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(54) Recirculated exhaust gas cooling device for internal combustion engine

(57) A part of the exhaust gas of an exhaust manifold (3) of an internal combustion engine is recirculated to an intake manifold (4) through an exhaust gas recirculation passage (18) passing through a cooling box (12). An exhaust gas recirculation valve (31) to regulate the flow rate of the recirculated exhaust gas is provided in the middle of the exhaust gas recirculation passage (18) in the cooling box (12). A water jacket (16) communicating with a water jacket in the cylinder head (2) is formed in the cooling box (12). By cooling the exhaust gas passage (18) and exhaust gas recirculation valve (31) with coolant in the water jacket (16), temperature of the recirculated exhaust gas efficiently lowers. With this construction, the cooling box (12) can be molded independently from the cylinder head (2), and complicated core molding is unnecessary.

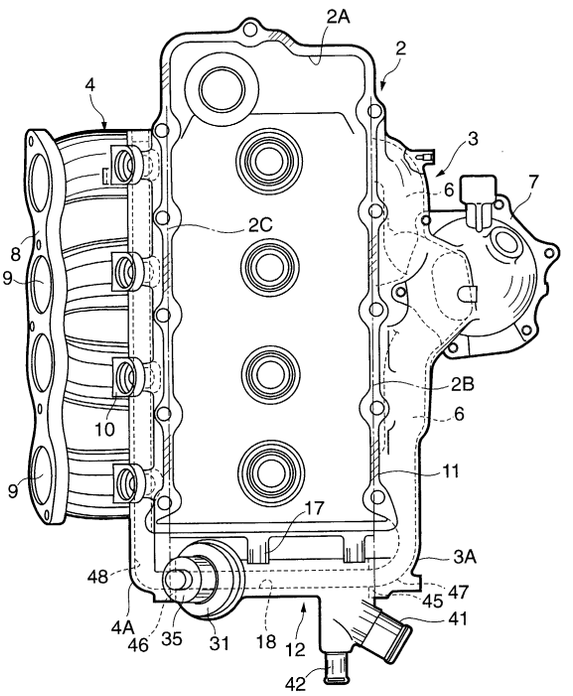

FIG. 1

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Description

FIELD OF THE INVENTION

[0001] This invention relates to recirculated exhaust gas cooling for an internal combustion engine.

BACKGROUND OF THE INVENTION

[0002] Tokkai Hei 11-82185 published by the Japanese Patent Office in 1999 discloses an exhaust gas recirculating (EGR) system to lower the combustion temperature of fuel mixture in an internal combustion engine by recirculating a part of the exhaust gas to intake air, and a cooling device to cool the recirculated exhaust gas.

[0003] The EGR system comprises an exhaust gas recirculation passage (EGR passage) passing through the cylinder head of the engine. The cooling device cools the recirculated exhaust gas by a coolant in a water jacket formed in the cylinder head. The flow rate of the recirculated exhaust gas in the EGR passage is regulated by an exhaust gas recirculation valve (EGR valve) mounted outside of the cylinder head.

SUMMARY OF THE INVENTION

[0004] Since the EGR valve is positioned outside of the cylinder head, cooling performance by a coolant in the water jacket does not exert on the EGR valve. When the EGR valve is operated by a step motor which is generally poor in heat resistance, therefore, the exhaust gas flow rate of the exhaust gas recirculation valve must be limited to a small amount in order to prevent the step motor from being overheated by the heat of the recirculated exhaust gas.

[0005] Further, the cylinder head is generally manufactured by molding, so according to the prior art, the water jacket and exhaust gas recirculation passage must be formed by core molding. Due to the restriction related to this forming process, it is difficult to optimize the shape and arrangement of the exhaust gas recirculation passage and water jacket for attaining the maximum cooling performance.

[0006] It is therefore an objective of this invention to provide a cooling device which has high cooling performance and is easy to build.

[0007] In order to achieve the above object, this invention provides a recirculated exhaust gas cooling device for an internal combustion engine of a vehicle that comprises an intake system, an exhaust system, an exhaust gas recirculation passage recirculating a part of exhaust gas from the exhaust system to the intake system, and a cylinder head in which a water jacket is formed.

[0008] The cooling device comprises a cooling box which is fitted to the cylinder head and houses a predetermined part of the exhaust gas recirculation passage. A water jacket is formed in the cooling box around the predetermined part, and the cooling box has an opening through which the water jacket in the cooling box is communicated with the water jacket in the cylinder head. The device further comprises a valve provided in the cooling box to regulate a flow rate of a recirculated exhaust gas flowing through the exhaust gas recirculation passage.

