



(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
08.10.2014 Bulletin 2014/41

(21) Application number: **12853010.2**

(22) Date of filing: **27.11.2012**

(51) Int Cl.:
F01P 3/18 ^(2006.01) **F01P 3/20** ^(2006.01)
F01P 5/12 ^(2006.01) **F01P 7/16** ^(2006.01)
F02M 25/07 ^(2006.01)

(86) International application number:
PCT/JP2012/080646

(87) International publication number:
WO 2013/080980 (06.06.2013 Gazette 2013/23)

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

(30) Priority: **28.11.2011 JP 2011258712**

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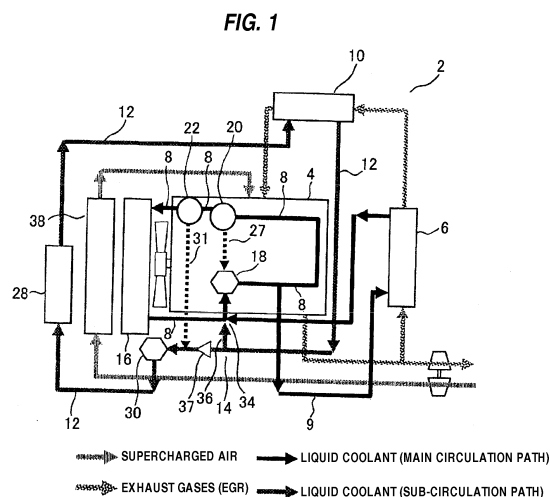
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(54) **ENGINE COOLING APPARATUS AND ENGINE COOLING METHOD**

(57) An object of the invention relates to a cooling system for an engine having an EGR system and the like and a cooling method for cooling the engine and is to provide a system and method for cooling an engine which realize a reduction in the capacity of a main radiator by giving a sub-radiator a function to assist the main radiator, a reduction in cost and an effective use of an installation space.

A sub-control valve (22) is provided which detects a temperature of a liquid coolant in a main circulation path and separates part of the liquid coolant which is to be sent to a main radiator (16) to send it into a sub-circulation path in case the detected temperature of the liquid coolant exceeds an upper limit value of the temperature of the liquid coolant when an engine runs in a steady state, and the liquid coolant which is sent into the sub-circulation path (12) by the sub-control valve (22) is cooled in a sub-radiator (28) and is then caused to flow into a cooler device, while the liquid coolant in the sub-circulation path (12) is separated to be returned to an upstream side of a first pump (18) in the main circulation path (8).



Description

TECHNICAL FIELD

[0001] The present invention relates to a system and method for cooling an engine having an EGR system and the like.

BACKGROUND ART

[0002] Conventionally, an EGR system (an exhaust gas recirculation mechanism) for re-circulating exhaust gases to an engine is widely adopted as a countermeasure against air pollution by exhaust gases on vehicles which install a diesel engine.

[0003] In the diesel engine, when exhaust gases at high temperatures are recirculated directly to an intake manifold of the engine to be mixed with the charge therein, soot is produced, and the fuel consumption is increased. As a solution to these problems, it is general practice that an EGR cooler (a heat exchanger) is provided so that exhaust gases are recirculated to an engine after having been cooled by a liquid coolant therein. In most cases, the coolant used in the EGR cooler is a liquid coolant which also cools the engine.

[0004] In a main coolant circulation path which cools the engine, although the coolant whose heat is dissipated in the radiator by running air is returned to the engine, part of the coolant is divided to flow into the EGR cooler before the coolant is recirculated to the engine to cool it. This divided coolant cools the EGR gas (the exhaust gases) in the EGR cooler, thereafter and merges into a liquid coolant which flows from the radiator into the engine. Further, part of the coolant is caused to flow into the EGR cooler, while the remaining coolant cools the engine and then forms a flow path which circulates the coolant to the radiator.

[0005] Although it depends on the operating conditions of the vehicle, in general, while the engine operates, the temperature of the coolant after it has been cooled in the radiator exceeds somehow 80°C. Because of this, the exhaust gases which are cooled by the coolant in the EGR cooler is never cooled down to a temperature which is equal to or lower than the temperature of the coolant.

[0006] In these days, for the purpose of dealing with the regulation on exhaust gases which is getting stricter, as one of means for clearing the regulation, the capacity of an EGR cooler used has been attempted to be increased, and the combustion temperature of an engine installed has been attempted to be reduced. Of these attempts, the attempt to increase the capacity of the EGR cooler has been dealt with by enlarging the size of the EGR cooler or by increasing the number of EGR coolers used. Additionally, in order to deal with the other attempt to reduce the combustion temperature of the engine, the temperature of exhaust gases (an EGR gas) that are recirculated to the engine needs to be reduced.

[0007] For example, Patent Document 1 describes a

cooling system for EGR gas shown in Fig. 6 as one of conventional techniques. In this technique, the dependence of the EGR gas temperature on the engine coolant temperature is reduced by providing a water pump 53 which is disposed in a liquid coolant passageway 52 in an engine 51, an EGR cooler 57 which is disposed in a branched circulation passageway 56 which branches off a downstream-side coolant path and an EGR radiator 59 which is disposed downstream of the EGR cooler 57.

[0008] Patent Document 2 describes an EGR apparatus in which an EGR radiator which is independent of an engine cooling apparatus and the EGR radiator is thermally connected with an EGR cooler to increase the cooling capability of the EGR cooler.

[0009] Additionally, Patent Document 3 discloses a cooling system for a supercharged internal combustion engine which has a first high-temperature cooling loop into which an internal combustion engine and a heat exchanger or the like are incorporated and a second low-temperature cooling loop into which a cooling unit (an inter-cooler) and a low-temperature heat exchanger or the like are incorporated as a means for reducing the warming-up time of an internal combustion engine of a motor vehicle such as a truck.

PRIOR ART DOCUMENT

PATENT DOCUMENT

[0010]

Patent Document 1: JP-A-2006-132469

Patent Document 2: JP-A-2003-278608

Patent Document 3: US Unexamined Patent Publication No. 2008/0066697

SUMMARY OF THE INVENTION

PROBLEMS THAT THE INVENTION IS TO SOLVE

[0011] The temperature of an engine liquid coolant tends to be increased to a high temperature while an engine is operated at a low speed and under a high load as when a vehicle is climbing hills. This is because the cooling efficiency of a radiator drops as a result of a reduction in speed of running air which is delivered to the radiator when the vehicle speed is reduced. This is also because the load under which the engine is operated is increased as the vehicle climbs hills, whereby the value of heat generated by the engine is increased.

[0012] To deal with this, conventionally, the heat dissipating performance of a radiator is set based on the aforesaid maximum load. However, in reality, only part of the capability of the radiator is used in light to medium load driving conditions which occupy most of the operation of the vehicle.

[0013] In case the radiator is designed to match a high load driving condition of the vehicle, there is caused a

problem that a radiator of a large size has to be made. This is also true with the conventional techniques according to Patent Documents 1 to 3 above. It is possible to reduce the size of the radiator only if the radiator is allowed to deal with the light to medium load driving conditions.

[0014] The invention has been made with a view to solving the problem, and an object thereof is to provide a system and method for cooling an engine which realize a reduction in the capacity of a main radiator by giving a sub-radiator a function to assist the main radiator, a reduction in cost and an effective use of an installation space.

