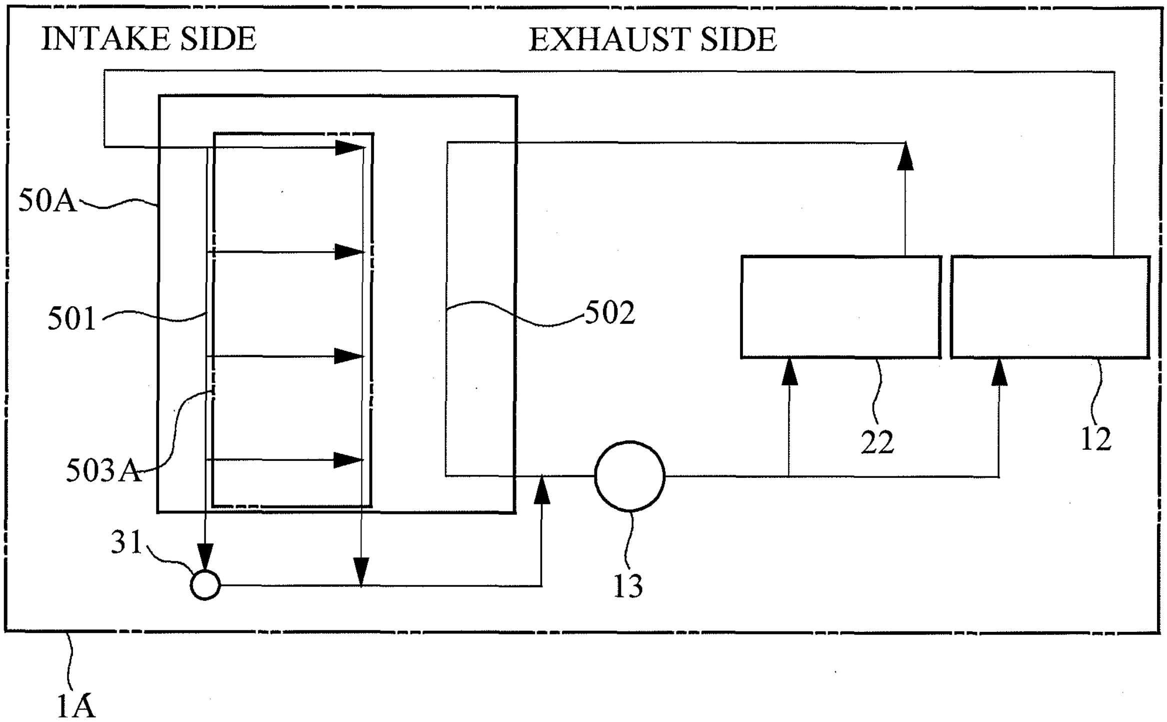
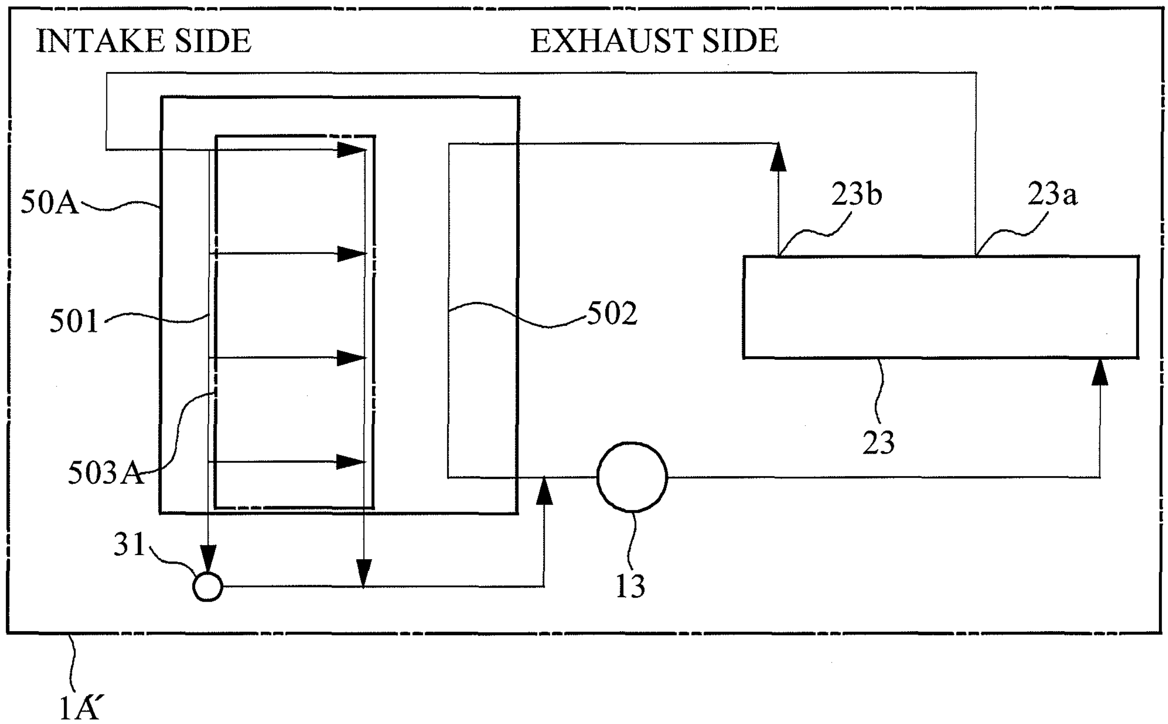


FIG. 24



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/071139

A. CLASSIFICATION OF SUBJECT MATTER
F01P3/02(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01P3/02

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2006-132376 A (Toyota Motor Corp.), 25 May 2006 (25.05.2006), entire text; all drawings (Family: none)	1-6
A	JP 2007-291913 A (Mazda Motor Corp.), 08 November 2007 (08.11.2007), entire text; all drawings (Family: none)	1-6

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 January, 2011 (06.01.11)	18 January, 2011 (18.01.11)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/071139

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 003747/1985(Laid-open No. 120022/1986) (Nissan Motor Co., Ltd.), 29 July 1986 (29.07.1986), entire text; all drawings (Family: none)	1-6
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 131885/1984(Laid-open No. 048917/1986) (Nissan Diesel Motor Co., Ltd.) 02 April 1986 (02.04.1986), entire text; all drawings (Family: none)	1-6

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Patent documents cited in the description

- JP 8177483 A **[0003]**