[0009] The details as well as other features and advantages of this invention are set forth in the remainder of the specification and are shown in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a plan view of a cylinder head of an internal combustion engine with a cooling box according to this invention, viewed from above.

[0011] FIG. 2 is a side view of an upper part of the internal combustion engine.

[0012] FIG. 3 is an enlarged view of essential parts of FIG. 2.

[0013] FIG. 4 is a side view of the cooling box.

[0014] FIG. 5 is a side view of the cooling box viewed from the opposite side of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] Referring to FIG. 1 of the drawings, an in-line four-cylinder internal combustion engine for a vehicle is provided with a cylinder head 2. The cylinder head 2 is fixed on top of a cylinder block 1 of the engine as shown in FIG. 2.

[0016] The cylinder block 1 has four cylinders arranged in-line. The cylinder head 2 has a top opening 2A closed by the cylinder head cover 5. This internal combustion engine is placed in an engine room of the vehicle, such that the engine rotation axis coincides with the lateral direction of the vehicle.

[0017] An exhaust manifold 3 is fitted to one side of the cylinder head 2 directed toward the rear of the vehicle. The intake manifold 4 is fixed to the other side of the cylinder head 2 directed toward the front of the vehicle. In FIG. 1 and FIG. 2, the left-hand side of the figures corresponds to the front of the vehicle, and the right-hand side of the figures corresponds to rear of the vehicle.

[0018] In the exhaust manifold 3, four exhaust branch passages 6 extending from each of the cylinders in the cylinder block 1 to a catalytic converter connecting flange 7 are formed. In the intake manifold 4, four intake branch passages 9 extending from a collector connecting flange 8 to each of the cylinders are formed.

[0019] The intake manifold 4 is provided with a fuel injector fitting portion 10 which has openings respectively communicating with the intake branch passages 9.

[0020] The cylinder block 1 is formed by molding of

cast iron or an aluminum alloy.

[0021] A water jacket for recirculating coolant is formed around each cylinder in the cylinder block 1.

[0022] A water jacket is also formed in the cylinder block 2. These water jackets mutually recirculate coolant via a plurality of communication holes provided on the connecting portion between the cylinder block 1 and cylinder head 2.

[0023] Referring to FIG. 1, the cylinder head 2 is provided with a cylinder head body 11 and a cooling box 12 fixed to the cylinder head body 11. The cylinder head body 11 is manufactured by molding of aluminum alloy. The cooling box 12 is fixed to one side of the cylinder head body 11 directed downward in FIG. 1.

[0024] Referring now to FIG. 5, the cooling box 12 is manufactured by molding of aluminum alloy, and is provided with a flange 15 around a joint surface with the cylinder head body 11. A plurality of bolt holes 17 are formed on the flange 15, and the cooling box 12 is fixed to the cylinder head body 11 by bolts penetrating these bolt holes 17.

[0025] The cylinder head body 11 has an opening communicating with the water jacket formed therein on a joint surface facing the cooling box 12. The cooling box 12 has an opening 16A communicating with a water jacket 16 formed therein as shown in FIG. 5 on a joint surface facing the cylinder head body 11. The opening 16A is in a shape similar to that of the opening of the water jacket on the cylinder head body 11 such that the water jacket 16 in the cooling box 12 and that in the cylinder head 2 mutually recirculate coolant via these openings in the state where the cylinder head body 11 and the cooling box 12 are joined together.

[0026] In order to prevent coolant leakage from the joint portion, a gasket such as a liquid gasket is gripped between the flange 15 of the cooling box 12 and the cylinder head body 11.

[0027] Referring to FIG. 1 again, the cooling box 12 comprises an exhaust air recirculation passage (EGR passage) 18, an exhaust air recirculation valve (EGR valve) 31 and a coolant inlet 41.

[0028] Referring to FIG. 4, the exhaust gas recirculation passage (EGR passage) 18 passes through the cooling box 12 from the right-hand side of the figure to the left-hand side thereof. The EGR passage 18 is divided into an upstream portion 18A and a downstream portion 18B, and the center axis of the downstream portion 18B is set in a position slightly offsetting upward relative to the center axis of the upstream portion 18A.