MEANS FOR SOLVING THE PROBLEMS

[0015] With a view to solving the technical problem described above, according to the invention, there is provided an engine cooling apparatus including: a main radiator configured to cool a liquid coolant which flows through an interior of an engine; a main circulation path for a liquid coolant which circulates through the engine and the main radiator; a first pump provided upstream of the engine along the main circulation path, the first pump configured to drive the liquid coolant to flow; a sub-radiator which is independent of the main circulation path, the sub-radiator configured to cool a liquid coolant used in a cooler device for cooling an onboard heater element; a sub-circulation path for the liquid coolant which circulates through the cooler device and the sub-radiator; a second pump provided in a halfway position along the sub-circulation path, the second pump configured to drive the liquid coolant in the sub-circulation path to flow; and a sub-control valve configured to detect a temperature of the liquid coolant in the main circulation path and configured to separate part of the liquid coolant which is sent to the main circulation path to be sent to the sub-circulation path in case the detected temperature exceeds an upper limit value of the temperature of the liquid coolant when the engine runs in a steady state, wherein: the liquid coolant which is sent to the sub-circulation path by the sub-control valve is cooled by the sub-radiator to thereafter be caused to flow into the cooler device; and part of the liquid coolant in the sub-circulation path is separated to be returned to an upstream side of the first pump in the main circulation path.

[0016] The engine cooling apparatus according to the invention further includes a main control valve configured to detect a temperature of the liquid coolant in the main circulation path, configured to return the liquid coolant, which has passed through the engine, to the engine to warm up the engine in case the detected temperature is less than a lower limit value of the temperature of the liquid coolant when the engine runs in the steady state, and configured to send part or all of the liquid coolant which has passed through the engine towards the main radiator in the main circulation path in case the detected temperature is equal to or more than the lower limit value.

[0017] In the engine cooling apparatus according to the invention, the lower limit value of the temperature of the liquid coolant when the engine runs in the steady state is set to 80°C and the upper limit value thereof is set to 100°C.

[0018] In the engine cooling apparatus according to the invention the lower limit value of the temperature of the liquid coolant when the engine runs in the steady state is set to any value in the range of 70°C to 90°C and the upper limit value thereof is set to any value in the range of 90°C to 120°C.

[0019] In this case, the lower value can be set to, for example, 70°C or 85°C within the aforesaid range, and the upper limit can also be set to, for example, 95°C or 120°C.

[0020] Additionally, the engine cooling apparatus according to the invention further includes a bypass circulation path configured to send the liquid coolant which is separated by the sub-control valve to an upstream side or a downstream side of the second pump.

[0021] In addition, the engine cooling apparatus according to the invention further includes an EGR cooler provided in a branched circulation path which branches off the main circulation path to allow the separated liquid coolant to flow therethrough.

[0022] Additionally, the engine cooling apparatus according to the invention further includes an EGR cooler provided in a halfway position along the sub-circulation path.

[0023] According to the invention, there is provided an engine cooling method by using the engine cooling apparatus according to any one of the above, including: sending part of the liquid coolant in the main circulation path to the sub-circulation path; cooling the cooled liquid coolant by the sub-radiator; and returning the cooled liquid coolant to the main circulation path in a position lying at an upstream side of the engine.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0024] According to the engine cooling apparatus of the invention, since the configuration is adopted in which the liquid coolant which is sent to the sub-circulation path by the sub-control valve is cooled in the sub-radiator and is caused to flow into the cooler device and the liquid coolant in the sub-circulation path is divided so that the divided portion of the liquid coolant is returned to the main circulation path in the position lying at the upstream side of the first pump, it is possible to set the capacity of the main radiator so as to match the light to medium load driving conditions, whereby the size of the main radiator can be made smaller than that of the conventional one. This advantageously helps to avoid the enlargement of the main radiator and also contributes to a reduction in cost and an effective utilization of the installation space of the radiator.

[0025] According to the engine cooling method of the invention, since the configuration is adopted in which by

using the engine cooling apparatus, part of the liquid coolant in the main circulation path is sent to the sub-circulation path so that the liquid coolant which is so sent is cooled by the sub-radiator, and the liquid coolant which is so cooled is then returned to the main circulation path in the position lying at the upstream side of the engine, it is possible to set the capacity of the main radiator so as to match the light to medium load driving conditions, and this advantageously avoids the enlargement of the main radiator and also contributes to a reduction in cost and an effective utilization of the installation space of the radiator.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026]

Fig. 1 is a block diagram showing the configuration of an engine cooling apparatus according to a first embodiment.

Fig. 2 is a block diagram showing a flowing mode of a liquid coolant in a sub-circulation path (and part of a main circulation path) according to the embodiment.

Fig. 3 is a block diagram showing the configuration of an engine cooling apparatus according to another embodiment.

Fig. 4 is a block diagram showing the configuration of an engine cooling apparatus according to a second embodiment.

Fig. 5 is a block diagram showing the configuration of an engine cooling apparatus according to a third embodiment.

Fig. 6 is a diagram showing a cooling system for EGR gas according to a conventional example.

MODES FOR CARRYING OUT THE INVENTION

[0027] Hereinafter, embodiments of the invention will be described based on the drawings.

[0028] In the embodiments, an engine cooling apparatus 2 and an engine cooling method are applied to a vehicle such as a truck which installs an engine 4 (here, a diesel engine) configured to deal with the regulations on exhaust gases with an EGR mechanism of a large capacity or the like.

Fig. 1 is a block diagram showing the configuration of an engine cooling apparatus 2 according to a first embodiment.

[0029] This engine cooling apparatus 2 has two circulation paths of a main circulation path 8 for a liquid coolant which cools an engine 4 and a first EGR cooler 6 by using a main radiator 16 and a sub-circulation path 12 for a low-temperature liquid coolant which cools a second EGR cooler 10 by using a sub-radiator 28.

[0030] Additionally, a branch portion 14 is provided in the sub-circulation path 12, so that a liquid coolant which flows through the sub-circulation path 12 is caused to

flow from this branch portion 14 into the main circulation path 8 when a predetermined condition is met, flows through an interior of the engine 4 and is returned to the sub-circulation path 12 from the main circulation path 8.

[0031] The engine 4, the main radiator 16, a first pump 18, a main control valve 20, a sub-control valve 22 and the first EGR cooler 6 are provided in the main circulation path 8. In addition, the sub-radiator 28, the second EGR cooler 10 and a second pump 30 are provided in the sub-circulation path 12. An inter-cooler 38 is also provided in the cooling system 2.

[0032] Formed in the main circulation path 8 are a circulation path in which the liquid coolant from the main radiator 16 is caused to flow into the engine 4 by way of the first pump 18 and is returned to the main radiator 16 and a branched circulation path 9 in which part of the liquid coolant from the interior of the engine 4 is separated to flow into the first EGR cooler 6 and is returned to the interior of the engine 4. As this branched circulation path 9, it is possible to provide a circulation path in which the liquid coolant is separated from the main circulation path 8 other than the engine 4 to flow into the first EGR cooler 6 and is returned to the main circulation path.

[0033] A first bypass circulation path 27 which allows the liquid coolant to flow from the main control valve 20 to the first pump 18 is provided in the main circulation path 8. Further, a second bypass circulation path 31 which allows the liquid coolant to flow from the sub-control valve 22 to the second pump 30 is also provided in the main circulation path 8.

[0034] A circulation path is formed in the sub-circulation path 12 in which the liquid coolant from the sub-radiator 28 is caused to flow into the second EGR cooler 10 and is returned to the sub-radiator 28 by way of the second pump 30.

[0035] Since the exhaust gases (the EGR gas) which have been cooled in the first EGR cooler 6 are cooled further to a lower temperature in the second EGR cooler 10, a liquid coolant is required whose temperature is lower than that of the liquid coolant which is cooled in the main radiator 16.

[0036] The main radiator 16 cools mainly the liquid coolant for the engine 4, and the sub-radiator 28 cools mainly the liquid coolant which is used for the cooler devices such as the second EGR cooler 10 and the inter-cooler 38.

[0037] Additionally, the first EGR cooler 6 and the second EGR cooler 10 are both configured to cool the exhaust gases (the EGR gas). The inter-cooler 38 is configured to cool pressurized induction air or air-fuel mixture for supercharging.

[0038] The first pump 18 and the second pump 30 which are provided individually in the main and sub-circulation paths are both a water pump which drives the liquid coolant to flow. A mechanical pump which uses the driving force of the engine 4 or an electric pump is used as the first pump 18 and the second pump 30. As this occurs, it is possible that a mechanical pump is used as

the first pump 18, while a mechanical pump which is the same as that used as the first pump 18 is used as the second pump 30 or that an electric pump can be used only for the second pump 30. The electric pump is electrically controlled and is easily controlled from an ECU or the like.

