

(19)



(11)

EP 2 806 135 A2

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
26.11.2014 Bulletin 2014/48

(51) Int Cl.:
F01P 11/04 ^(2006.01) **F01P 3/02** ^(2006.01)

(21) Application number: **14161960.1**

(22) Date of filing: **27.03.2014**

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

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(30) Priority: **23.05.2013 JP 2013108640**

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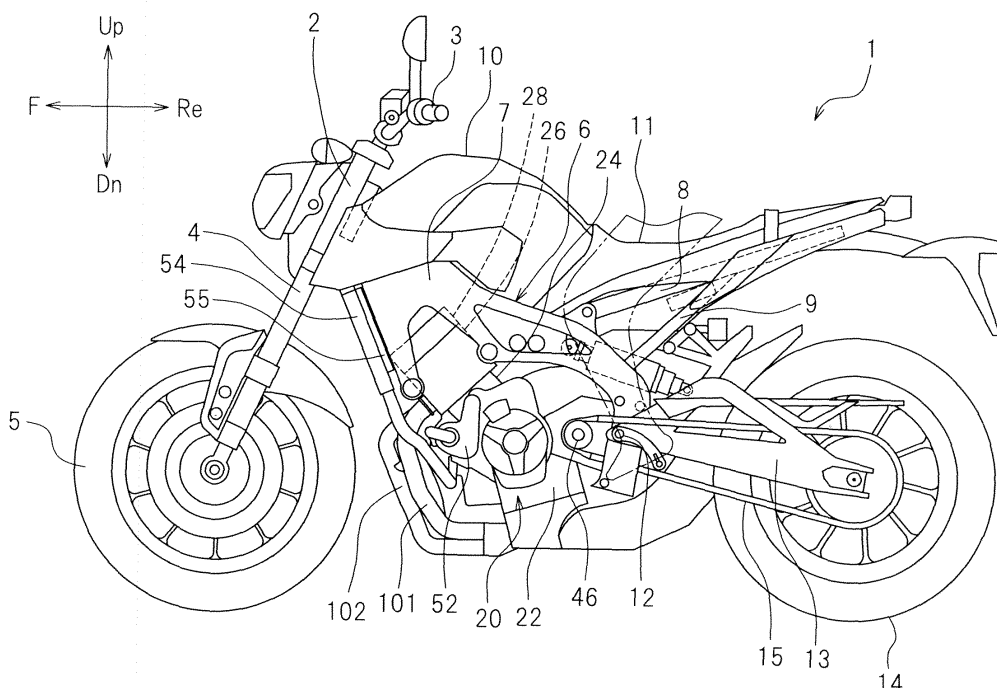
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(54) **Cooling apparatus for internal combustion engine and motorcycle including same**

(57) A cooling apparatus 50 includes a cooling passage 80 and an introduction passage 71. The cooling passage 80 includes: a cylinder head cooling passage 81 provided in a cylinder head 26; a cylinder body cooling passage 82 provided in a cylinder body 24; and a connection passage 83 through which the cylinder head cool-

ing passage 81 and the cylinder body cooling passage 82 are connected to each other. The introduction passage 71 is provided in the cylinder body 24 and arranged to guide cooling water from a water pump 52 to the cylinder head cooling passage 81.

FIG.1

**EP 2 806 135 A2**

Description

[0001] The present invention relates to a cooling apparatus for an internal combustion engine and a motorcycle including the apparatus.

[0002] A water-cooling cooling apparatus is conventionally known as an apparatus for cooling an internal combustion engine of a motorcycle, for example. A cooling apparatus of this type includes: a cooling passage which is provided inside an internal combustion engine and through which cooling water flows; a water pump that conveys the cooling water; and a radiator that cools the cooling water.

[0003] For example, JP 2007-2678 A and JP 2007-107492 A each disclose a cooling apparatus that includes cooling passages that allow cooling water discharged from a water pump to flow through a crankcase, a cylinder body and a cylinder head of an internal combustion engine in this order.

[0004] For an internal combustion engine, it is desirable that an adjacent region of a combustion chamber should be effectively cooled from the standpoint of preventing knocking, for example. Of components of an internal combustion engine such as a crankcase, a cylinder body and a cylinder head, the component located closest to a combustion chamber is the cylinder head. Therefore, it is desirable that the cylinder head should be effectively cooled. However, in the above-mentioned conventional technique, the cooling water discharged from the water pump passes through the cooling passage of the cylinder body before reaching the cooling passage of the cylinder head. This cooling water is heated through the cooling passage of the cylinder body, and then flows into the cooling passage of the cylinder head. As a result, the cooling water that will flow into the cooling passage of the cylinder head is likely to increase in temperature, which makes it difficult to effectively cool the cylinder head.

[0005] The inventor of the present invention has studied a technique of allowing cooling water discharged from a water pump to flow into a cooling passage of a cylinder head without flowing through a cooling passage of a cylinder body. However, when the water pump is fixed to a crankcase as in the conventional cooling apparatus, there occurs another problem that water piping through which a discharge port of the water pump and the cooling passage of the cylinder head are connected to each other is increased in length. An increase in length of the water piping disadvantageously results in an increase in cost. In the case of a cooling apparatus for a motorcycle, an increase in length of water piping unfavorably reduces installation space for other vehicle-mounted components and layout flexibility thereof.

[0006] Accordingly, it is the object of the present invention to provide a cooling apparatus capable of effectively cooling an adjacent region of a combustion chamber of an internal combustion engine while preventing an increase in length of water piping.

[0007] According to the present invention said object is solved by a cooling apparatus for cooling an internal combustion engine having the features of independent claim 1. Preferred embodiments are laid down in the dependent claims.

[0008] A cooling apparatus for an internal combustion engine according to an embodiment of the present teaching is a cooling apparatus for cooling an internal combustion engine including: a crankcase in which a crankshaft is contained; a cylinder body including a cylinder provided therein; and a cylinder head connected to the cylinder body and defining a portion of a combustion chamber. The cooling apparatus includes: a radiator that cools cooling water; a water pump that conveys the cooling water cooled by the radiator; a cooling passage that includes a cylinder head cooling passage provided in the cylinder head, a cylinder body cooling passage provided in the cylinder body, and a connection passage through which the cylinder head cooling passage and the cylinder body cooling passage are connected to each other; and an introduction passage provided in the cylinder body to guide the cooling water to the cylinder head cooling passage of the cooling passage.

[0009] In the above-described cooling apparatus, the cooling water flows through the cooling passage, thus cooling the internal combustion engine. The cooling water is guided to the cylinder head cooling passage through the introduction passage, flows through the cylinder head cooling passage, and then flows into the cylinder body cooling passage via the connection passage. The cooling water flows through the cylinder head cooling passage before flowing through the cylinder body cooling passage, thus making it possible to effectively cool the cylinder head. Hence, an adjacent region of the combustion chamber can be effectively cooled. The introduction passage is provided in the cylinder body. As a result, there is no need for long water piping through which the water pump and the cylinder head cooling passage are connected to each other.

[0010] According to one embodiment of the present teaching, the introduction passage is preferably provided at a position farther away from the cylinder than the cylinder body cooling passage.

[0011] According to the above-described embodiment, the cooling water flowing through the introduction passage is less prone to being heated. Consequently, the cooling water having a lower temperature can be introduced into the cylinder head cooling passage.

[0012] According to another embodiment of the present teaching, a portion of the cylinder body cooling passage is preferably provided between the cylinder and the introduction passage.

[0013] According to the above-described embodiment, the cooling water flowing through the introduction passage is less prone to being heated. Consequently, the cooling water having a lower temperature can be introduced into the cylinder head cooling passage.

[0014] According to still another embodiment of the

present teaching, the cylinder body cooling passage preferably consists of a water jacket provided around the cylinder, and the introduction passage preferably extends substantially parallel to an axis of the cylinder.

[0015] According to the above-described embodiment, the suitable introduction passage can be provided inside the cylinder body.

[0016] According to yet another embodiment of the present teaching, the water pump is preferably attached to the crankcase.

[0017] According to the above-described embodiment, a distance between the water pump and the introduction passage is short, and therefore, water piping through which the water pump and the introduction passage are connected to each other can be shortened or eliminated.

[0018] According to still yet another embodiment of the present teaching, the internal combustion engine preferably includes a balancer disposed inside the crankcase and connected to the crankshaft. The water pump is preferably connected to the balancer so as to be driven by the balancer.

[0019] According to the above-described embodiment, the balancer can be utilized as a driving source for the water pump, thus eliminating the need for a dedicated motor for driving the water pump.

[0020] According to another embodiment of the present teaching, the introduction passage preferably includes an inlet through which the cooling water flows in. The water pump preferably includes a discharge port connected to the inlet of the introduction passage.

[0021] According to the above-described embodiment, water piping through which the water pump and the internal combustion engine are connected to each other can be eliminated.

[0022] According to still another embodiment of the present teaching, the cylinder body preferably includes one or more other cylinders arranged in alignment with the cylinder. The cooling passage preferably includes an outlet which is provided in the cylinder body and through which the cooling water flows out from the cylinder body cooling passage. As viewed from a direction of the axis of the cylinder, a midpoint of a line connecting the axes of endmost ones of the cylinders is preferably located between the inlet of the introduction passage and the outlet of the cooling passage.

[0023] According to the above-described embodiment, the inlet of the introduction passage and the outlet of the cooling passage are disposed far away from each other. Thus, sufficient space for the introduction passage can be easily ensured in the cylinder body.

[0024] A motorcycle according to an embodiment of the present teaching includes the above-described cooling apparatus.

[0025] Thus, the motorcycle that achieves the above-described effects can be obtained.

[0026] According to another embodiment of the present teaching, the cylinder body preferably extends obliquely upward and forward from the crankcase. The

internal combustion engine preferably includes an exhaust pipe that extends obliquely downward and forward from the cylinder head and then extends obliquely downward and rearward in side view of the motorcycle. The radiator is preferably disposed forward of the internal combustion engine.

[0027] In general, in a motorcycle having such a structure, water piping through which the internal combustion engine, the radiator and the water pump are connected to each other is prone to interfere with the exhaust pipe, thus making it difficult to perform layout of the overall water piping. However, according to the above-described embodiment, water piping through which the water pump and the cylinder head cooling passage are connected to each other is unnecessary or can be reduced in length, thus making it possible to compactly dispose the entire water piping while preventing interference of the water piping with the exhaust pipe even when the motorcycle has the above-described structure.

[0028] According to still another embodiment of the present teaching, the radiator preferably includes: an inlet through which the cooling water flows in; and an outlet through which the cooling water flows out. The cooling apparatus preferably includes: first water piping connected to the outlet of the radiator and the water pump; and second water piping connected to the outlet of the cooling passage and the inlet of the radiator. When one of a region located rightward of a motorcycle center line in front view of the motorcycle and a region located leftward of the motorcycle center line in front view of the motorcycle is defined as a first region and the other region is defined as a second region, the outlet of the radiator and the water pump are preferably disposed in the first region, and the inlet of the radiator and the outlet of the cooling passage are preferably disposed in the second region.

[0029] According to the above-described embodiment, the first water piping and the second water piping are disposed far away from each other. Thus, the first water piping and the second water piping can be compactly disposed while interference between the first water piping and the second water piping is prevented.

[0030] According to yet another embodiment of the present teaching, the cylinders are preferably arranged in a lateral direction of the motorcycle. The introduction passage is preferably disposed rightward of a rightmost one of the cylinders in front view of the motorcycle, or disposed leftward of a leftmost one of the cylinders in front view of the motorcycle.

[0031] According to the above-described embodiment, sufficient space for the introduction passage can be easily ensured inside the cylinder body. Thus, the suitable introduction passage is easily provided inside the cylinder body. Furthermore, the cooling water flowing through the introduction passage is less prone to being heated.

[0032] According to still yet another embodiment of the present teaching, the cylinders are preferably arranged in a lateral direction of the motorcycle. When one of a rightward end and a leftward end in front view of the mo-

torcycle is defined as a first end and the other end is defined as a second end, the introduction passage is preferably disposed closer to the first end than the cylinders, and the cylinder head cooling passage and the cylinder body cooling passage are preferably arranged so that the cooling water flows therethrough toward the second end.

[0033] According to the above-described embodiment, the cooling water is likely to flow smoothly through the cylinder head cooling passage and the cylinder body cooling passage. As a result, the internal combustion engine can be suitably cooled.

ADVANTAGEOUS EFFECTS OF INVENTION

[0034] Various embodiments of the present teaching provide a cooling apparatus capable of effectively cooling an adjacent region of a combustion chamber of an internal combustion engine while preventing an increase in length of water piping.

BRIEF DESCRIPTION OF DRAWINGS

[0035]

FIG. 1 is a side view of a motorcycle according to an embodiment of the present teaching.

FIG. 2 is a partial cross-sectional view of an internal combustion engine.

FIG. 3 is another partial cross-sectional view of the internal combustion engine.