[0029] The upstream portion 18A and downstream portion 18B are respectively partitioned by pipe-shaped cylindrical walls 19A and 19B from the water jacket 16.

[0030] The upstream portion 18A and downstream portion 18B are connected via the EGR valve 31.

[0031] The upstream portion 18A is provided with an inlet 20 which is an opening formed on the end face on the right-hand side of the cooling box 12 in the figure. A flange 45 is formed around the inlet 20.

[0032] The downstream portion 18B is provided with an outlet 21 which is an opening formed on the end face of the left-hand side of the cooling box 12 in the figure. A flange 46 is formed around the outlet 21. The cylindrical walls 19A and 19B are formed by molding as a part of the cooling box 12. A half of the outer circumference of the cylindrical walls 19A and 19B forms a part of the outer wall of the cooling box 12 while the other half is disposed in the water jacket 16. A plurality of fins 24 for heat radiation are formed on the outer circumference of the cylindrical wall 19A which is exposed in the water jacket 16 as shown in FIG. 5.

[0033] The EGR valve 31 is housed in a valve housing 23. The valve housing 23 is also formed by molding in a cylindrical shape as a part of the cooling box 12. Similar to the structure of the cylindrical walls 19A, 19B, a half of the outer circumference of the valve housing 23 forms a part of the outer wall of the cooling box 12 while the other half is disposed in the water jacket 16.

[0034] A plurality of fins 25 for heat radiation are formed on the outer circumference of the valve housing 23 exposed in the water jacket 16 as shown in FIG. 5.

[0035] The valve housing 23 is disposed in the downstream portion of the EGR passage 18 in an inclined state with its top end directed downstream. As a result, the upstream portion 18A of the EGR passage 18 has a longer flow path than the downstream portion 18B.

[0036] Referring to FIG. 4, a valve chamber 22 is formed in the valve housing 23. The upstream portion 18A and downstream portion 18B of the EGR passage 18, respectively, open into the valve chamber 22. In the valve chamber 22, an annular valve seat 33 is provided between these openings and the flow of the recirculated exhaust gas from the upstream portion 18A to the downstream portion 18B is shut off by a valve body 34 seated on the valve seat 33.

[0037] The valve body 34 is provided with a valve stem 34A. The valve housing 23 has an opening 22A on the top opening toward the upper left of FIG. 4 and the flange 26 is formed around the opening 22A. The valve stem 34A projects from this opening 22A of the valve housing 23, and is connected to the step motor 35 fixed to the flange 26.

[0038] The step motor 35 controls the flow rate of recirculated exhaust gas in the EGR passage 18 by operating the valve body 34 via the valve stem 34A in response to a step signal input from a controller not shown. In contrast to the EGR valve 31, the coolant inlet 41 is provided at the upstream side of the cooling box 12. The coolant inlet 41 has an opening 41B which is directed to the water jacket 16 as shown in FIG. 5.

[0039] A coolant hose from a coolant pump is connected to the coolant inlet 41. The coolant inlet 41 is disposed diagonally with respect to the cooling box 12 as shown in FIG. 1 such that the coolant supplied from the coolant inlet 41 forms a flow directed toward the valve housing 23 in the water jacket 16.

[0040] This arrangement enhances the performance

of the coolant in cooling the EGR passage 18 and valve housing 23. The coolant after cooling the EGR passage 18 and valve housing 23 flows into the water jacket in the cylinder head body 11. The coolant inlet 41 is provided with a connector 42. The engine is provided with a throttle driven by a motor, and the coolant that has cooled this motor is recirculated to the water jacket 16 via the connector 42.

[0041] Referring to FIG. 1, the cylinder head 2 has a front fitting surface 2C on its left side face, i.e., the side face directed toward the front of vehicle, to fit the intake manifold 4.

[0042] The cylinder head 2 has a rear fitting surface 2B on its right side face, i.e., the side face directed toward the rear of vehicle, to fit the exhaust manifold 3.

[0043] The flange 45 around the inlet 20 of the EGR passage 18 is formed on the same vertical plane as that of the rear fitting surface 2B.

[0044] The flange 46 around the outlet 21 of the EGR passage 18 is formed on the same vertical plane as that of the front fitting surface 2C.

[0045] An extension 3A extending downward in FIG. 1 is formed on the exhaust manifold 3. An extension 4A extending downward in FIG. 1 is also formed on the intake manifold 4. The cooling box 12 while being gripped between these extensions 3A and 4A is fixed to the cylinder head body 11.