[0039] In both of the first pump 18 and the second pump 30, there are provided one liquid coolant entrance (however, the liquid coolants from the two circulation paths are merged at the entrance of the first pump 18) and one liquid coolant exit.

[0040] The first pump 18 is provided along the main circulation path 8 in a position lying between the main radiator 16 and the engine 4 (at an upstream side of the engine 4) and drives the liquid coolant outputted from the main radiator 16 towards the engine 4 so as to cause the liquid coolant within the main circulation path 8 to circulate therethrough. Additionally, the second pump 30 is provided along the sub-circulation path 12 in a position lying between the second EGR cooler 10 and the sub-radiator 28 (at a downstream side of the second EGR cooler 10) and drives the liquid coolant in the sub-circulation path 12 towards an input side of the sub-radiator 28 so as to cause the liquid coolant within the sub-circulation path 12 to circulate therethrough.

[0041] The main control valve 20 and the sub-control valve 22 are both a three-way valve (one entrance and two exits) and are both a so-called thermostat which detects the temperature of the liquid coolant to open or close a flow path of the liquid coolant (to separate the liquid coolant).

[0042] This main control valve 20 opens or closes the valve based on a temperature of the liquid coolant, for example, 85°C (a lower limit value of the temperature of the liquid coolant when the engine runs in a steady state). In addition, the sub-control valve 22 opens or closes the valve based on a temperature of the liquid coolant, for example, 95°C (an upper limit value of the temperature of the liquid coolant when the engine runs in the steady state) which is higher than the temperature of the liquid coolant based on which the main control valve 20 opens or closes the valve. The main control valve 20 can fully open or close the valve, but the sub-control valve 22 does not always fully close the valve (the flow of the liquid coolant to the main circulation path 8 is ensured).

[0043] The main control valve 20 is provided along the main circulation path 8 in a position where the liquid coolant has just passed through the engine 4 to emerge therefrom (at a downstream side of the engine 4). This main control valve 20 detects a temperature of the liquid coolant near the main circulation path 8 and opens or closes the valve so as to control the liquid coolant that has passed through the interior of the engine 4 to flow towards the main radiator 16 or towards the first bypass circulation path 27 (to flow back to the interior of the engine 4).

[0044] In addition, the sub-control valve 22 is provided along the main circulation path 8 in a position lying between the main control valve 20 and the main radiator

16 and detects a temperature of the liquid coolant near the main circulation path 8 to open or close the valve. This sub-control valve 22 controls the liquid coolant that has passed through the main control valve 20 to flow towards the main radiator 16 or the second bypass circulation path 31 (to flow into the sub-circulation path 12).

[0045] Further, a merging portion 34 is provided near the entrance (an upstream side) of the first pump 18 along the main circulation path 8. The liquid coolant that flows from the first EGR cooler 6 merges into the merging portion 34.

[0046] In addition, a branch portion 14 is provided along the sub-circulation path 12 in a position lying between the second EGR cooler 10 and the second pump 30, and a sub-bypass circulation path 36 which branches off the branch portion 14 merges into the merging portion 34. This sub-bypass circulation path 36 establishes a communication between the sub-circulation path 12 and the main circulation path 8 so that the liquid coolant in the sub-circulation path 12 is returned to the main circulation path 8.

[0047] Consequently, in the merging portion 34, the liquid coolants from the three circulation paths of the circulation path from the main radiator 16, the circulation path from the first EGR cooler 6 and the sub-bypass circulation path 36 are merged together, and the resulting merged liquid coolant flows into the first pump 18.

[0048] Additionally, a check valve 37 (which permits a flow in one direction only) is provided between the branch portion 14 of the sub-circulation path 12 and a location where the second bypass circulation path 31 merges with the sub-circulation path 12. This is because a reverse flow of the sub-circulation path 12 is prevented from resulting by the competition between the second pump 30 and the first pump 18.

[0049] Here, flow modes of the liquid coolants which flow through the main circulation path 8 and the sub-circulation path 12 will be described according to temperatures of the liquid coolant which flows through the main circulation path 8 which vary based on operating conditions of the engine 4.

[0050] The temperature of the liquid coolant in the main circulation path (near the main control valve 20, the sub-control valve 22) when the engine runs in the steady state (operates normally) is set to be in the range of 85°C (a lower limit value) to 95°C (an upper limit value) in this engine 4.

[0051] In addition to the setting above, the temperature of the liquid coolant when the engine runs in the steady state may be set so that the lower limit value is 80°C and the upper limit value is 100°C. Additionally, the temperature of the liquid coolant when the engine runs in the steady state may be set so that the lower limit value is any temperature in the range of 70°C to 90°C and the upper limit value is any temperature in the range of 90°C to 120°C.

[0052] The lower limit value of the temperature when the engine runs in the steady state varies according to

an engine friction which varies based on the characteristics and temperature of engine oil. The viscosity of engine oil is increased when the engine oil is not warmed up, which generates a friction loss, deteriorating the fuel economy. Additionally, the upper limit value varies whether or not the liquid coolant boils and the durability of engine parts. For example, liquid coolant boils at temperatures less than 90°C at altitude. The boiling point of liquid coolant becomes high when it is pressurized, and a restriction is imposed on the upper limit value by the thermal resistance and heat load durability of parts used as engine parts. In view of these situations, the lower limit value and upper limit value are set to be in different ranges or to vary within a certain width.

[0053] Firstly, a flow mode when the engine 4 is warmed up will be described.

[0054] In this case, the temperature of the liquid coolant in the main circulation path 8 is in a range which is less than the lower limit value (85°C) when the engine runs in the steady state.

[0055] As this occurs, the main control valve 20 detects the temperature of the liquid coolant and is closed, whereby all the liquid coolant is separated by the main control valve 20 to flow into the first bypass circulation path 27. Then, the liquid coolant circulates in the interior of the engine 4 again by way of the first pump 18.

[0056] Namely, the liquid coolant in the main circulation path 8 is driven by the first pump 18 to flow from the interior of the engine 4 through the first bypass circulation path 27 and is then returned to the first pump 18 to be sent back to the engine 4, resulting in a warming-up state in which the liquid coolant circulates in the interior of the engine 4 to warm up the engine 4.

[0057] Part of the liquid coolant which flows through the main circulation path 8 is used to cool the first EGR cooler 6, and the liquid coolant which has passed through the first EGR cooler 6 is returned to the main circulation path 8. Here, the liquid coolant for the first EGR cooler 6 is let out of the interior of the engine 4 to flow through the first EGR cooler 6 and is thereafter sent to the merging portion 34 so as to merge with the liquid coolant from the main radiator 16 for return to the engine 4.

[0058] The flow mode of the liquid coolant associated with the first EGR cooler 6 is constant and does not vary even though the operating conditions of the engine 4 vary.

[0059] On the other hand, the sub-circulation path 12 forms an independent liquid coolant circulation path which is different from the main circulation path 8 for cooling the engine 4. The liquid coolant in this sub-circulation path 12 is driven by the second pump 30 to flow through the sub-radiator 28 and then passes through the second EGR cooler 10 to be returned to the second pump 30.

[0060] In this case, the second pump 30 is an electric pump, and when the cooling by the second EGR cooler 10 is not necessary, the second pump 30 may not be driven.

[0061] Next, a flow mode when the engine runs in the

steady state will be described.

[0062] In this case, the temperature of the liquid coolant in the main circulation path 8 is in the range of the lower limit value to the upper limit value when the engine runs in the steady state (85°C to 95°C).

[0063] Firstly, the main circulation path 8 will be described. The main control valve 20 of the main circulation path 8 detects the temperature of the liquid coolant and to open the valve thereof, and the liquid coolant flows towards the main radiator 16 in the main circulation path 8.