FIG. 4 is a diagram illustrating a cooling water circuit of a cooling apparatus according to an embodiment of the present teaching.

FIG. 5 is a perspective view of the internal combustion engine and the cooling apparatus.

FIG. 6 is a front view of the internal combustion engine and the cooling apparatus.

FIG. 7 is a left side view of the internal combustion engine and the cooling apparatus.

FIG. 8 is a cross-sectional view taken along the line VIII-VIII of FIG. 7.

FIG. 9 is a diagram illustrating how water passages of the internal combustion engine are arranged.

FIG. 10 is a partial plan view of a cylinder body.

FIG. 11 is a right side view of the internal combustion engine and the cooling apparatus.

FIG. 12 is a front view of the internal combustion engine, the cooling apparatus, and exhaust pipes.

DESCRIPTION OF EMBODIMENTS

[0036] FIG. 1 is a side view of a motorcycle (vehicle) 1 according to one embodiment of the present teaching. In the following description, unless otherwise specified, "front", "rear", "right", "left", "up" and "down" indicate front, rear, right, left, up and down with respect to a rider (not illustrated) sitting on a seat 11 of the motorcycle 1, re-

spectively. "Up" and "down" correspond to a vertically upward direction and a vertically downward direction when the motorcycle 1 is brought to a stop on a horizontal plane, respectively. Reference signs "F", "Re", "R", "L", "Up" and "Dn" in the drawings represent front, rear, right, left, up and down, respectively. It is to be noted that directions defined as viewed from the front of the vehicle may also be used in the following description. When the directions defined as viewed from the front of the vehicle and the directions defined with respect to the rider sitting on the seat 11 are compared to each other, right and left are reversed. Specifically, left and right defined as viewed from the front of the vehicle correspond to right and left defined with respect to the rider sitting on the seat 11, respectively. Reference signs "R" and "L" indicate right and left defined as viewed from the front of the vehicle.

[0037] As illustrated in FIG. 1, the motorcycle 1 preferably includes a head pipe 2. A handlebar 3 is supported by the head pipe 2 so that the handlebar 3 can be turned to the right and left. A front fork 4 is connected to a lower end portion of the handlebar 3. A front wheel 5 is rotatably supported by a lower end portion of the front fork 4. A body frame 6 is fixed to the head pipe 2. The body frame 6 preferably includes: a main frame 7 that extends obliquely downward and rearward from the head pipe 2 in side view of the vehicle; a seat frame 8 that extends obliquely upward and rearward from the main frame 7 in side view of the vehicle; and a back stay 9 connected to the main frame 7 and the seat frame 8. A fuel tank 10 is disposed rearward of the head pipe 2, and the seat 11 is disposed rearward of the fuel tank 10. The fuel tank 10 and the seat 11 are supported by the body frame 6. A rear arm 13 is rotatably supported by the main frame 7. A front end portion of the rear arm 13 is connected to the main frame 7 via a pivot shaft 12. A rear wheel 14 is rotatably supported by a rear end portion of the rear arm 13.

[0038] An internal combustion engine 20 is supported by the body frame 6. The internal combustion engine 20 preferably includes: a crankcase 22; a cylinder body 24 that extends obliquely upward and forward from the crankcase 22; a cylinder head 26 that extends obliquely upward and forward from the cylinder body 24; and a head cover 28 connected to a front end portion of the cylinder head 26. In the present embodiment, the cylinder body 24 is integral with the crankcase 22. Alternatively, the cylinder body 24 and the crankcase 22 may be separate components. The internal combustion engine 20 preferably includes a drive shaft 46 that outputs a driving force. The drive shaft 46 is connected to the rear wheel 14 via a chain 15.

[0039] As illustrated in FIG. 2, the internal combustion engine 20 is a multi-cylinder internal combustion engine. A first cylinder 31, a second cylinder 32 and a third cylinder 33 are provided inside the cylinder body 24. The first, second and third cylinders 31, 32 and 33 are disposed in this order from the left to the right. A piston 34 is contained in each of the first, second and third cylinders

31, 32 and 33. Each piston 34 is connected to a crankshaft 36 via a connecting rod 35. The crankshaft 36 is contained in the crankcase 22.

[0040] Concaves 27 are provided in portions of the cylinder head 26 which are located above the first, second and third cylinders 31, 32 and 33. The cylinders 31 to 33, the pistons 34 and the concaves 27 define combustion chambers 43. The cylinder head 26 is provided with intake ports 95 and exhaust ports 96 (see FIG. 7) which are communicated with the combustion chambers 43. An intake pipe 120 (see FIG. 7) is connected to each intake port 95, and thus air is introduced into the combustion chambers 43 through the intake ports 95. Exhaust pipes 101 to 103 (see FIG. 12) which will be described later are connected to the exhaust ports 96, and thus exhaust gas is discharged from the combustion chambers 43 through the exhaust ports 96.

[0041] A generator 37 is attached to a left end portion of the crankshaft 36. A sprocket 39 is attached to a right end portion of the crankshaft 36. A cam chain 41 is wound around the sprocket 39. A gear 42 is fixed to a portion of the crankshaft 36 which is located leftward of the sprocket 39.

[0042] As illustrated in FIG. 3, the internal combustion engine 20 preferably includes a clutch 38. The clutch 38 preferably includes a clutch housing 38a and a clutch boss 38b. The clutch housing 38a is connected to the gear 42. A torque of the crankshaft 36 is transmitted to the clutch housing 38a via the gear 42. The clutch housing 38a rotates together with the crankshaft 36. A main shaft 44 is fixed to the clutch boss 38b.

[0043] The internal combustion engine 20 preferably includes a transmission 40. The transmission 40 preferably includes: a plurality of gears 45 provided at the main shaft 44; a plurality of gears 47 provided at the drive shaft 46; a shift cam 48; and a shift fork 49. Upon rotation of the shift cam 48, the shift fork 49 causes the gears 45 and/or the gears 47 to move axially, thus changing a combination of the gears 45 and 47 which intermesh with each other. As a result, a transmission gear ratio is changed.

[0044] The internal combustion engine 20 preferably includes a balancer 90. The balancer 90 preferably includes: a balancer shaft 91; and a balancer weight 92 provided at the balancer shaft 91. A gear 93 that intermeshes with the gear 42 is fixed to a right portion of the balancer shaft 91. The balancer shaft 91 is connected to the crankshaft 36 via the gear 42 and the gear 93. The balancer shaft 91 is driven by the crankshaft 36, and is rotated together with the crankshaft 36. A gear 94 is fixed to a left end portion of the balancer shaft 91.

[0045] The gear 42 is press-fitted to the crankshaft 36. As mentioned above, the gear 42 intermeshes with both of the clutch housing 38a of the clutch 38 and the gear 93 of the balancer 90. The gear 42 is provided by a press-fitted gear, thus making it possible to reduce an outer diameter of the gear 42. A reduction in the outer diameter of the gear 42 can reduce a distance between the crank-

shaft 36 and the main shaft 44 and a distance between the crankshaft 36 and the balancer shaft 91. Note that the crankshaft 36, the main shaft 44, the drive shaft 46 and the balancer shaft 91 extend laterally (namely, extend in a right-left direction), and are disposed in parallel with each other.

[0046] The internal combustion engine 20 is a water-cooled internal combustion engine, at least a portion of which is cooled by cooling water. The motorcycle 1 preferably includes a cooling apparatus 50 that cools the internal combustion engine 20. Next, the cooling apparatus 50 will be described.

[0047] First, a configuration of a cooling water circuit of the cooling apparatus 50 will be described. FIG. 4 is a schematic diagram of the cooling water circuit of the cooling apparatus 50. The cooling apparatus 50 preferably includes: a water pump 52; a cooling passage 80 provided inside the internal combustion engine 20; a radiator 54; a thermostat 58; and an oil cooler 56.

[0048] The water pump 52 preferably includes: a discharge port 52o through which cooling water is discharged; and a suction port 52i through which the cooling water is sucked. The cooling passage 80 preferably includes: an inlet 80i through which the cooling water flows in; and an outlet 80o through which the cooling water flows out. The radiator 54 preferably includes: a radiator main body 54a through which heat is exchanged between the cooling water and air; an inlet tank 54b; and an outlet tank 54c. The inlet tank 54b is provided with an inlet 54i through which the cooling water flows in. The outlet tank 54c is provided with an outlet 54o through which the cooling water flows out. The oil cooler 56 is provided with: an inlet 56i through which the cooling water flows in; and an outlet 56o through which the cooling water flows out.

[0049] The cooling apparatus 50 preferably includes: a first passage 71 connected to the discharge port 52o of the water pump 52 and the inlet 80i of the cooling passage 80; a second passage 72 connected to the outlet 80o of the cooling passage 80 and the inlet 54i of the radiator 54; a third passage 73 connected to the outlet 54o of the radiator 54 and the suction port 52i of the water pump 52; and an oil cooler passage 74. The oil cooler passage 74 preferably includes: a first end portion 74i connected to the second passage 72; and a second end portion 74o connected to the third passage 73. The oil cooler 56 is provided in the oil cooler passage 74.

[0050] The thermostat 58 is provided in a portion of the third passage 73 which is located between the outlet 54o of the radiator 54 and the second end portion 74o. The thermostat 58 preferably includes: a thermostat case 59 provided with a first inlet 59i1, a second inlet 59i2 and an outlet 59o; and a valve body 57 contained inside the thermostat case 59 to open and close communication between the first inlet 59i1 and the outlet 59o. The third passage 73 preferably includes: an upstream passage 73a connected to the outlet 54o of the radiator 54 and the first inlet 59i1 of the thermostat case 59; and a downstream passage 73b connected to the outlet 59o of the

thermostat case 59 and the suction port 52i of the water pump 52. The oil cooler passage 74 preferably includes: an upstream passage 74a connected to the first end portion 74i and the inlet 56i of the oil cooler 56; and a downstream passage 74b connected to the outlet 56o of the oil cooler 56 and the second inlet 59i2 of the thermostat case 59. Note that the second inlet 59i2 of the thermostat case 59 constitutes the second end portion 74o.

[0051] The thermostat 58 is an "in-line type" thermostat, and the second inlet 59i2 and the outlet 59o of the thermostat case 59 are always communicated with each other. The thermostat 58 is arranged to shut off communication between the first inlet 59i1 and the outlet 59o by the valve body 57 and allow communication between the second inlet 59i2 and the outlet 59o when an internal temperature of the thermostat case 59 is lower than a reference temperature. The thermostat 58 is arranged to allow communication between the first inlet 59i1 and the outlet 59o and allow communication between the second inlet 59i2 and the outlet 59o when the internal temperature of the thermostat case 59 is equal to or higher than the reference temperature. The second inlet 59i2 and the outlet 59o are always communicated with each other irrespective of a value of the internal temperature of the thermostat case 59, and thus the cooling water always flows through the oil cooler passage 74. Therefore, the cooling water always flows through the oil cooler 56. Note that the reference temperature is uniquely determined depending on the thermostat 58, but is not limited to any particular temperature. For example, the particular thermostat 58 may be selected from a plurality of the thermostats 58 having different reference temperatures, so that a suitable reference temperature can be set.

[0052] Up to this point, the configuration of the cooling water circuit of the cooling apparatus 50 has been described. Next, structures of main components of the cooling apparatus 50 will be described.

[0053] As illustrated in FIG. 5, the water pump 52 is fixed to the internal combustion engine 20. In this embodiment, the water pump 52 is fixed to the cylinder body 24. Alternatively, the water pump 52 may be fixed to the crankcase 22, for example. The water pump 52 is fixed to a left side wall of the cylinder body 24. As illustrated in FIG. 6, the water pump 52 is disposed rightward of a vehicle center line CL in front view of the vehicle. Note that the term "vehicle center line CL" refers to a line that passes through a lateral center of the motorcycle 1 and coincides with a center line of the front wheel 5 and a center line of the rear wheel 14.

[0054] As illustrated in FIG. 3, the water pump 52 preferably includes: a pump housing 52B; a pump cover 52A disposed leftward of the pump housing 52B; an impeller 61 disposed inside the pump housing 52B; and a pump shaft 62 fixed to the impeller 61. The pump cover 52A preferably includes a suction portion 60a through which the cooling water is sucked toward the impeller 61. The pump housing 52B preferably includes: a discharge portion 60b through which the cooling water ejected from

the impeller 61 is discharged; and a passage portion 60c (see FIG. 7) through which the cooling water is guided from the discharge portion 60b toward the internal combustion engine 20.

[0055] A gear 63 is fixed to the pump shaft 62. The gear 63 intermeshes with the gear 94 fixed to the balancer shaft 91. The gear 94 is press-fitted to the balancer shaft 91. The pump shaft 62 is connected to the balancer shaft 91 via the gear 63 and the gear 94. The water pump 52 is driven by the balancer shaft 91. Upon rotation of the balancer shaft 91, the impeller 61 rotates. As already mentioned above, the balancer shaft 91 is driven by the crankshaft 36. Hence, the water pump 52 is driven by the balancer shaft 91 directly, and is driven by the crankshaft 36 indirectly.