[0046] In the extension 3A, an EGR passage 47 is formed for connecting the exhaust gas branch passages 6 and the inlet 20 of the

[0047] EGR passage 18 In the extension 4A, an EGR passage 48 is formed for connecting the intake gas branch passages 9 and the outlet 21 of the EGR passage 18.

[0048] A sheet-shaped gasket is gripped between the flange 45 and the extension 3A. A similar gasket is gripped between the flange 46 and the extension 4A.

[0049] A gasket is gripped between the exhaust manifold 3 and the cylinder head 11, as well as between the intake manifold 4 and the cylinder head 11. Since the flange 45 is formed on the same vertical plane as that of the rear fitting surface 2B as mentioned above, the gasket between the flange 45 and the extension 3A may be provided in a one-piece construction with the gasket between the cylinder head body 11 and the exhaust manifold 3. Similarly, the gasket between the flange 46 and the extension 4A may be provided in a one-piece construction with the gasket between the cylinder head body 11 and the intake manifold 4.

[0050] A part of exhaust gas discharged to the exhaust manifold 3 from the engine is recirculated to the intake manifold 4 through the EGR passages 47, 18 and 48 connected in this manner. The exhaust gas which has reached the intake manifold 4 is supplied to the cylinder in intake stroke through any of the intake branch passages 9 together with fresh air provided to the intake manifold 4.

[0051] The flow rate of the recirculated exhaust gas is controlled by the EGR valve 31 provided in the middle of the EGR passage 18. Since the EGR valve 31 is inclined along the flow of the recirculated exhaust gas in accordance with a difference in the level between the upstream portion 18A and downstream portion 18B of the EGR passage 18, energy loss caused by flow refraction when passing the EGR valve 31 is small and the exhaust gas flows smoothly even if the difference in pressure between the exhaust manifold 3 and the intake manifold 4 is small.

[0052] The exhaust gas flowing down the EGR passage 18 in the cooling box 12 is cooled by heat-exchange with the coolant in the water jacket 16 through the fins 24 of the upstream portion 18A before flowing into the valve housing 23.

[0053] The fact that the EGR valve 31 is provided in the downstream portion of the EGR passage 18 helps lower the temperature of the recirculated exhaust gas flowing into the valve housing 23. Further, due to this arrangement of the EGR valve 31, the step motor 35 driving the EGR valve 31 is located near the intake manifold 4 which suffers a lower heat load than the exhaust manifold 3. This position is close to the front side of the vehicle that receives plenty of fresh air while the vehicle is running. Such an arrangement of the EGR valve 31 is preferable for suppressing a temperature rise of the step motor 35 caused by heat of the recirculated exhaust gas, so the EGR valve 31 can recirculate a large amount of exhaust gas. For passenger vehicles in which the engine room is provided at the front portion of the vehicle and covered by a hood having hinges at its rear end, such an arrangement of the EGR valve 31 renders ease of maintenance of the EGR valve 31 and step motor 35.

[0054] Since the cooling box 12 is provided with the coolant inlet 41, the coolant cools the EGR passage 18 and valve housing 23 before it flows into the cylinder head 2, so it efficiently cools the EGR passage 18 and the EGR valve 31.

[0055] Since the water jacket 16 has the opening 16A as shown in FIG. 5, the cooling box 12 can be manufactured without core molding. Therefore, the cooling box 12 does not suffer limitations in its shape and structure associated with the core molding.

[0056] The contents of Tokugan 2001-42826 with a filing date of February 20, 2001 in Japan, are hereby incorporated by reference.

[0057] Although the invention has been described above by reference to certain embodiments of the invention, the invention is not limited to the embodiments described above. Modifications and variations of the embodiments described above will occur to those skilled in the art, in light of the above teachings.

[0058] The embodiments of this invention in which an exclusive property or privilege is claimed are defined as follows:

Claims

1. A recirculated exhaust gas cooling device for an internal combustion engine of a vehicle, the engine comprising an intake system (4), an exhaust system (3), an exhaust gas recirculation passage (18, 18A, 18B, 47, 48) recirculating a part of exhaust gas from the exhaust system (3) to the intake system (4), and a cylinder head (2) in which a water jacket is formed, the device comprising:

   a cooling box (12) which is fitted to the cylinder head (2) and houses a predetermined part (18, 18A, 18B) of the exhaust gas recirculation passage (18, 18A, 18B, 47, 48), a water jacket (16) being formed in the cooling box (12) around the predetermined part (18, 18A, 18B), the cooling box (12) having an opening (16A) through which the water jacket in the cooling box (12) is communicated with the water jacket in the cylinder head (2); and
   a valve (31) provided in the cooling box to regulate a flow rate of a recirculated exhaust gas flowing through the exhaust gas recirculation passage (18, 18A, 18B, 47, 48).