[0064] On the other hand, the sub-control valve 22 also opens the valve thereof, and the liquid coolant passes through the sub-control valve 22 and flows towards the main radiator 16 in the main circulation path 8, while the valve is closed to the sub-circulation path 12, whereby the liquid coolant does not flow into the second bypass circulation path 31.

[0065] In addition, the main control valve 20 repeatedly opens or closes the valve (a medium open state) in the temperature band of the liquid coolant when the engine runs in the steady state, whereby the temperature of the liquid coolant is maintained constant while the liquid coolant flows towards the main radiator 16 or towards the first bypass circulation path 27.

[0066] As the flow mode of the liquid coolant when the engine 4 runs in the steady state, the liquid coolant which is driven by the first pump 18 flows through the interior of the engine 4 and then flows from the main control valve 20 (which is opened to the main circulation path) into the sub-control valve 22 by way of the main circulation path 8. Then, the liquid coolant is sent from the sub-control valve 22 (which is opened to the main circulation path but is fully closed to the sub-circulation path) to the main radiator 16 and is returned to the first main pump 18 for circulation in the main circulation path 8.

[0067] Next, the sub-circulation path 12 will be described. A circulation path of the liquid coolant, which is associated with the sub-circulation path 12 and is independent of the main circulation path 8 for cooling the engine 4, is formed by the second pump 30.

[0068] In case no liquid coolant flows into or out of the sub-circulation path 12, a certain amount of liquid coolant is held in the sub-circulation path 12 as an independent circulation path. Even though a vacuum is produced in the branch portion 14 from the sub-circulation path 12 to the main circulation path 8 to reduce the pressure in the circulation path, there is caused no such situation that the liquid coolant flows out of the sub-circulation path 12 into the main circulation path 8.

[0069] As a flow mode of the liquid coolant in the sub-circulation path 12 when the engine 4 runs in the steady state, the liquid coolant is driven by the second pump 30 to flow through the sub-radiator 28, passes through the second EGR cooler 10 and is returned to the second pump 30 for circulation in the sub-circulation path 12. The sub-circulation path 12 is a circulation path in which the liquid coolant whose temperature is lower than that

flowing in the main circulation path 8. Additionally, the flow rate of the liquid coolant in the sub-circulation path 12 is 30L/min.

[0070] Next, a flow mode of the liquid coolant when the engine is in a high load operating condition will be described.

[0071] In this case, the temperature of the main circulation path 8 exceeds the upper limit value (95°C) of the temperature of the liquid coolant when the engine runs in the steady state. The engine is about to overheat at this temperature.

[0072] When the temperature of the liquid coolant exceeds the upper limit value, the main control valve 20 of the main circulation path 8 detects the temperature of the liquid coolant to keep the valve opened, whereas the sub-control valve 22 of the main circulation path 8 detects the temperature of the liquid coolant and is started to be closed from the opened state. Then, the liquid coolant in the main circulation path 8 is separated by the sub-control valve 22 so as to flow into the second bypass circulation path 31, from which the liquid coolant flows into the sub-circulation path 12.

[0073] However, the sub-control valve 22 is closed to such an extent that the flow path to the main circulation path 8 is slightly closed (and is not closed to the full extent), and part of the liquid coolant is separated to flow into the sub-circulation path 12, the remaining liquid coolant flowing through the main circulation path 8. As this occurs, a construction can be adopted in which the flow rate of the liquid coolant towards the sub-circulation path 12 is increased by increasing the resistance to the flow of the liquid coolant into the main circulation path 8.

[0074] As this occurs, although depending on the degree at which the sub-control valve 22 is opened, part of the liquid coolant in the main circulation path 8 is separated (for example, 50L/min) to flow through (merge into) the sub-circulation path 12 by way of the second pump 30. The amount of liquid coolant in the sub-circulation path 12 then becomes a total of its original amount (30L/min) and the amount of liquid coolant which additionally flows from the main circulation path into the sub-circulation path 12 (50L/min).

[0075] Then, the liquid coolant (30+50L/min) in the sub-circulation path 12 is cooled in the sub-radiator 28, flows through the second EGR cooler 10 and arrives at the second pump 30. In the liquid coolant which flows through the sub-circulation path 12, the amount of liquid coolant which is separated from the main circulation path 8 (50L/min) is returned to the main circulation path 8 from the branch portion 14.

[0076] The flow mode of the liquid coolant in the main circulation path 8 is the same as that when the engine runs in the steady state except for the diverging of liquid coolant by the sub-control valve 22. Thus, the liquid coolant which is driven by the first pump 18 flows through the interior of the engine 4, flows from the main control valve 20 (which is opened) towards the sub-control valve 22, and is sent from the sub-control valve 22 (which is

opened) to the main radiator 16 to then be returned to the first pump 18.

[0077] Fig. 2 shows a flow mode of liquid coolant in the sub-circulation path 12 (and part of the main circulation path 8).

[0078] Part of the liquid coolant in the main circulation path 8 is separated from the sub-control valve 22 (50L/min) and flows into the entrance of the second pump 30 by way of the second bypass circulation path 31. In addition to this there is a circulation path in which the liquid coolant flows into the sub-circulation path 12 at a downstream of the second pump by way of a third bypass circulation path 32, which will be described later.

[0079] The liquid coolant (30L/min) in the sub-circulation path 12 which passes through the branch portion 14 flows into the entrance of the second pump 30.

[0080] In addition, the liquid coolant merges into the entrance of the second pump 30 (30+50L/min), and the resulting liquid coolant flows out of the exit of the second pump 30 to flow along the sub-circulation path 12, flowing through the sub-radiator 28.

[0081] In the liquid coolant which passes through the second EGR cooler 10 by way of the sub-radiator 28, the liquid coolant (50L/min) which is separated at the branch portion 14 of the sub-circulation path 12 flows by way of the sub-bypass circulation path 36 and the merging portion 34, is further driven by the first pump 18 to flow through the interior of the engine 4 and pass through the main circulation path 8, and then arrives at the sub-control valve 22 by way of the main control valve 20.

[0082] In addition, the liquid coolant which is not separated from the branch portion 14 of the sub-circulation path 12 (30L/min) continues to flow along the sub-circulation path 12 to flow into the second pump 30.

[0083] Thus, the sub-circulation path 12 is subordinated to the main circulation path 8, and the liquid coolant which is cooled by the sub-radiator 28 of the sub-circulation path 12 contributes to the cooling of the engine 4 by the main circulation path 8. In this way, when the engine 4 is in the high load operating condition, the flows of liquid coolant are controlled to be switched, and the sub-radiator 28 which cools the liquid coolant to the lower temperature is used to compensate for the reduction in the capacity of the main radiator 16 to dissipate the heat of the liquid coolant.

[0084] Fig. 3 is a block diagram showing the configuration of an engine cooling apparatus 40 according to another embodiment.

[0085] Here, like reference numerals will be given to like constituent elements of the engine cooling apparatus 40 to those of the engine cooling apparatus 2 described above, and a detailed description thereof will be omitted.

[0086] This cooling system 40 is such that a third bypass circulation path 32 is provided in place of the second bypass circulation path 31 of the engine cooling apparatus 2 described above and a liquid coolant in a main circulation path 8 that is separated by a sub-control valve 22 is merged into a sub-circulation path 12.

[0087] The third bypass circulation path 32 establishes a communication between the sub-control valve 22 and a portion of the sub-circulation path 12 which lies at a downstream side of a second pump 30 (between the second pump 30 and a sub-radiator 28). The third bypass circulation path 32 bypasses the second pump 30. By bypassing the second pump 30, it is possible to eliminate the influence of a hydraulic pressure of a first pump 18 (whose output is larger than that of the second pump 30) on the second pump 30.

[0088] When part of the liquid coolant is caused to flow from the main circulation path 8 into the sub-circulation path 12 by way of the third bypass circulation path 32 by the sub-control valve 22, a second pump 30 may not be driven.