[0056] As illustrated in FIG. 7, a shaft center of the pump shaft 62 is located above a shaft center of the crankshaft 36 in side view of the vehicle. The shaft center of the pump shaft 62 is located forward of the shaft center of the crankshaft 36 in side view of the vehicle.

[0057] The water pump 52 is attached to the internal combustion engine 20 together with an ACM cover 64 that covers the generator 37 (see FIG. 2). FIG. 8 is a cross-sectional view taken along the line VIII-VIII of FIG. 7. As illustrated in FIG. 8, a portion of the water pump 52 is attached via bolts 53 to the cylinder body 24 together with the ACM cover 64. A portion of the pump cover 52A, a portion of the pump housing 52B and a portion of the ACM cover 64 are fixed to the cylinder body 24 via the same bolts 53.

[0058] Next, water passages provided inside the internal combustion engine 20 will be described. As already mentioned above with reference to FIG. 4, the cooling apparatus 50 preferably includes: the first passage 71; and the cooling passage 80 provided inside the internal combustion engine 20. In the present embodiment, the first passage 71 is provided inside the internal combustion engine 20. The first passage 71 constitutes an introduction passage through which the cooling water is introduced from the water pump 52 to the cooling passage 80. Hereinafter, the first passage 71 may also be referred to as the "introduction passage 71".

[0059] As illustrated in FIG. 9, the cooling passage 80 preferably includes: a cylinder head cooling passage 81 provided in the cylinder head 26; a cylinder body cooling passage 82 provided in the cylinder body 24; and a connection passage 83 through which the cylinder head cooling passage 81 and the cylinder body cooling passage 82 are connected to each other.

[0060] The cylinder head cooling passage 81 is provided around the concaves 27 (see FIG. 2) of the combustion chambers 43 of the first, second and third cylinders 31, 32 and 33. The cylinder head cooling passage 81 is provided so that the cooling water flows from the right to the left in front view of the vehicle.

[0061] The cylinder body cooling passage 82 consists of a water jacket provided around the first, second and third cylinders 31, 32 and 33. The cylinder body cooling

passage 82 is provided so that the cooling water flows from the right to the left in front view of the vehicle.

[0062] A gasket 25 is sandwiched between the cylinder head 26 and the cylinder body 24. The gasket 25 is provided with a plurality of holes 25b located above the cylinder body cooling passage 82 and below the cylinder head cooling passage 81. The holes 25b constitute the connection passage 83. The locations and number of the holes 25b constituting the connection passage 83 are not limited to any particular locations and number. For example, in this embodiment, the gasket 25 is provided with: the two holes 25b located leftward of the third cylinder 33; the two holes 25b located rearward of the third cylinder 33; the two holes 25b located rearward of the second cylinder 32; the two holes 25b located rearward of the first cylinder 31; and the single hole 25b located rightward of the first cylinder 31.

[0063] As illustrated in FIG. 9, the first passage 71 is provided in the cylinder body 24. The first passage 71 is disposed rightward of the rightmost first cylinder 31 in front view of the vehicle. In front view of the vehicle, the first passage 71 preferably includes: an inlet 71i opened rightward; an outlet 71o opened at an upper surface of the cylinder body 24; a lateral portion 71a extending leftward from the inlet 71i; and a longitudinal portion 71b extending parallel to cylinder axes from the lateral portion 71a toward the outlet 71o. Similarly to the outlet 71o, the longitudinal portion 71b has a lateral cross section in the form of a segment of a circle, the center of which is an axial center (cylinder axis) 31c of the first cylinder 31. Note that reference signs "32c" and "33c" denote axes of the second cylinder 32 and the third cylinder 33, respectively.

[0064] The first passage 71 and the cooling passage 80 are both provided inside the internal combustion engine 20, and serve as water passages through which the cooling water flows. Although the cooling passage 80 is provided to allow the cooling water to flow therethrough in order to cool the internal combustion engine 20, the first passage 71 is provided in order to guide the cooling water to the cylinder head cooling passage 81 but not to cool the internal combustion engine 20. The first passage 71 and the cylinder body cooling passage 82 are both provided in the cylinder body 24, but the first passage 71 and the cylinder body cooling passage 82 define different spaces. Inside the cylinder body 24, the first passage 71 and the cylinder body cooling passage 82 are not connected to each other.

[0065] The first passage 71 is provided at a position located farther away from the cylinders 31 to 33 than the cylinder body cooling passage 82. A portion of the cylinder body cooling passage 82 is provided between the cylinders 31 to 33 and the first passage 71. As illustrated in FIG. 10, the first passage 71 has a lateral width 71W greater than a lateral width 82W of the cylinder body cooling passage 82, but has a longitudinal width 71L smaller than a length of an entire circumference of the cylinder body cooling passage 82. The first passage 71 has a flow

passage cross-sectional area smaller than a flow passage cross-sectional area of the cylinder body cooling passage 82. The first passage 71 is provided in the form of a segment of a circle, the center of which is the cylinder axis 31c, and therefore, the longitudinal width 71L corresponds to a maximum length of the first passage 71 in a cross section orthogonal to the cylinder axis 31c. The longitudinal width 71L of the first passage 71 is smaller than an inner diameter 31D of the first cylinder 31 in the cross section orthogonal to the cylinder axis 31c. Note that the first to third cylinders 31 to 33 have the same inner diameter. The first passage 71 has a passage length shorter than a passage length of the cylinder body cooling passage 82. The first passage 71 has a surface area smaller than a surface area of the cylinder body cooling passage 82.

[0066] As illustrated in FIG. 9, a hole 25a is provided in a portion of the gasket 25 which is located above the first passage 71 and below the cylinder head cooling passage 81. The first passage 71 and the cylinder head cooling passage 81 are communicated with each other through the hole 25a. The hole 25a constitutes a connection passage through which the first passage 71 and the cylinder head cooling passage 81 are connected to each other. The inlet 80i of the cooling passage 80 is provided in a portion of the cylinder head 26 which is located above the hole 25a.

[0067] The cylinder body 24 is provided with the outlet 80o of the cooling passage 80. The outlet 80o is connected to the cylinder body cooling passage 82. The outlet 80o is disposed leftward of the vehicle center line CL in front view of the vehicle. The outlet 80o is disposed forward of the third cylinder 33. The outlet 80o is opened obliquely downward and forward. Up to this point, how the water passages of the internal combustion engine 20 are arranged has been described.

[0068] As illustrated in FIG. 7, the radiator 54 is disposed forward of the internal combustion engine 20. The radiator 54 is disposed forward of the cylinder body 24, the cylinder head 26 and the head cover 28. The radiator 54 is inclined forward. An upper end portion 54t of the radiator 54 is located forward of a lower end portion 54s of the radiator 54. A fan 55 is disposed rearward of the radiator 54. As illustrated in FIG. 6, in front view of the vehicle, the inlet tank 54b is disposed leftward of the radiator main body 54a, and the outlet tank 54c is disposed rightward of the radiator main body 54a. In front view of the vehicle, the inlet tank 54b is disposed leftward of the vehicle center line CL, and the outlet tank 54c is disposed rightward of the vehicle center line CL. The inlet 54i of the radiator 54 is provided at a lower end portion of the inlet tank 54b. The outlet 54o of the radiator 54 is provided at a lower end portion of the outlet tank 54c.

[0069] The thermostat 58 is disposed rightward of the vehicle center line CL in front view of the vehicle. The thermostat 58 is disposed forward of the internal combustion engine 20. The thermostat 58 is disposed forward of the crankcase 22 and the cylinder body 24. The ther-

mostat 58 is disposed below the radiator 54 in front view of the vehicle. The thermostat case 59 of the thermostat 58 has a vertically long and substantially cylindrical shape. In front view of the vehicle, the first inlet 59i1 and the outlet 59o are provided at a right portion of the thermostat case 59, and the second inlet 59i2 is provided at a left portion of the thermostat case 59. The first inlet 59i1 is provided below the second inlet 59i2, and the outlet 59o is provided above the second inlet 59i2.

[0070] The oil cooler 56 cools oil inside the crankcase 22 with the cooling water. The oil cooler 56 is arranged so that heat is exchanged between the cooling water and oil. The oil cooler 56 is attached to the crankcase 22. As illustrated in FIG. 6, the oil cooler 56 is disposed forward of the crankcase 22. The oil cooler 56 has a substantially tubular shape that extends forward. The oil cooler 56 is disposed on the vehicle center line CL in front view of the vehicle. A center 56c of the oil cooler 56 is located below the thermostat 58. An upper end 56t of the oil cooler 56 is located below an upper end 58t of the thermostat 58, and a lower end 56s of the oil cooler 56 is located below a lower end 58s of the thermostat 58. The inlet 56i of the oil cooler 56 is provided rightward of the outlet 56o and above the outlet 56o in front view of the vehicle.

[0071] The outlet 80o of the cooling passage 80 of the internal combustion engine 20 and the inlet 54i of the radiator 54 are connected to each other through water piping 72A. As used herein, the term "water piping" includes, for example, a pipe, a hose, a tube, a joint, and a combination thereof. The water piping 72A is disposed leftward of the vehicle center line CL in front view of the vehicle.

[0072] The outlet 54o of the radiator 54 and the first inlet 59i1 of the thermostat 58 are connected to each other through water piping 73A. The outlet 59o of the thermostat 58 and the suction port 52i of the water pump 52 are connected to each other through water piping 73B. The water piping 73A and the water piping 73B are disposed rightward of the vehicle center line CL in front view of the vehicle. A portion 73A1 of the water piping 73A overlaps with the water piping 73B in front view of the vehicle. As illustrated in FIG. 7, the portion 73A1 of the water piping 73A is disposed forward of the water piping 73B. Another portion 73A2 of the water piping 73A is disposed below the water piping 73B. Although not illustrated, the portion 73A2 of the water piping 73A overlaps with the water piping 73B in plan view of the vehicle.

[0073] As illustrated in FIG. 6, the outlet 80o of the cooling passage 80 of the internal combustion engine 20 and the inlet 56i of the oil cooler 56 are connected to each other through water piping 74A. The outlet 56o of the oil cooler 56 and the second inlet 59i2 of the thermostat 58 are connected to each other through water piping 74B. In front view of the vehicle, the water piping 74A is first extended downward from the outlet 80o, and then the water piping 74A is bent rightward and subsequently bent downward so as to be connected to the inlet 56i. In front view of the vehicle, the water piping 74B is first ex-

tended leftward from the outlet 56o, and then the water piping 74B is bent upward, extended upward and subsequently bent rightward so as to be connected to the second inlet 59i2. A portion 74B1 of the water piping 74B overlaps with the water piping 74A in front view of the vehicle. As illustrated in FIG. 11, the portion 74B1 of the water piping 74B is disposed forward of the water piping 74A. Another portion 74B2 of the water piping 74B is disposed below the water piping 74A. Although not illustrated, the portion 74B2 of the water piping 74B overlaps with the water piping 74A in plan view of the vehicle.

[0074] The above-mentioned second passage 72 (see FIG. 4) preferably includes the water piping 72A. The upstream passage 73a and the downstream passage 73b of the third passage 73 preferably include the water piping 73A and the water piping 73B, respectively. The upstream passage 74a and the downstream passage 74b of the oil cooler passage 74 preferably include the water piping 74A and the water piping 74B, respectively. In the structure described in this embodiment, one end of the water piping 74A is connected to the outlet 80o, which means that the upstream passage 74a of the oil cooler passage 74 is connected to an upstream end of the second passage 72. Alternatively, one end of the water piping 74A may be connected to the water piping 72A instead of being connected to the outlet 80o.

[0075] As illustrated in FIG. 6, the water piping 74A and the water piping 74B are thinner than the water piping 72A, the water piping 73A and the water piping 73B. Thus, the oil cooler passage 74 has a flow passage cross-sectional area smaller than flow passage cross-sectional areas of the second passage 72 and the third passage 73.

[0076] Note that reference signs "78" and "79" denote a recovery tank and an oil filter, respectively. The recovery tank 78 and the oil filter 79 are disposed forward of the internal combustion engine 20 similarly to the thermostat 58 and the oil cooler 56. The oil cooler 56 is disposed rightward of the recovery tank 78 and leftward of the oil filter 79 in front view of the vehicle. The oil cooler 56 is disposed between the recovery tank 78 and the oil filter 79 in front view of the vehicle.