[0089] In such a state that the second pump 30 is not driven, it is possible for the liquid coolant to flow there-through. As this occurs, it is anticipated that the liquid coolant which flows from the sub-control valve 22 into the sub-circulation path 12 by way of the third bypass circulation path 32 flows reversely in the sub-circulation path 12 and passes through the second pump 30 to flow into the first pump 18 whose pressure is lower.

[0090] To deal with this, a check valve 37 is provided between a branch portion 14 of the sub-circulation path 12 and the second pump 30 to prevent the reverse flow of the liquid coolant in the sub-circulation path 12.

[0091] According to the third bypass circulation path 32 described above, the sub-circulation path 12 is subordinated to the main circulation path 8, and the output of the first pump 18 of the main circulation path 8 is higher than the output of the second pump 30. Therefore, both the liquid coolants in the main circulation path 8 and the sub-circulation path 12 can be circulated therein by the first pump 18. In addition to driving the liquid coolant in the main circulation path 8, the first pump 18 drives the liquid coolant in a circulation path which extends from the main circulation path 8, reaches the sub-circulation path 12 by way of the third bypass circulation path 32 and returns from the sub-circulation path to the main circulation path 8 to flow through the circulation path. Because of this, the driving of the liquid coolant by the second pump 30 becomes unnecessary.

[0092] In this cooling system 40, except for the configurations of the third bypass circulation path 32 and the circulation path associated therewith, other configurations and circulations thereof are similar to those of the engine cooling apparatus 2 described above.

[0093] In this cooling system 40, when the temperature of the liquid coolant in the main circulation path 8 exceeds an upper limit value (95°C) of the temperature of the liquid coolant when the engine runs in a steady state, the sub-control valve 22 of the main circulation path 8 detects the temperature of the liquid coolant and is started to be closed from the opened state to a state in which the valve is slightly closed. Then, the liquid coolant is separated by the sub-control valve 22 so as to flow into the third bypass circulation path 32 and then flows into the sub-

circulation path 12 by way of the third bypass circulation path 32.

[0094] Thus, the sub-circulation path 12 is subordinated to the main circulation path 8, and as has been described above, the liquid coolant which is cooled by the sub-radiator 28 of the sub-circulation path 12 contributes to the cooling of the engine 4 by the main circulation path 8.

[0095] Consequently, according to the embodiment, the cooling capability of the sub-radiator which is provided to cool the liquid coolant to a lower temperature for an improved fuel economy is used as a radiator which temporarily (in the high load operating condition) assists a main radiator, whereby the main radiator can be set so as to match its size with a size suitable for light to medium driving conditions of the vehicle. Consequently, it is possible to configure the main radiator which is smaller in size than the conventional one, this avoiding the enlargement in size of the main radiator. Thus, the embodiment advantageously contributes to realizing a reduction in cost and an effective use of the installation space of the main radiator.

[0096] Next, an engine cooling apparatus 42 according to a second embodiment will be described.

[0097] Fig. 4 is a block diagram showing the configuration of this engine cooling apparatus 42.

[0098] Here, like reference numerals will be given to like constituent elements of the engine cooling apparatus 42 to those of the engine cooling apparatus 2 according to the first embodiment, and a detailed description thereof will be omitted here.

[0099] This cooling system 42 has a main circulation path 8 in which a liquid coolant circulates through a main radiator 16 and an engine 4 and a sub-circulation path 12 in which a liquid coolant of a lower temperature circulates through a sub-radiator 28 and between a second EGR cooler 10 and an inter-cooler 38.

[0100] In this way, the inter-cooler 38 is provided in the sub-circulation path 12.

[0101] The engine 4, the main radiator 16, a first pump 18, a main control valve 20, a sub-control valve 22 and a first EGR cooler 6 are provided in the main circulation path 8. Additionally, a first bypass circulation path 27 and a second bypass circulation path 31 are provided in the main circulation path 8.

[0102] The sub-radiator 28, the second EGR cooler 10, a second pump 30 and the inter-cooler 38 are provided in the sub-circulation path 12.

[0103] The inter-cooler 38 is provided along a portion of the sub-circulation path 12 which branches off a portion of the sub-circulation path 12 which extends from the second pump 30 to reach the sub-radiator 28 in such a way as to allow the liquid coolant which is separated after the second pump 30 to flow thereinto, and the liquid coolant which flows out of the inter-cooler 38 merges into a portion of the sub-circulation path 12 which lies downstream of the second EGR cooler 10.

[0104] In this cooling system 42, except for the config-

urations of the inter-cooler 38 and the circulation path associated therewith, other configurations and circulations thereof are similar to those of the engine cooling apparatus 2 according to the first embodiment.

[0105] The inter-cooler 38 is described as exemplifying the portion of the sub-circulation path 12 which circulates between the sub-radiator 28 and itself. Consequently, in this cooling system 42, the inter-cooler 38 and the second EGR cooler 10 are provided as the cooler devices which form the circulation path together with the sub-radiator 28.

[0106] In this cooling system 42, too, the flow mode of the liquid coolant which flows through the main circulation path 8 and the sub-circulation path 12 according to the operating conditions of the engine 4 (except for the flow of the liquid coolant associated with the inter-cooler 38) is similar to that of the cooling system 2.

[0107] In addition, a branch portion 14 is provided in the sub-circulation path 12, whereby the liquid coolant which flows through the sub-circulation path 12 is caused to flow from the branch portion 14 into the main circulation path 8 under a predetermined condition to flow through an interior of the engine 4 and is then returned from the main circulation path 8 into the sub-circulation path 12. Thus, the sub-circulation path 12 is subordinated to the main circulation path 8, and the liquid coolant which is cooled by the sub-radiator 28 in the sub-circulation path 12 contributes to the cooling of the engine 4 by the main circulation path 8.

[0108] Consequently, according to the second embodiment, as with the first embodiment, the main radiator can be set so as to match its size with a size suitable for light to medium driving conditions of the vehicle to thereby avoid the enlargement in size of the main radiator. Additionally, the embodiment advantageously contributes to realizing a reduction in cost and an effective use of the installation space of the main radiator.

[0109] Next, an engine cooling apparatus 44 according to a third embodiment will be described.

[0110] Fig. 5 is a block diagram showing the configuration of the engine cooling apparatus 44.

[0111] Here, like reference numerals will be given to like constituent elements of the engine cooling apparatus 44 to those of the engine cooling apparatus 2 according to the first embodiment, and a detailed description thereof will be omitted here.

[0112] This engine cooling apparatus 44 has two circulation paths of a main circulation path 8 of a liquid coolant which cools an engine 4 and a sub-circulation path 12 which cools a second EGR cooler 10 and a first EGR cooler 6 using a liquid coolant of a lower temperature.

[0113] The engine 4, a main radiator 16, a first pump 18, a main control valve 20 and a sub-control valve 22 are provided in the main circulation path 8. Additionally, a first bypass circulation path 27 and a second bypass circulation path 31 are provided in the main circulation path 8.

[0114] A sub-radiator 28, the second EGR cooler 10,

the first EGR cooler 6 and a second pump 30 are provided in the sub-circulation path 12.

[0115] This sub-circulation path 12 forms a circulation path in which the liquid coolant from the sub-radiator 28 is caused to flow through the second EGR cooler 10 and is further caused to flow through the first EGR cooler 6, being returned to the sub-radiator 28.

[0116] In this cooling system 44, except for the configuration of the circulation path associated with the second EGR cooler 10, other configurations and circulations thereof are similar to those of the engine cooling apparatus 2 according to the first embodiment.

[0117] In this cooling system 44, too, the flow mode of the liquid coolant which flows through the main circulation path 8 and the sub-circulation path 12 according to the operating conditions of the engine 4 (except for the flow of the liquid coolant associated with the second EGR cooler 10) is similar to that of the cooling system 2.

[0118] In addition, a branch portion 14 is provided in the sub-circulation path 12, whereby the liquid coolant which flows through the sub-circulation path 12 is caused to flow from the branch portion 14 into the main circulation path 8 under a predetermined condition to flow through an interior of the engine 4 and is then returned from the main circulation path 8 into the sub-circulation path 12. Thus, the sub-circulation path 12 is subordinated to the main circulation path 8, and the liquid coolant which is cooled by the sub-radiator 28 in the sub-circulation path 12 contributes to the cooling of the engine 4 by the main circulation path 8.

[0119] Consequently, according to the third embodiment, as with the first embodiment, the main radiator can be set so as to match its size with a size suitable for light to medium driving conditions of the vehicle to thereby avoid the enlargement in size of the main radiator. Additionally, the embodiment advantageously contributes to realizing a reduction in cost and an effective use of the installation space of the main radiator.

[0120] While the invention has been described in detail and by reference to the specific embodiments, it is obvious to those skilled in the art to which the invention pertains that various alterations and modifications can be made thereto without departing from the spirit and scope of the invention.

[0121] This patent application is based on Japanese Patent Application No. 2011-258712 filed on November 28, 2011, the contents of which are incorporated herein by reference.

DESCRIPTION OF REFERENCE NUMERALS

[0122] 4: engine; 6 EGR cooler/(first EGR cooler); 8: main circulation path; 9: branched circulation path; 10: cooler device (second EGR cooler); 12: sub-circulation path; 14: branch portion; 16: main radiator; 18: first pump; 20: main control valve; 22: sub-control valve; 28: sub-radiator; 30: second pump; 31: bypass circulation path (second bypass circulation path); 32: bypass circulation

path (third bypass circulation path); 38: cooler device (inter-cooler).

Claims

1. An engine cooling apparatus comprising:

a main radiator configured to cool a liquid coolant which flows through an interior of an engine; a main circulation path for a liquid coolant which circulates through the engine and the main radiator; a first pump provided upstream of the engine along the main circulation path, the first pump configured to drive the liquid coolant to flow; a sub-radiator which is independent of the main circulation path, the sub-radiator configured to cool a liquid coolant used in a cooler device for cooling an onboard heater element; a sub-circulation path for the liquid coolant which circulates through the cooler device and the sub-radiator; a second pump provided in a halfway position along the sub-circulation path, the second pump configured to drive the liquid coolant in the sub-circulation path to flow; and a sub-control valve configured to detect a temperature of the liquid coolant in the main circulation path and configured to separate part of the liquid coolant which is sent to the main circulation path to be sent to the sub-circulation path in case the detected temperature exceeds an upper limit value of the temperature of the liquid coolant when the engine runs in a steady state, wherein:

the liquid coolant which is sent to the sub-circulation path by the sub-control valve is cooled by the sub-radiator to thereafter be caused to flow into the cooler device; and part of the liquid coolant in the sub-circulation path is separated to be returned to an upstream side of the first pump in the main circulation path.

2. The engine cooling apparatus according to Claim 1, further comprising

a main control valve configured to detect a temperature of the liquid coolant in the main circulation path, configured to return the liquid coolant, which has passed through the engine, to the engine to warm up the engine in case the detected temperature is less than a lower limit value of the temperature of the liquid coolant when the engine runs in the steady state, and configured to send part or all of the liquid coolant which has passed through the engine towards the main radiator in the main circulation path

in case the detected temperature is equal to or more than the lower limit value.

3. The engine cooling apparatus according to Claim 1 or 2, wherein the lower limit value of the temperature of the liquid coolant when the engine runs in the steady state is set to 80°C and the upper limit value thereof is set to 100°C.

4. The engine cooling apparatus according to Claim 1 or 2, wherein the lower limit value of the temperature of the liquid coolant when the engine runs in the steady state is set to any value in the range of 70°C to 90°C and the upper limit value thereof is set to any value in the range of 90°C to 120°C.

5. The engine cooling apparatus according to any one of Claims 1 to 4, further comprising a bypass circulation path configured to send the liquid coolant which is separated by the sub-control valve to an upstream side or a downstream side of the second pump.

6. The engine cooling apparatus according to any one of Claims 1 to 5, further comprising an EGR cooler provided in a branched circulation path which branches off the main circulation path to allow the separated liquid coolant to flow there-through.

7. The engine cooling apparatus according to any one of Claims 1 to 5, further comprising an EGR cooler provided in a halfway position along the sub-circulation path.

8. An engine cooling method by using the engine cooling apparatus according to any one of Claims 1 to 7, comprising:

sending part of the liquid coolant in the main circulation path to the sub-circulation path; cooling the cooled liquid coolant by the sub-radiator; and returning the cooled liquid coolant to the main circulation path in a position lying at an upstream side of the engine.