[0077] As illustrated in FIG. 12, the cylinder head 26 is provided with exhaust pipe connection ports 97 connected to the exhaust ports 96. The internal combustion engine 20 preferably includes the first exhaust pipe 101, the second exhaust pipe 102 and the third exhaust pipe 103 which are connected to the exhaust pipe connection ports 97. The first, second and third exhaust pipes 101, 102 and 103 are communicated with the combustion chambers 43 (see FIG. 2) of the first, second and third cylinders 31, 32 and 33, respectively. The exhaust pipe connection ports 97 are provided at a front portion of the cylinder head 26, and therefore, the first, second and third exhaust pipes 101, 102 and 103 are connected to the front portion of the cylinder head 26. As illustrated in FIG. 7, in side view of the vehicle, the first exhaust pipe 101 preferably includes: an upper portion 101A extending obliquely downward and forward from the cylinder head

26; first and second intermediate portions 101 B and 101C extending obliquely downward and rearward from the upper portion 101A; and a lower portion 101 D extending rearward from the second intermediate portion 101C. As illustrated in FIGS. 7 and 11, in side view of the vehicle, the second exhaust pipe 102 preferably includes: an upper portion 102A extending obliquely downward and forward from the cylinder head 26; first and second intermediate portions 102B and 102C extending obliquely downward and rearward from the upper portion 102A; and a lower portion 102D extending rearward from the second intermediate portion 102C. As illustrated in FIG. 11, in side view of the vehicle, the third exhaust pipe 103 preferably includes: an upper portion 103A extending obliquely downward and forward from the cylinder head 26; first and second intermediate portions 103B and 103C extending obliquely downward and rearward from the upper portion 103A; and a lower portion 103D extending rearward from the second intermediate portion 103C. As illustrated in FIG. 12, in front view of the vehicle, the first intermediate portions 101 B, 102B and 103B extend obliquely downward and rightward, and the second intermediate portions 101C, 102C and 103C extend obliquely downward and leftward.

[0078] As illustrated in FIG. 11, the thermostat 58 and the oil cooler 56 are disposed rearward of the first, second and third exhaust pipes 101, 102 and 103. More specifically, the thermostat 58 and the oil cooler 56 are disposed rearward of the intermediate portions 101 B and 101C of the first exhaust pipe 101, the intermediate portions 102B and 102C of the second exhaust pipe 102, and the intermediate portions 103B and 103C of the third exhaust pipe 103. The thermostat 58 is disposed between the crankcase 22 and the exhaust pipes 101 to 103 in a front-rear direction.

[0079] As illustrated in FIG. 7, in side view of the vehicle, the water piping 73B is disposed between the crankcase 22 and the first to third exhaust pipes 101 to 103, and between the cylinder body 24 and the first to third exhaust pipes 101 to 103. As illustrated in FIG. 11, in side view of the vehicle, the water piping 74A and the water piping 74B are also disposed between the crankcase 22 and the first to third exhaust pipes 101 to 103, and between the cylinder body 24 and the first to third exhaust pipes 101 to 103. As illustrated in FIG. 7, in side view of the vehicle, the water piping 73B, in particular, is disposed compactly within a space defined by the crankcase 22, the cylinder body 24, and the upper portion 101A and the first intermediate portion 101B of the first exhaust pipe 101. As illustrated in FIG. 11, in side view of the vehicle, a portion of the water piping 72A is disposed rearward of the upper portions 101A to 103A and the first intermediate portions 101 B to 103B of the first to third exhaust pipes 101 to 103, and another portion of the water piping 72A intersects with the first to third exhaust pipes 101 to 103 and then connects with the inlet 54i of the radiator 54. As illustrated in FIG. 7, in side view of the vehicle, a portion of the water piping 73A is disposed

rearward of the first intermediate portions 101 B to 103B of the first to third exhaust pipes 101 to 103, and another portion of the water piping 73A intersects with the first to third exhaust pipes 101 to 103 and then connects with the outlet 54o of the radiator 54.

[0080] Up to this point, the structures of the internal combustion engine 20 and the cooling apparatus 50 have been described. Next, how the cooling water flows in the cooling apparatus 50 will be described.

[0081] During a warming up operation performed immediately after startup of the internal combustion engine 20, the cooling water has a low temperature. In this case, the temperature of the cooling water is lower than the reference temperature of the thermostat 58, and the communication between the first inlet 59i1 and the outlet 59o of the thermostat 58 is shut off. In contrast, when the temperature of the cooling water is equal to or higher than the reference temperature of the thermostat 58 after the warming up operation, the first inlet 59i1 and the outlet 59o of the thermostat 58 are communicated with each other, thus performing an operation of allowing the cooling water that has cooled the internal combustion engine 20 to radiate heat through the radiator 54 (which will hereinafter be referred to as a "normal operation"). Next, how the cooling water flows during the warming up operation and the normal operation will be described.

[0082] First, how the cooling water flows during the warming up operation will be described. As indicated by arrows in FIG. 9, the cooling water discharged from the water pump 52 goes into the introduction passage 71, and then flows into the cylinder head cooling passage 81 from the introduction passage 71.

[0083] The cooling water, which has flowed into the cylinder head cooling passage 81, flows leftward through the cylinder head cooling passage 81 in front view of the vehicle. In this case, some of the cooling water flows into the cylinder body cooling passage 82 through the hole 25b located rightward of the first cylinder 31 and the holes 25b located rearward of the first, second and third cylinders 31, 32 and 33 in front view of the vehicle. The remainder of the cooling water flows into the cylinder body cooling passage 82 through the holes 25b located leftward of the third cylinder 33 in front view of the vehicle. Thus, the cooling water inside the cylinder head cooling passage 81 sequentially flows into the cylinder body cooling passage 82 while flowing leftward in front view of the vehicle.

[0084] The cooling water inside the cylinder body cooling passage 82 flows leftward in front view of the vehicle. The cooling water that has reached a region surrounding the third cylinder 33 then flows out forward from the outlet 80o.

[0085] Since the communication between the first inlet 59i1 and the outlet 59o of the thermostat 58 is shut off, the cooling water, which has flowed out from the outlet 80o of the cooling passage 80, does not flow into the radiator 54. As indicated by solid arrows in FIG. 6, the cooling water, which has flowed out from the outlet 80o,

flows through the water piping 74A, the oil cooler 56 and the water piping 74B, and then flows into the thermostat 58 from the second inlet 59i2. The cooling water, which has flowed into the thermostat 58, flows out from the outlet 59o, flows through the water piping 73B, and is then sucked into the water pump 52. From then onwards, the cooling water circulates in a similar manner.

[0086] Next, how the cooling water flows during the normal operation will be described. Similarly to the warming up operation, the cooling water discharged from the water pump 52 passes through the introduction passage 71 and the cooling passage 80, and then flows out from the outlet 80o (see FIG. 9).

[0087] In the thermostat 58, the first inlet 59i1 and the outlet 59o are communicated with each other, and the second inlet 59i2 and the outlet 59o are communicated with each other. As indicated by broken arrows in FIG. 6, some of the cooling water that has flowed out from the outlet 80o flows into the inlet tank 54b of the radiator 54 through the water piping 72A. The cooling water, which has flowed into the inlet tank 54b, flows through the radiator main body 54a rightward in front view of the vehicle. In this case, the cooling water inside the radiator main body 54a exchanges heat with air outside the radiator main body 54a, and is thus cooled by this air. The cooling water, which has flowed through the radiator main body 54a, flows into the outlet tank 54c. The cooling water inside the outlet tank 54c flows through the water piping 73A, and then flows into the thermostat 58 from the first inlet 59i1.

[0088] As indicated by the solid arrows in FIG. 6, the remainder of the cooling water that has flowed out from the outlet 80o flows through the oil cooler passage 74. Specifically, this cooling water flows through the water piping 74A, and then flows into the oil cooler 56. The cooling water cools the oil in the oil cooler 56. The cooling water that has flowed out from the oil cooler 56 flows through the water piping 74B, and then flows into the thermostat 58 from the second inlet 59i2.

[0089] The cooling water, which has flowed into the thermostat 58 from the first inlet 59i1, and the cooling water, which has flowed into the thermostat 58 from the second inlet 59i2, flow out from the outlet 59o, and are then sucked into the water pump 52 through the water piping 73B. From then onwards, the cooling water circulates in a similar manner.

[0090] As described above, in the cooling apparatus 50, the cooling water flows through the cooling passage 80, thus cooling the internal combustion engine 20 (see FIG. 9). The cooling water discharged from the water pump 52 is guided to the cylinder head cooling passage 81 through the first passage 71 (hereinafter referred to as the "introduction passage 71"), and then flows into the cylinder body cooling passage 82 via the connection passage 83. The cooling water flows through the cylinder head cooling passage 81 before flowing through the cylinder body cooling passage 82. Therefore, the cooling water having a low temperature flows through the cylin-

der head cooling passage 81. Accordingly, the cooling apparatus 50 can effectively cool the cylinder head 26. Of the components of the internal combustion engine 20, the cylinder head 26 is located close to the combustion chambers 43. Hence, the cooling apparatus 50 can effectively cool adjacent regions of the combustion chambers 43 of the internal combustion engine 20. The effect of suppressing knocking, for example, can be obtained by effectively cooling the adjacent regions of the combustion chambers 43. The introduction passage 71 is provided in the cylinder body 24, and therefore, there is no need for long water piping through which the water pump 52 and the cylinder head cooling passage 81 are connected to each other. As a result, the cooling apparatus 50 can effectively cool the adjacent regions of the combustion chambers 43 of the internal combustion engine 20 while preventing an increase in length of water piping through which the water pump 52 and the cylinder head cooling passage 81 are connected to each other.

[0091] The introduction passage 71 is provided at a position located farther away from the cylinders 31 to 33 than the cylinder body cooling passage 82. A portion of the cylinder body cooling passage 82 is provided between the cylinder 31 and the introduction passage 71. Therefore, the cooling water flowing through the introduction passage 71 is less prone to being heated than the cooling water flowing through the cylinder body cooling passage 82. Consequently, the cooling water having a lower temperature can be introduced into the cylinder head cooling passage 81.

[0092] The introduction passage 71 extends substantially parallel to the axis 31 c of the cylinder 31. According to the present embodiment, the introduction passage 71 has such a structure, thus making it possible to provide the suitable introduction passage 71 inside the cylinder body 24.

[0093] As already mentioned above, the flow passage cross-sectional area of the introduction passage 71 is smaller than the flow passage cross-sectional area of the cylinder body cooling passage 82. In the cross section of the cylinder body 24 which is orthogonal to the cylinder axis 31 c, the maximum length 71 L of the introduction passage 71 is smaller than the inner diameter 31 D of the cylinder 31 (see FIG. 10). According to the present embodiment, the surface area of the introduction passage 71 is smaller than the surface area of the cylinder body cooling passage 82, and thus the cooling water flowing through the introduction passage 71 is less prone to being warmed than the cooling water flowing through the cylinder body cooling passage 82. Consequently, the cooling water having a lower temperature can be introduced into the cylinder head cooling passage 81.

[0094] In the present embodiment, the water pump 52 is attached to the crankcase 22. Therefore, a distance between the water pump 52 and the introduction passage 71 can be shortened. Accordingly, when the discharge port 52o of the water pump 52 and the inlet 71 i of the introduction passage 71 are connected to each other

through water piping, this water piping can be reduced in length.

[0095] Although the discharge port 52o of the water pump 52 and the inlet 71i of the introduction passage 71 may be connected to each other through short water piping, the discharge port 52o of the water pump 52 is directly connected to the inlet 71 i of the introduction passage 71 in the present embodiment. Accordingly, the present embodiment can eliminate water piping through which the discharge port 52o of the water pump 52 and the inlet 71 i of the introduction passage 71 are connected to each other.

[0096] As illustrated in FIG. 3, the water pump 52 is connected to the balancer 90 so as to be driven by the balancer 90. The balancer 90 can be utilized as a driving source for the water pump 52, and therefore, there is no need for a dedicated motor for driving the water pump 52. Space located laterally of the balancer 90 can be effectively utilized as installation space for the water pump 52, thus making it possible to compactly dispose the water pump 52.

[0097] It is apparent from FIG. 9 that as viewed from the direction of the axis 31 c, the axis 32c of the second cylinder 32 corresponds to a midpoint of a line connecting the axis 31 c of the first cylinder 31 rightward of the second cylinder 32 and the axis 33c of the third cylinder 33 leftward of the second cylinder 32. As viewed from the direction of the axis 31c, the axis 32c is located between the inlet 71i of the introduction passage 71 and the outlet 80o of the cooling passage 80. In front view of the vehicle, the inlet 71i of the introduction passage 71 is located rightward of the axis 32c, and the outlet 80o of the cooling passage 80 is located leftward of the axis 32c. In this manner, the inlet 71i of the introduction passage 71 and the outlet 80o of the cooling passage 80 are disposed far away from each other. According to the present embodiment, there is no need to concern about interference between the inlet 71 i of the introduction passage 71 and the outlet 80o of the cooling passage 80, and therefore, sufficient space for the introduction passage 71 can be easily ensured in the cylinder body 24.