FIG. 1

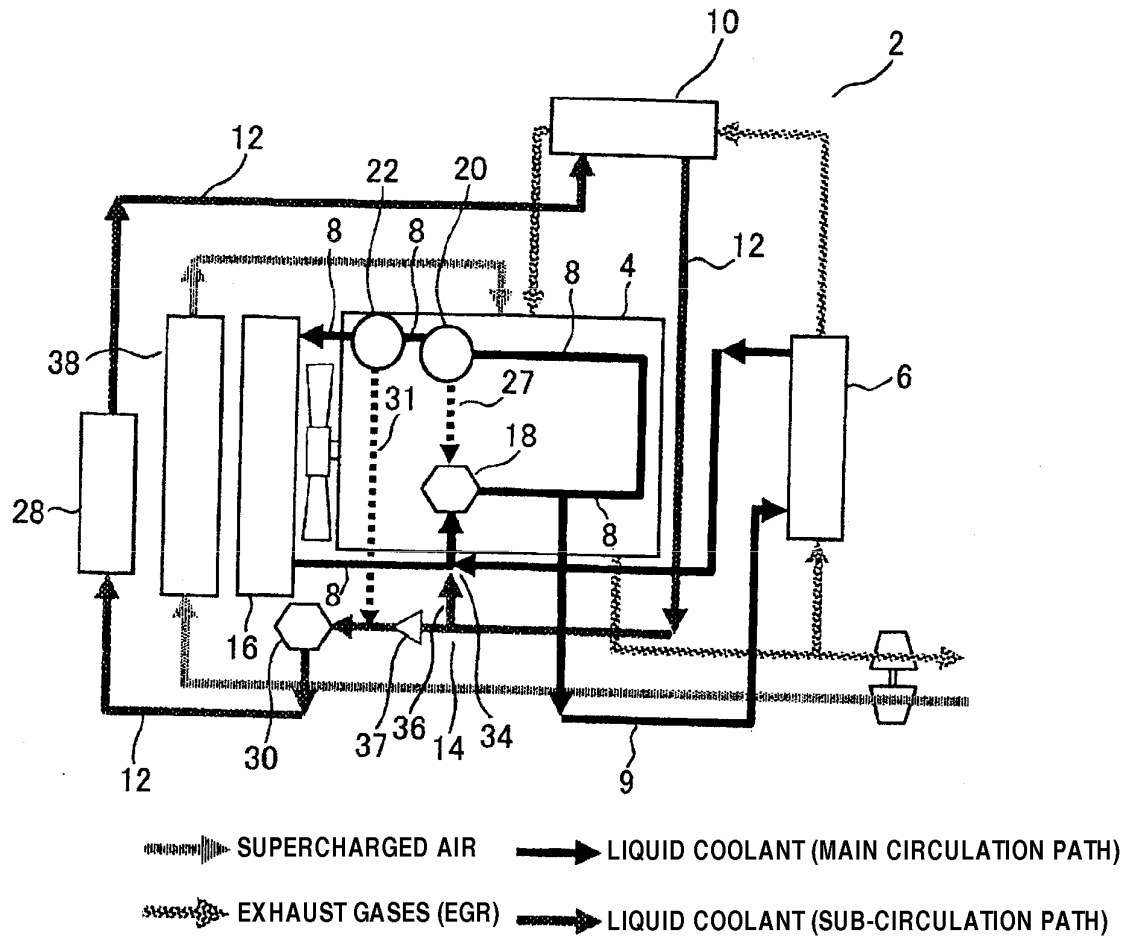


FIG. 2

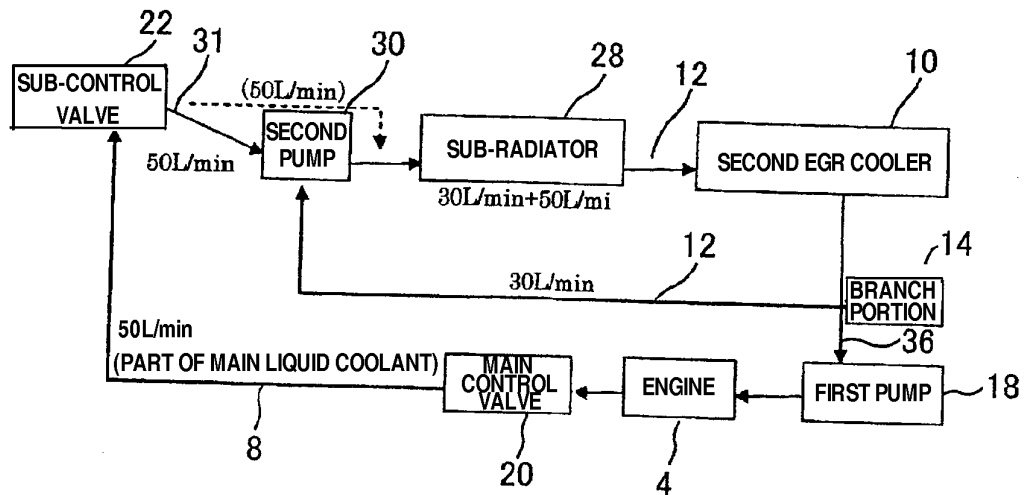


FIG. 3

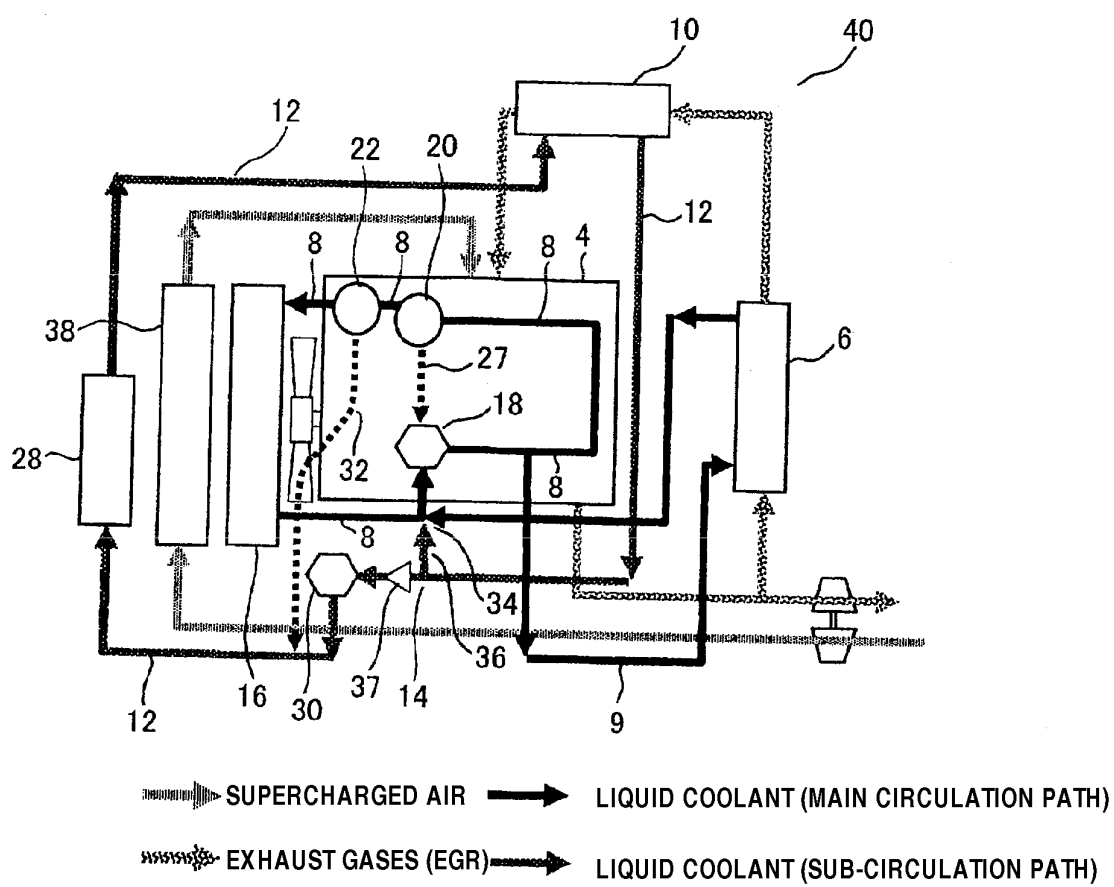


FIG. 4

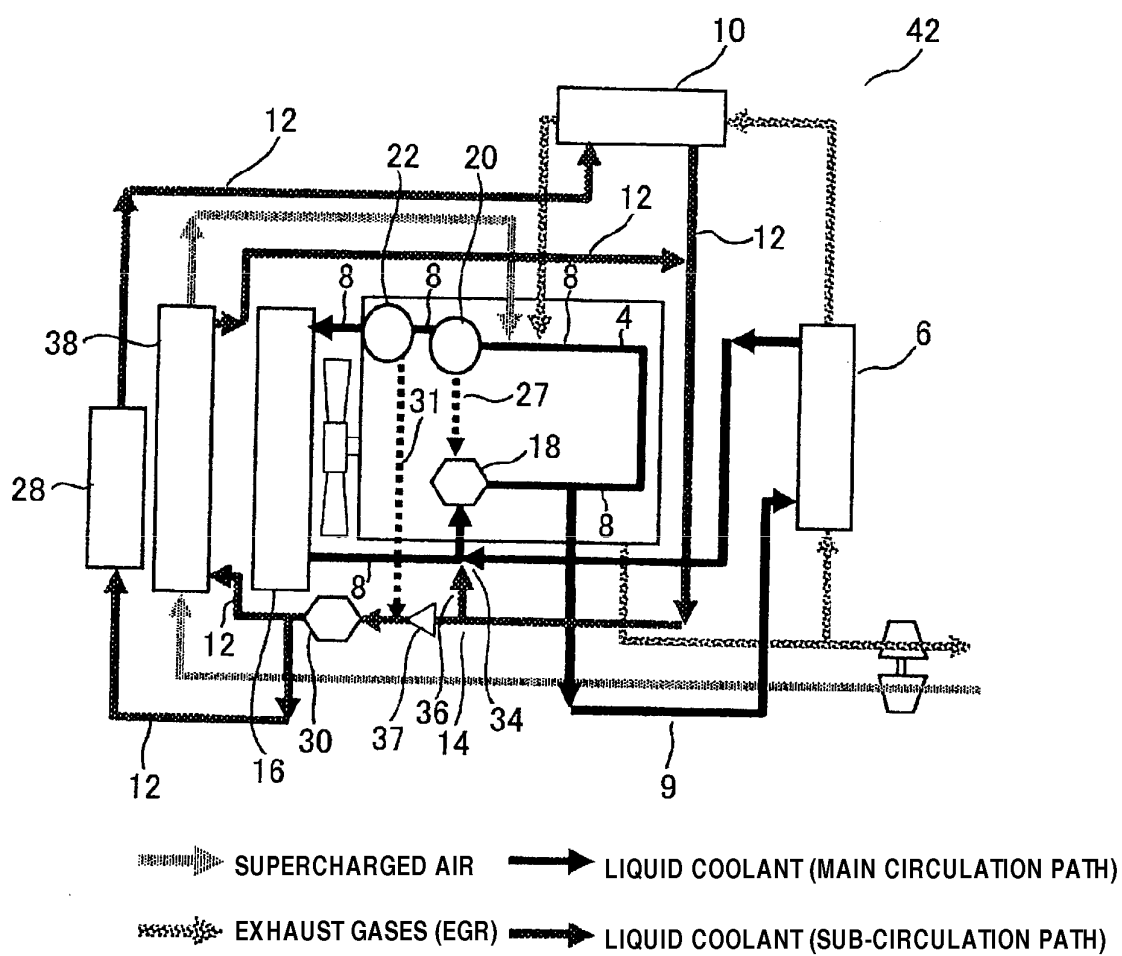


FIG. 5

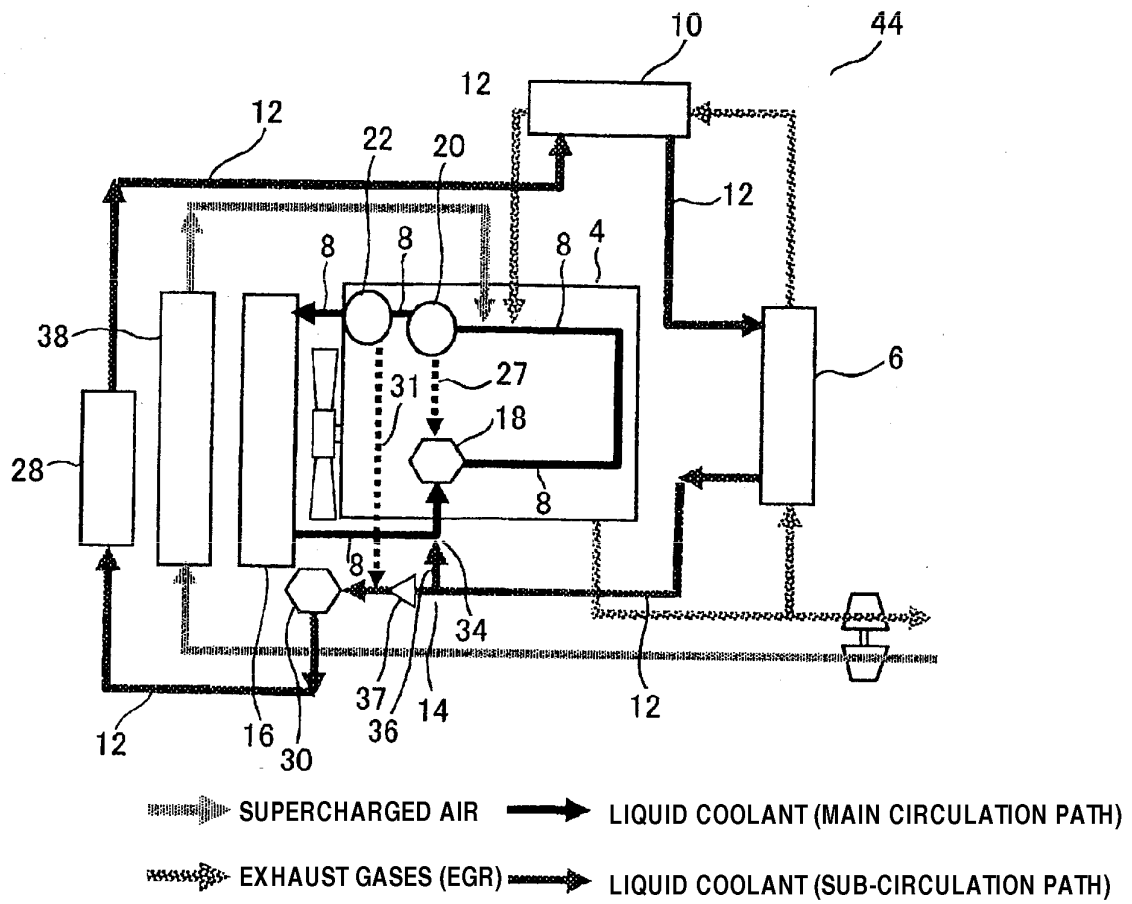
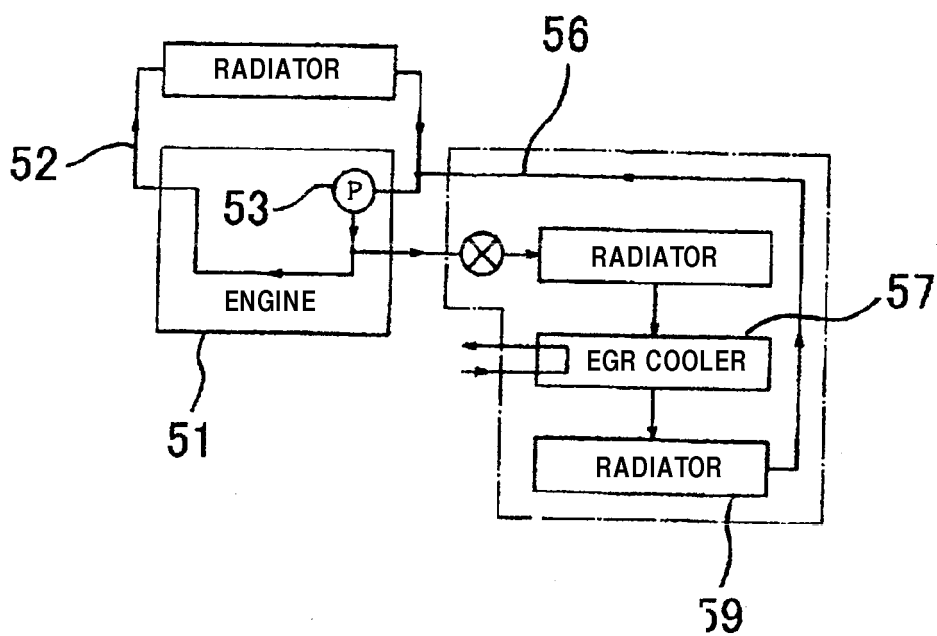


FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/080646

A. CLASSIFICATION OF SUBJECT MATTER

F01P3/18(2006.01)i, F01P3/20(2006.01)i, F01P5/12(2006.01)i, F01P7/16
(2006.01)i, F02M25/07(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)

F01P3/18, F01P3/20, F01P5/12, F01P7/16, F02M25/07

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 1996-2013
Kokai Jitsuyo Shinan Koho 1971-2013 Toroku Jitsuyo Shinan Koho 1994-2013

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 2002-276364 A (Denso Corp.), 25 September 2002 (25.09.2002), paragraphs [0002] to [0005], [0041]; fig. 1, 2, 5 (Family: none)	1-8
A	JP 2011-523691 A (Scania CV AB.), 18 August 2011 (18.08.2011), paragraph [0024]; fig. 1 & WO 2009/151377 A1 & US 2011/0139131 A1 & SE 533942 C2 & RU 2454554 C1 & KR 10-2011-0026477 A & CN 102057143 B	1-8
A	JP 2008-290636 A (Sanyo Electric Co., Ltd.), 04 December 2008 (04.12.2008), paragraph [0046]; fig. 10 (Family: none)	1-8

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
25 February, 2013 (25.02.13)

Date of mailing of the international search report
05 March, 2013 (05.03.13)

Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/080646

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 11-22460 A (Nissan Motor Co., Ltd.), 26 January 1999 (26.01.1999), paragraphs [0042] to [0043]; fig. 12 to 13 (Family: none)	1-8
A	JP 2010-228686 A (Toyota Motor Corp.), 14 October 2010 (14.10.2010), paragraphs [0009] to [0010]; fig. 2 (Family: none)	1-8
A	JP 2010-64527 A (Denso Corp.), 25 March 2010 (25.03.2010), entire text; fig. 1 to 5 & DE 102009039798 A1	1-8
A	JP 2006-132469 A (Mitsubishi Fuso Truck and Bus Corp.), 25 May 2006 (25.05.2006), entire text; fig. 1 to 2 (Family: none)	1-8

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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- US 20080066697 A [0010]
- JP 2011258712 A [0121]