[0098] In the present embodiment, the cylinder body 24 extends obliquely upward and forward from the crankcase 22, the exhaust pipes 101 to 103 extend obliquely downward and forward from the cylinder head 26 and then extend obliquely downward and rearward in side view of the vehicle, and the radiator 54 is disposed forward of the internal combustion engine 20. In general, in a motorcycle having such a structure, water piping through which the internal combustion engine 20, the radiator 54 and the water pump 52 are connected to each other is prone to interfere with the exhaust pipes 101 to 103, thus making it difficult to perform layout of the overall water piping. However, according to the present embodiment, there is no need for water piping through which the water pump 52 and the cooling passage 80 of the internal combustion engine 20 are connected to each other, thus making it possible to compactly dispose the

water piping 72A, 73A and 73B while preventing interference of the water piping 72A, 73A and 73B with the exhaust pipes 101 to 103.

[0099] As illustrated in FIG. 6, when a region located rightward of the vehicle center line CL in front view of the vehicle and a region located leftward of the vehicle center line CL in front view of the vehicle are defined as a first region and a second region, respectively, the outlet 54o of the radiator 54 and the water pump 52 are disposed in the first region, and the inlet 54i of the radiator 54 and the outlet 80o of the cooling passage 80 are disposed in the second region. In front view of the vehicle, the water piping 73A and 73B connected to the outlet 54o of the radiator 54 and the water pump 52 (which will hereinafter be referred to as "first water piping 73A and 73B") is disposed rightward of the vehicle center line CL, and the water piping 72A connected to the inlet 54i of the radiator 54 and the outlet 80o of the cooling passage 80 (which will hereinafter be referred to as "second water piping 72A") is disposed leftward of the vehicle center line CL. In this manner, the first water piping 73A and 73B and the second water piping 72A are disposed far away from each other, thus making it possible to compactly dispose the first water piping 73A and 73B and the second water piping 72A while preventing interference between the first water piping 73A and 73B and the second water piping 72A. Alternatively, the locations of the first water piping 73A and 73B and the second water piping 72A may be reversed. For example, when the region located leftward of the vehicle center line CL in front view of the vehicle and the region located rightward of the vehicle center line CL in front view of the vehicle are defined as the first region and the second region, respectively, the outlet 54o of the radiator 54 and the water pump 52 may be disposed in the first region, and the inlet 54i of the radiator 54 and the outlet 80o of the cooling passage 80 may be disposed in the second region. In that case, in front view of the vehicle, the first water piping 73A and 73B connected to the outlet 54o of the radiator 54 and the water pump 52 may be disposed leftward of the vehicle center line CL, and the second water piping 72A connected to the outlet 80o of the cooling passage 80 and the inlet 54i of the radiator 54 may be disposed rightward of the vehicle center line CL. Also in that case, effects similar to those mentioned above are obtainable.

[0100] As illustrated in FIG. 9, in front view of the vehicle, the introduction passage 71 is disposed rightward of the rightmost cylinder 31. A relatively large space can be ensured in a portion of the cylinder body 24 which is located laterally of the cylinders 31 to 33. The introduction passage 71 is disposed laterally of the cylinders 31 to 33, thus making it possible to easily provide the suitable introduction passage 71 inside the cylinder body 24. The cooling water flowing through the introduction passage 71 is less prone to being heated because the introduction passage 71 is disposed laterally of the cylinders 31 to 33. Alternatively, the introduction passage 71 may be disposed leftward of the leftmost cylinder 33 in front view

of the vehicle. Also in that case, effects similar to those mentioned above are obtainable.

[0101] In front view of the vehicle, the introduction passage 71 is disposed rightward of the cylinders 31 to 33, and the cylinder head cooling passage 81 and the cylinder body cooling passage 82 are arranged so that the cooling water flows therethrough leftward. When a rightward end and a leftward end in front view of the vehicle are defined as a first end and a second end, respectively, the introduction passage 71 is disposed closer to the first end than the cylinders 31 to 33, and the cylinder head cooling passage 81 and the cylinder body cooling passage 82 are arranged so that the cooling water flows therethrough toward the second end. As a result, the cooling water is likely to flow smoothly through the cylinder head cooling passage 81 and the cylinder body cooling passage 82, thus making it possible to suitably cool the internal combustion engine 20. Alternatively, in front view of the vehicle, the introduction passage 71 may be disposed leftward of the cylinders 31 to 33, and the cylinder head cooling passage 81 and the cylinder body cooling passage 82 may be arranged so that the cooling water flows therethrough rightward. When the leftward end and the rightward end in front view of the vehicle are defined as the first end and the second end, respectively, the introduction passage 71 may be disposed closer to the first end than the cylinders 31 to 33, and the cylinder head cooling passage 81 and the cylinder body cooling passage 82 may be arranged so that the cooling water flows therethrough toward the second end. Also in that case, effects similar to those mentioned above are obtainable.

REFERENCE SIGNS LIST

[0102]

20	internal combustion engine
22	crankcase
24	cylinder body
26	cylinder head
52	water pump
54	radiator
71	first passage (introduction passage)
80	cooling passage
81	cylinder head cooling passage
82	cylinder body cooling passage
83	connection passage

Claims

1. A cooling apparatus (50) for cooling an internal combustion engine (20) comprising: a crankcase (22) in which a crankshaft (36) is contained; a cylinder body (24) comprising a cylinder (31) provided therein; and a cylinder head (26) connected to the cylinder body (24) and defining a portion of a combustion chamber

(43),

the cooling apparatus (50) comprising:

a radiator (54) that cools cooling water;
 a water pump (52) that conveys the cooling water cooled by the radiator (54);
 a cooling passage (80) that comprises a cylinder head cooling passage (81) provided in the cylinder head (26), a cylinder body cooling passage (82) provided in the cylinder body (24), and a connection passage (83) through which the cylinder head cooling passage (81) and the cylinder body cooling passage (82) are connected to each other; and
 an introduction passage (71) provided in the cylinder body (24) to guide the cooling water to the cylinder head cooling passage (81) of the cooling passage (80).

2. The cooling apparatus (50) according to Claim 1, wherein the introduction passage (71) is provided at a position farther away from the cylinder (31) than the cylinder body cooling passage (82).
3. The cooling apparatus (50) according to Claim 2, wherein a portion of the cylinder body cooling passage (82) is provided between the cylinder (31) and the introduction passage (71).
4. The cooling apparatus (50) according to any one of Claims 1 to 3, wherein the cylinder body cooling passage (82) consists of a water jacket provided around the cylinder (31), and wherein the introduction passage (71) extends substantially parallel to an axis (31 c) of the cylinder (31).
5. The cooling apparatus (50) according to any one of Claims 1 to 4, wherein the water pump (52) is attached to the crankcase (22).
6. The cooling apparatus (50) according to Claim 5, wherein the internal combustion engine (20) comprises a balancer (90) disposed inside the crankcase (22) and connected to the crankshaft (36), and wherein the water pump (52) is connected to the balancer (90) so as to be driven by the balancer (90).
7. The cooling apparatus (50) according to Claim 5 or 6, wherein the introduction passage (71) comprises an inlet (71 i) through which the cooling water flows in, and wherein the water pump (52) comprises a discharge port (52o) connected to the inlet (71 i) of the introduction passage (71).
8. The cooling apparatus (50) according to Claim 7,

wherein the cylinder body (24) comprises one or more other cylinders (32, 33) arranged in alignment with the cylinder (31),

wherein the cooling passage (80) comprises an outlet (80o) which is provided in the cylinder body (24) and through which the cooling water flows out from the cylinder body cooling passage (82), and

wherein as viewed from a direction of the axis (31 c) of the cylinder (31), a midpoint of a line connecting the axes (31 c, 33c) of endmost ones (31, 33) of the cylinders (31, 32, 33) is located between the inlet (71 i) of the introduction passage (71) and the outlet (80o) of the cooling passage (80).

9. A motorcycle (1) comprising the cooling apparatus (50) according to any one of Claims 1 to 8. 15

10. The motorcycle (1) according to Claim 9, wherein the cylinder body (24) extends obliquely upward and forward from the crankcase (22), wherein the internal combustion engine (20) comprises an exhaust pipe (101) that extends obliquely downward and forward from the cylinder head (26) and then extends obliquely downward and rearward in side view of the motorcycle, and wherein the radiator (54) is disposed forward of the internal combustion engine (20). 20 25

11. The motorcycle (1) according to Claim 10, wherein the radiator (54) comprises: an inlet (54i) through which the cooling water flows in; and an outlet (54o) through which the cooling water flows out, wherein the cooling apparatus (50) comprises: first water piping (73A, 73B) connected to the outlet (54o) of the radiator (54) and the water pump (52); and second water piping (72A) connected to the outlet (80o) of the cooling passage (80) and the inlet (54i) of the radiator (54), and wherein when one of a region located rightward of a motorcycle center line (CL) in front view of the motorcycle and a region located leftward of the motorcycle center line (CL) in front view of the motorcycle is defined as a first region and the other region is defined as a second region, the outlet (54o) of the radiator (54) and the water pump (52) are disposed in the first region, and the inlet (54i) of the radiator (54) and the outlet (80o) of the cooling passage (80) are disposed in the second region. 30 35 40 45

12. A motorcycle (1) comprising the cooling apparatus (50) according to Claim 8, wherein the cylinders (31, 32, 33) are arranged in a lateral direction of the motorcycle (1), and wherein the introduction passage (71) is disposed rightward of a rightmost one (31) of the cylinders (31, 32, 33) in front view of the motorcycle, or disposed leftward of a leftmost one (33) of the cylinders (31, 32, 33) in front view of the motorcycle. 50 55

13. A motorcycle (1) comprising the cooling apparatus (50) according to Claim 8, wherein the cylinders (31, 32, 33) are arranged in a lateral direction of the motorcycle (1), and wherein when one of a rightward end and a leftward end in front view of the motorcycle is defined as a first end and the other end is defined as a second end, the introduction passage (71) is disposed closer to the first end than the cylinders (31, 32, 33), and the cylinder head cooling passage (81) and the cylinder body cooling passage (82) are arranged so that the cooling water flows therethrough toward the second end.

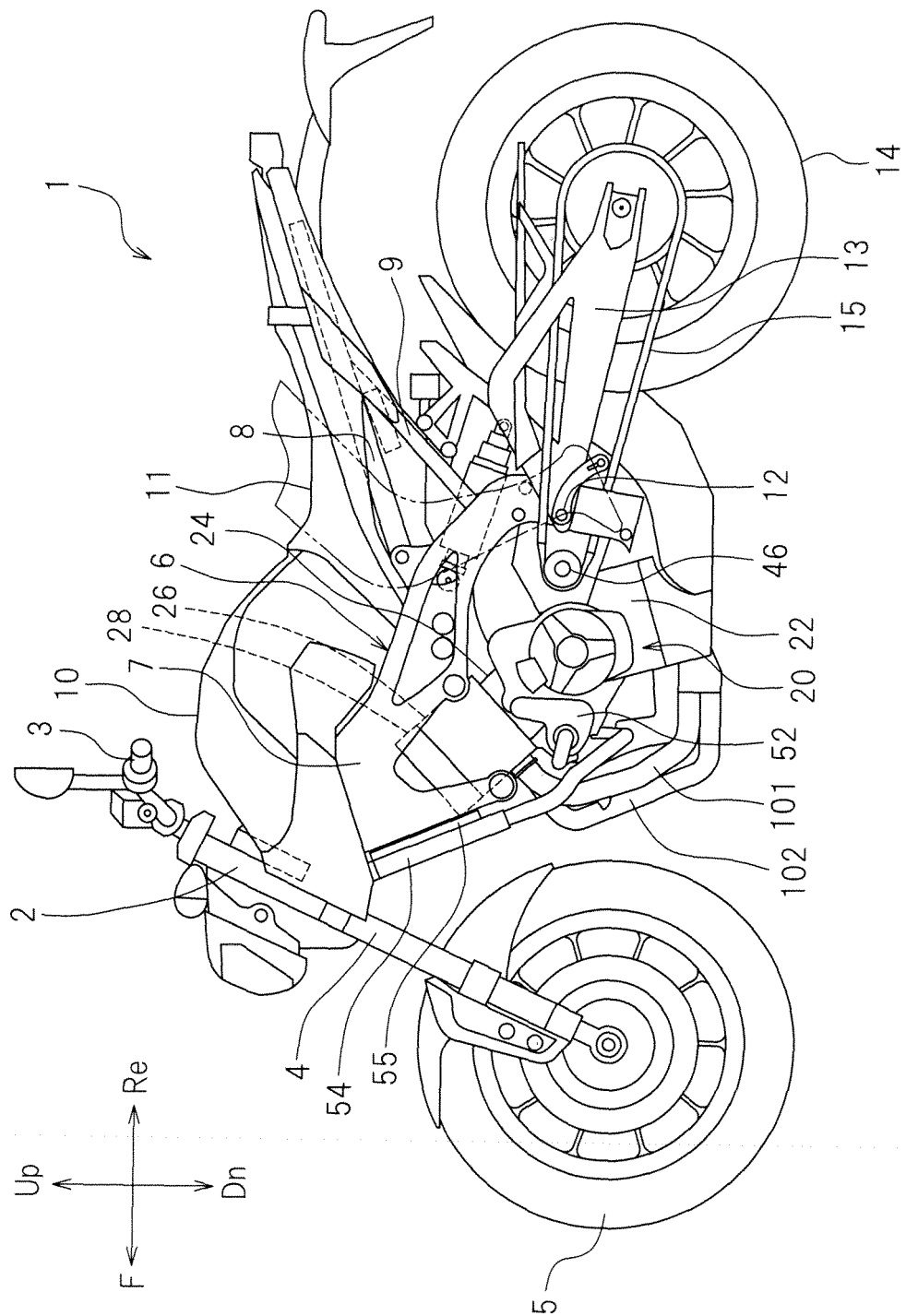


FIG. 1

FIG.2

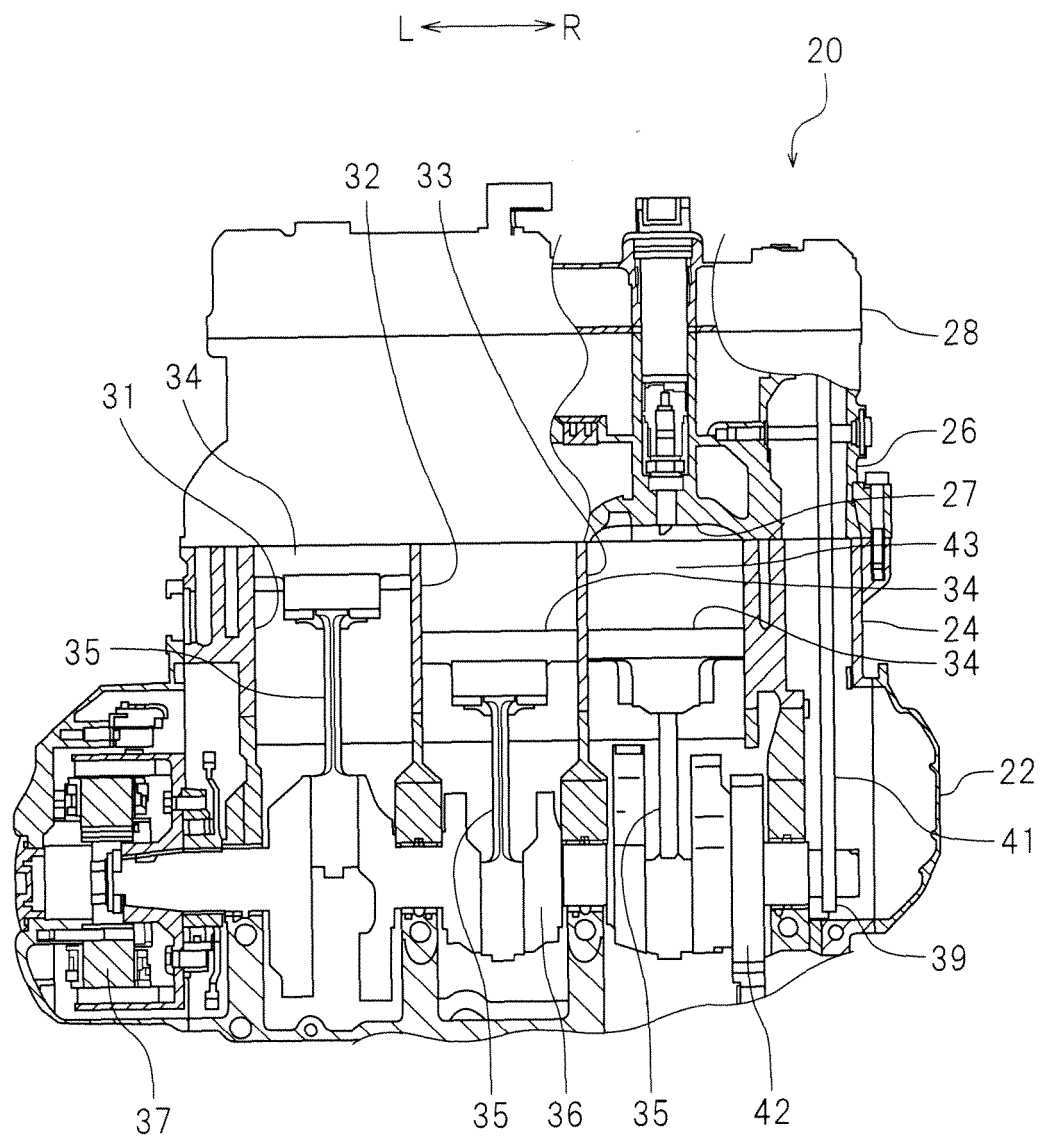


FIG.3

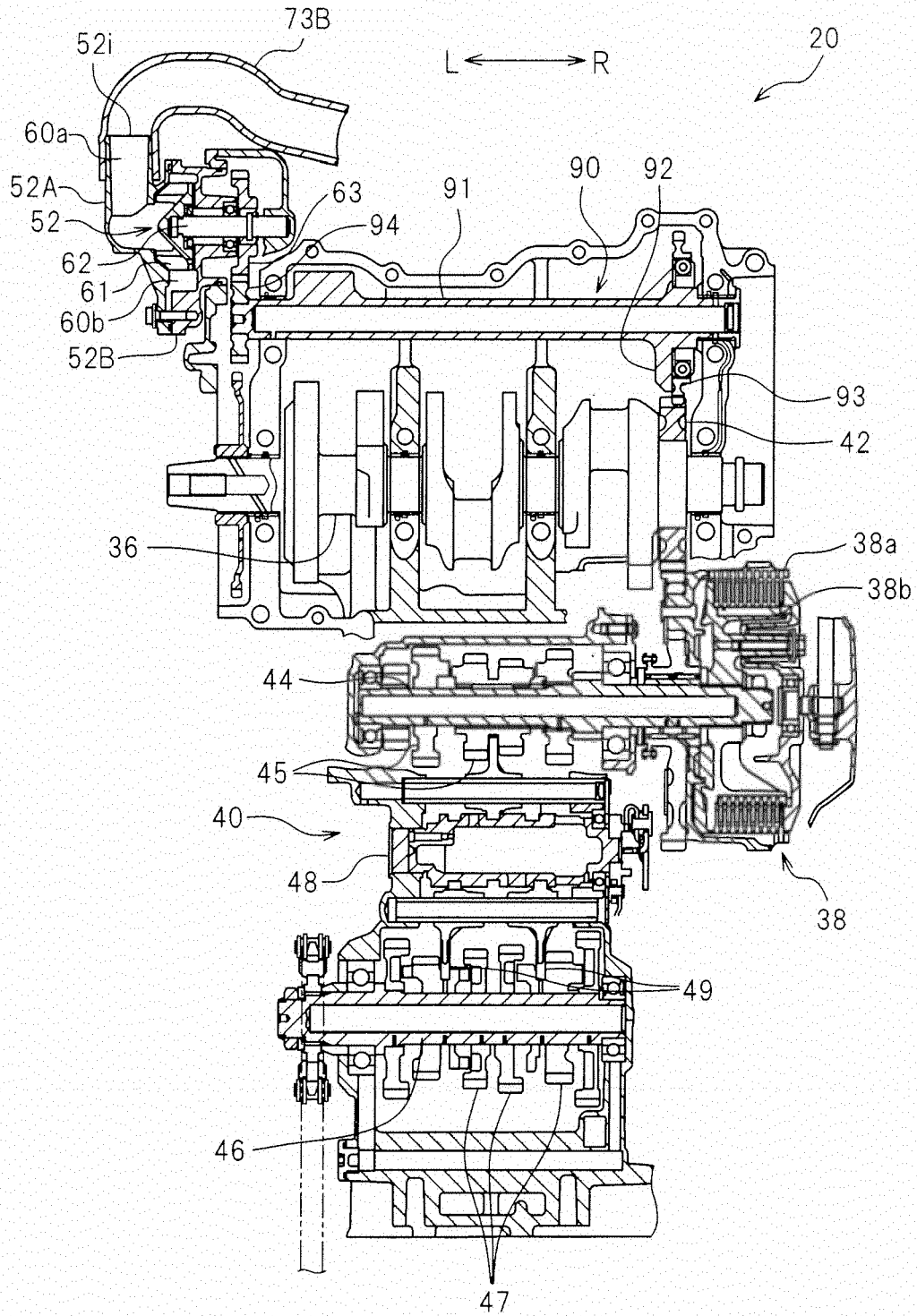
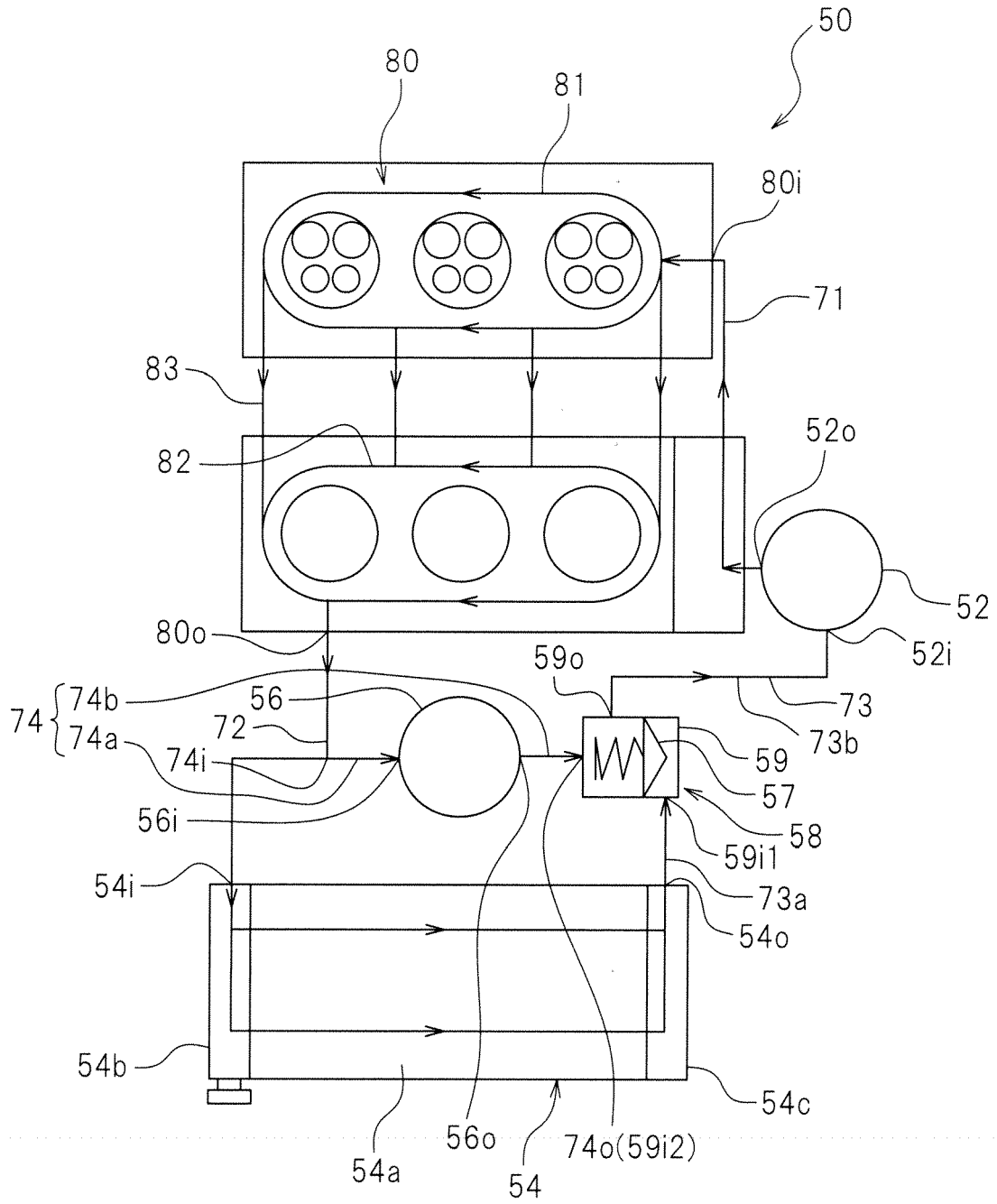


FIG.4



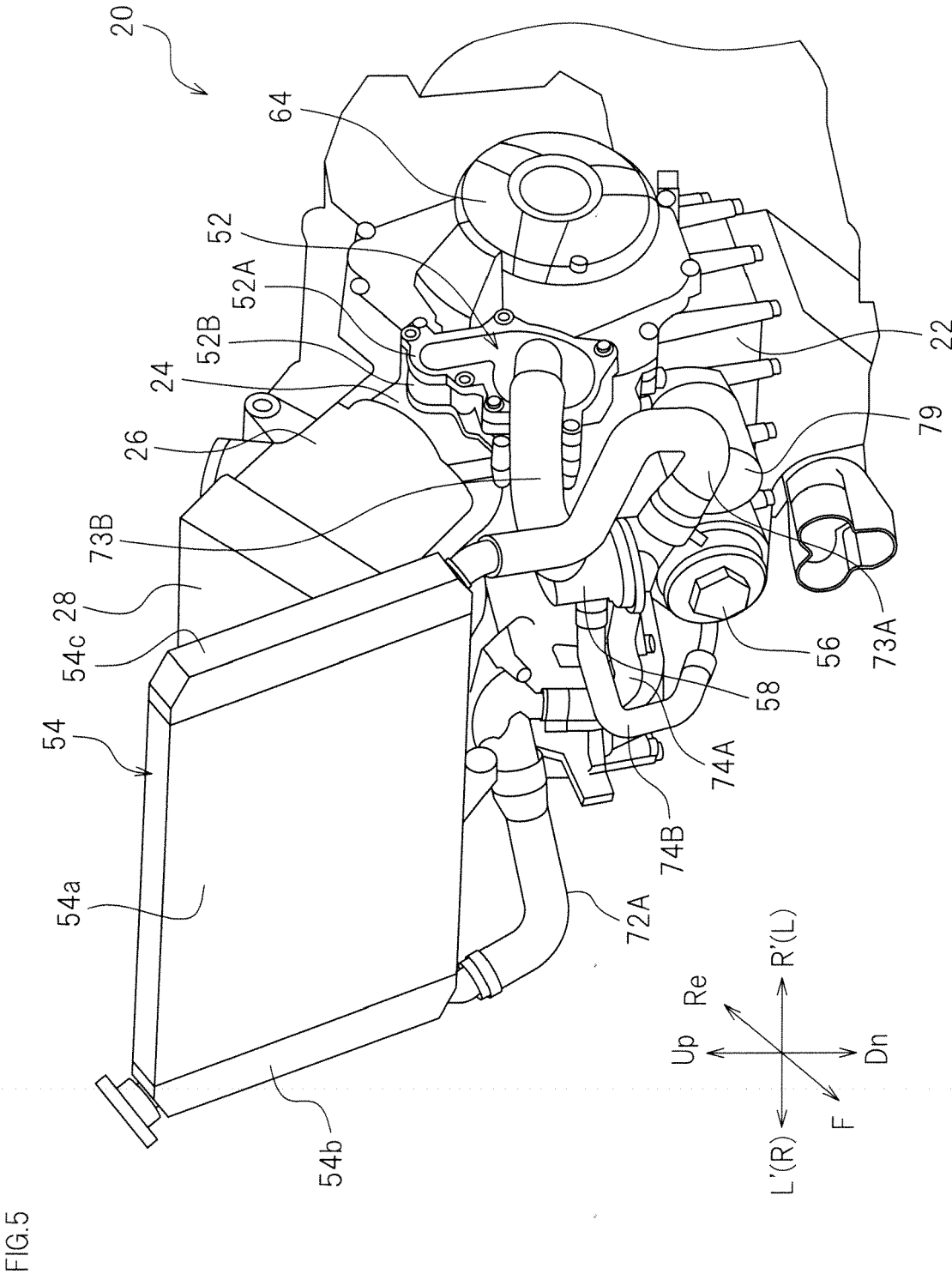


FIG.6

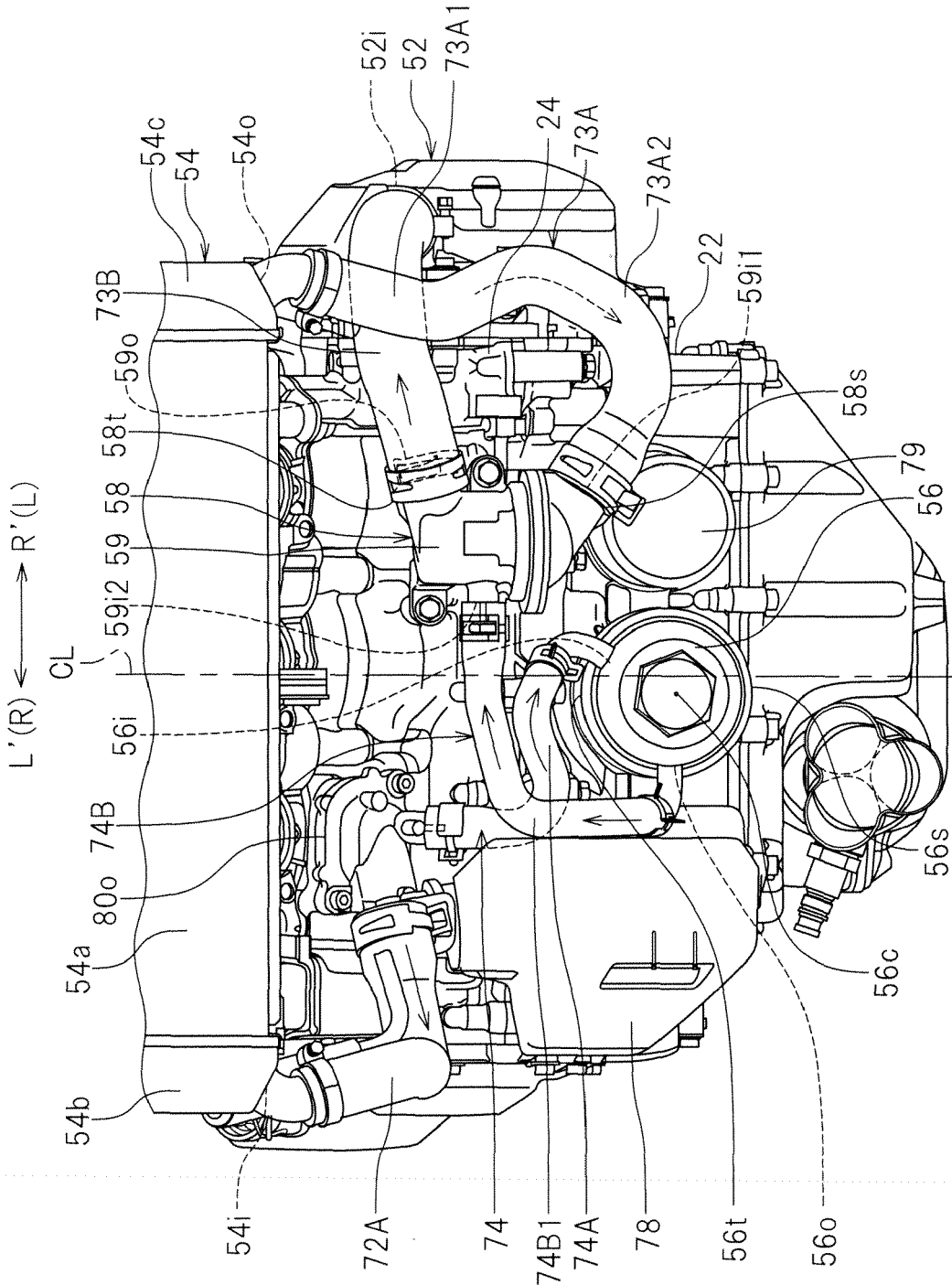


FIG. 7

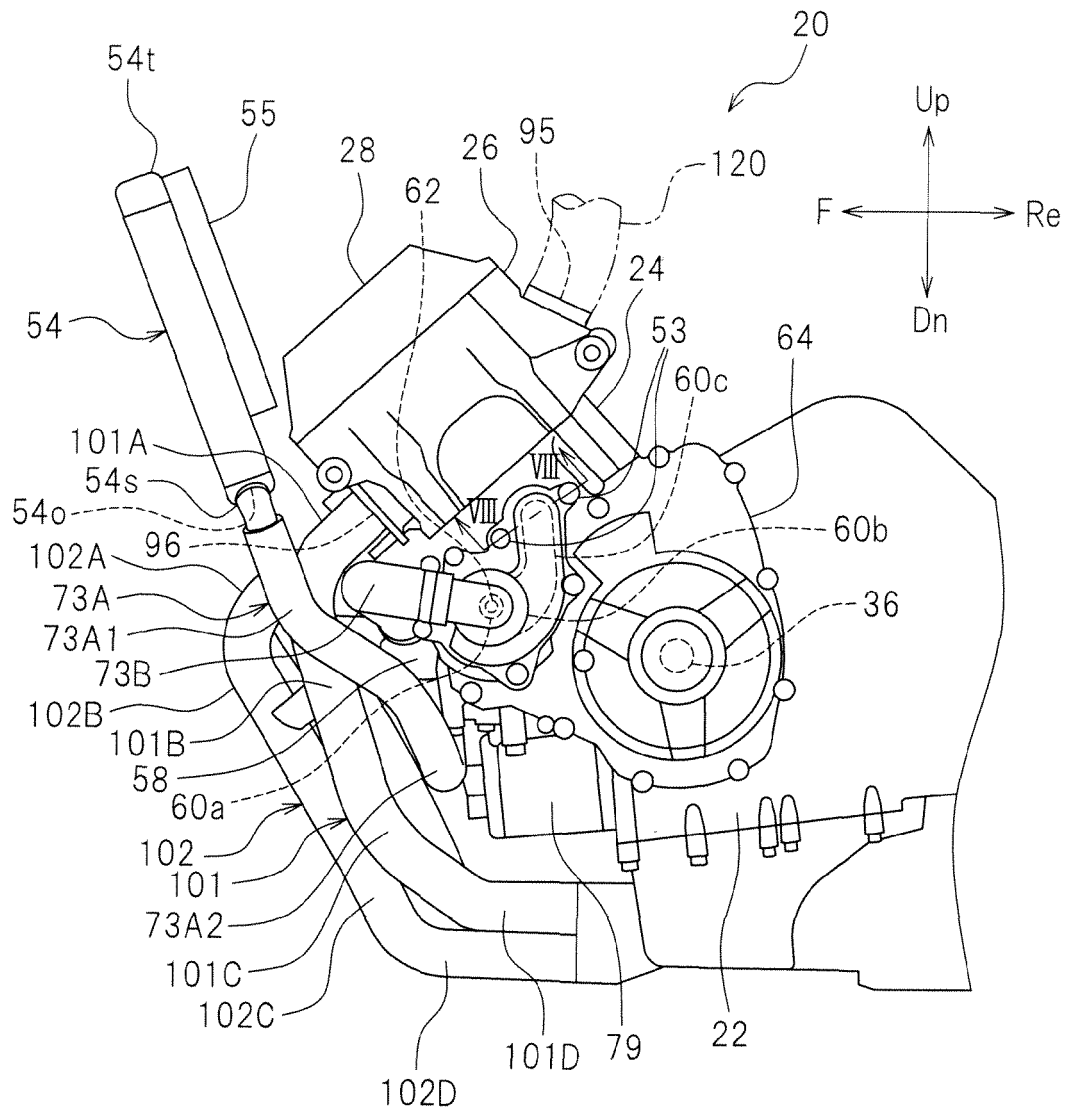


FIG.8

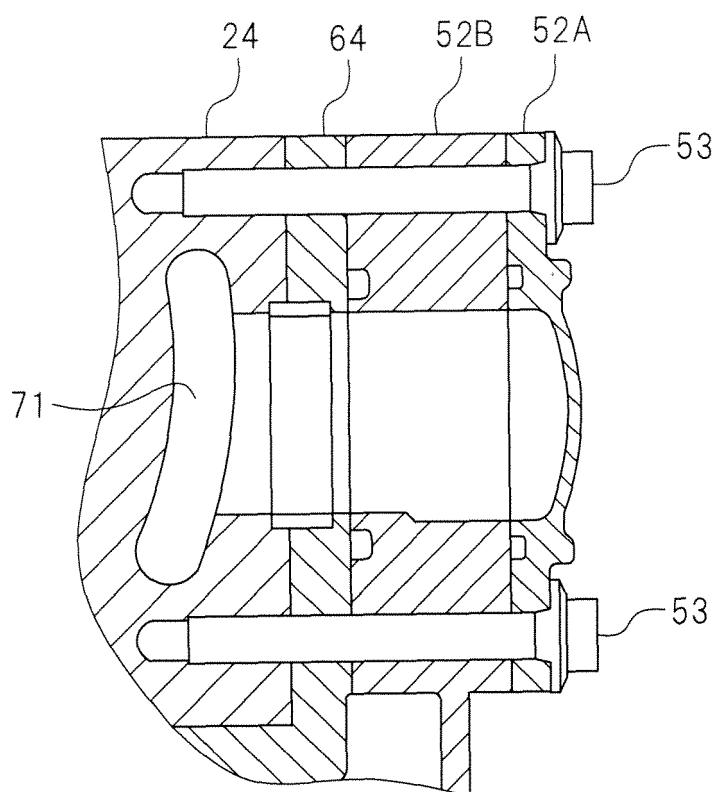


FIG.9

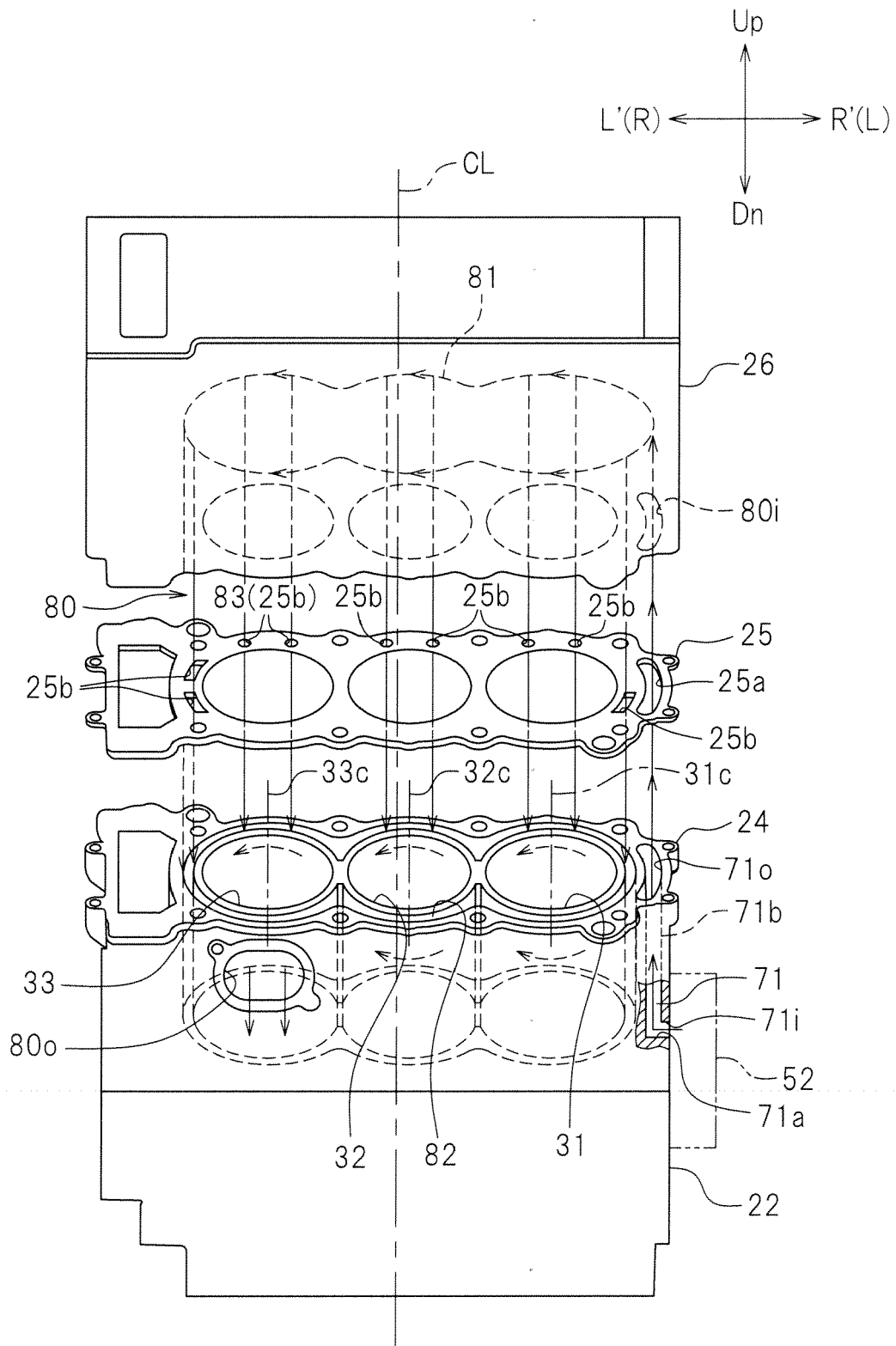


FIG.10

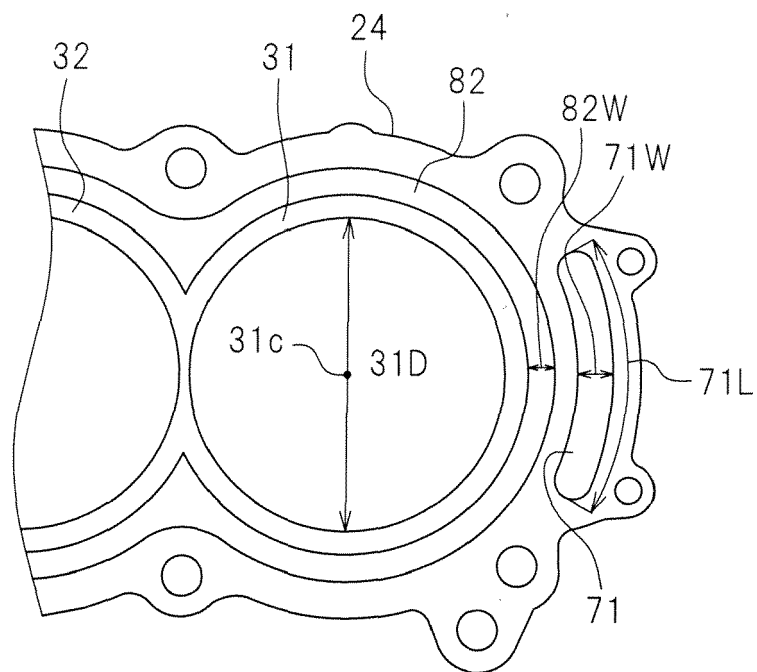


FIG.11

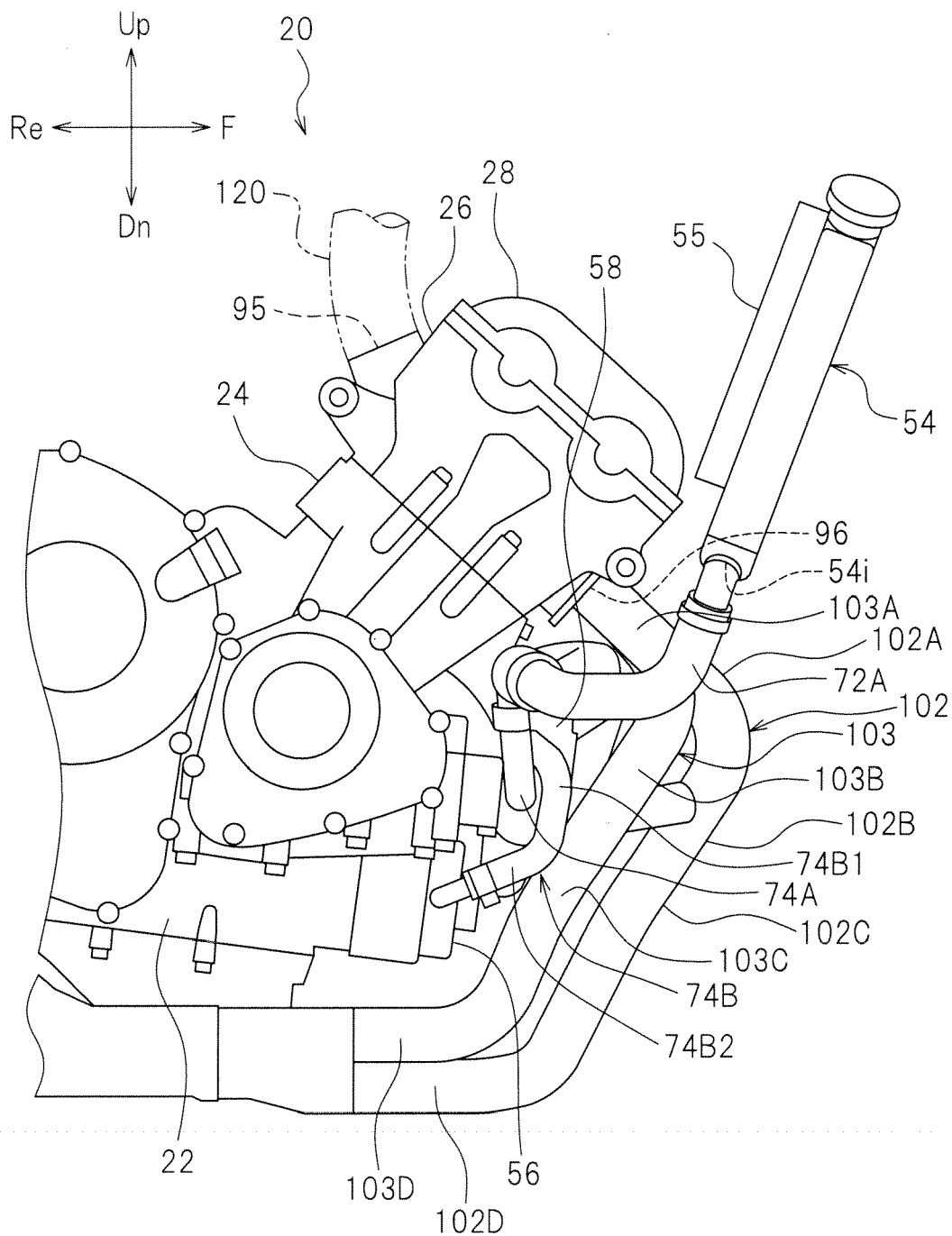
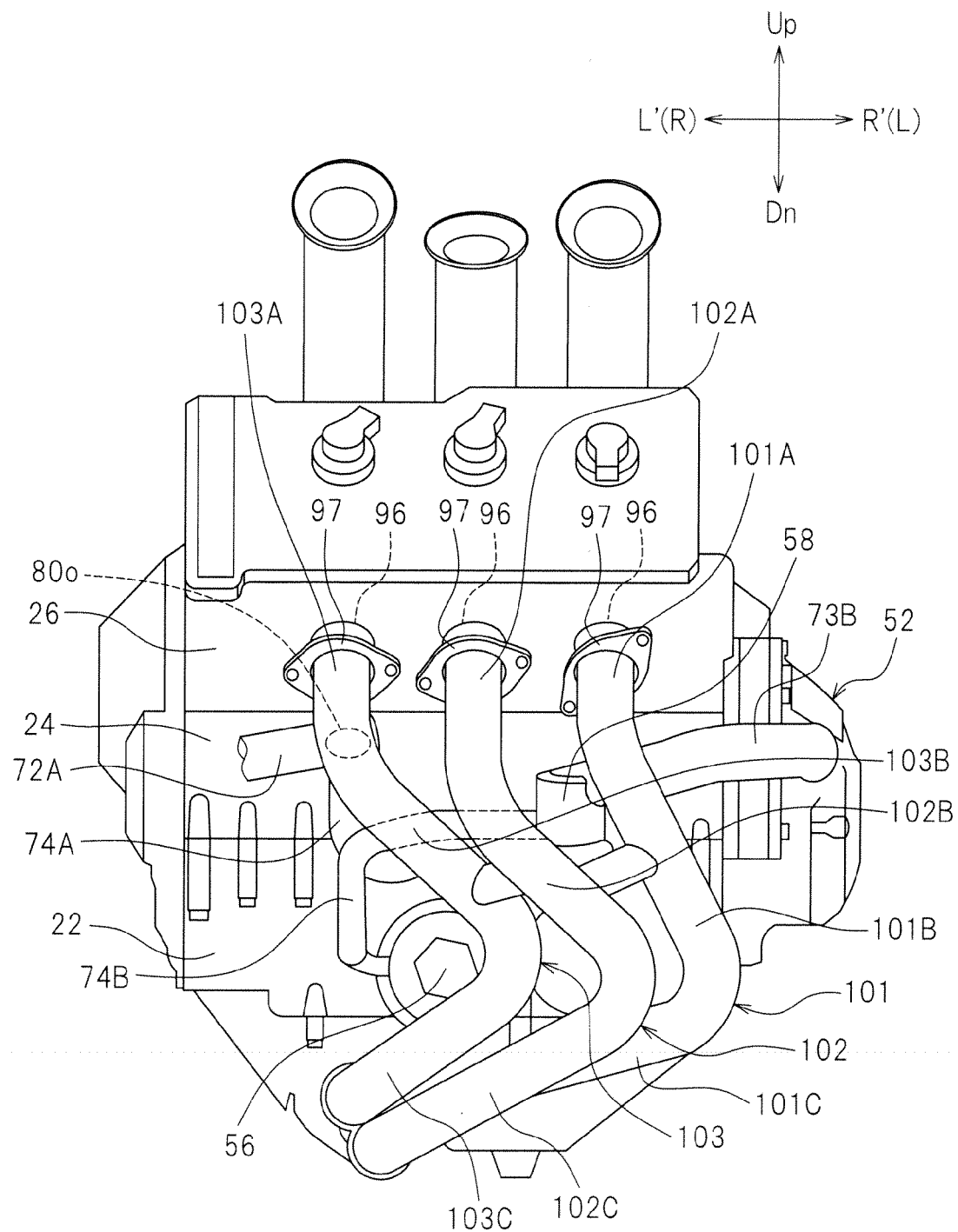


FIG.12



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2007002678 A [0003]
- JP 2007107492 A [0003]