2. The recirculated exhaust gas cooling device as defined in Claim 1, wherein the predetermined part (18, 18A, 18B) is partitioned by a pipe-shaped cylindrical wall (19A, 19B).

3. The recirculated exhaust gas cooling device as defined in Claim 1 or Claim 2, wherein the cylindrical wall (19A, 19B) comprises a heat radiation fin (24) contacting with coolant in the water jacket (16) in the cooling box (12).

4. The recirculated exhaust gas cooling device as defined in any of Claim 1 through Claim 3, wherein the cooling box (12) comprises a coolant inlet (41) to the water jacket (16) in the cooling box (12).

5. The recirculated exhaust gas cooling device as defined in any of Claim 1 through Claim 4, wherein the cooling box (12) comprises a valve housing (23) provided in a one-piece construction with the cooling box (12) to house the valve (31).

6. The recirculated exhaust gas cooling device as defined in Claim 5, wherein the valve housing (23) comprises a heat radiation fin (25) contacting with coolant in the water jacket (16) in the cooling box (12).

7. The recirculated exhaust gas cooling device as defined in Claim 5 or Claim 6, wherein the valve housing (23) has an opening (22A) directed upward, and the cooling device further comprises a motor (35) which drives the valve (31) through the opening (22A).

8. The recirculated exhaust gas cooling device as defined in any of Claim 1 through Claim 7, wherein the valve (31) is provided in the middle of the predetermined part (18, 18A, 18B) in the cooling box (12), and the predetermined part (18, 18A, 18B) is divided into an upstream portion (18A) and a downstream portion (18B) which is shorter in length than the upstream portion (18A)

9. The recirculated exhaust gas cooling device as defined in Claim 8, wherein a center axis of the upstream portion (18A) is offset from a center axis of the downstream portion (18B), and the valve housing (23) is of a cylindrical shape inclining for guiding the flow of the exhaust gas from the upstream portion (18A) to downstream portion (18B).

10. The recirculated exhaust gas cooling device as defined in Claim 8 or Claim 9, wherein the internal combustion engine is mounted laterally on the vehicle, the center axis of the downstream portion (18B) is offset upward with respect to the center axis of the upstream portion (18A), and the valve housing (23) is inclined to cause an upper end to be directed towards a front of the vehicle.

11. The recirculated exhaust gas cooling device as defined in any of Claim 8 through Claim 10, wherein the cooling box (12) has an inlet (20) of the upstream portion (18A) and an outlet (21) of the downstream portion (18B) respectively opening outwardly.

12. The recirculated exhaust gas cooling device as defined in Claim 11, wherein the cylinder head (2) has a front fitting surface (2C) directed toward the front of the vehicle to fit the intake system (4), and a rear fitting surface (2B) directed toward the rear of the vehicle to fit the exhaust system (3), the outlet (21) is formed on the same vertical plane as the front fitting surface (2C), and the inlet (20) is formed on the same vertical surface as the rear fitting surface (2B).

13. The recirculated exhaust gas cooling device as defined in Claim 12, wherein the intake system (4) comprises an intake manifold (4) fitted to the front fitting surface (2C), and the exhaust system (3) comprises an exhaust manifold (3) fitted to the rear fitting surface (2B).

14. The recirculated exhaust gas cooling device as defined in Claim 13, wherein the intake manifold (4) has an air passage (9) which provides air to the internal combustion engine and a part (48) of the ex-

haust gas recirculation passage (18, 18A, 18B, 47, 48) which provides a recirculated exhaust gas from the outlet (21) to the air passage (9).

15. The recirculated exhaust gas cooling device as defined in Claim 13 or Claim 14, wherein the exhaust manifold (4) has an exhaust passage (6) which discharges exhaust gas from the internal combustion engine and a part (47) of the exhaust gas recirculation passage (18, 18A, 18B, 47, 48) which provides a recirculated exhaust gas from the exhaust passage (6) to the inlet (22).

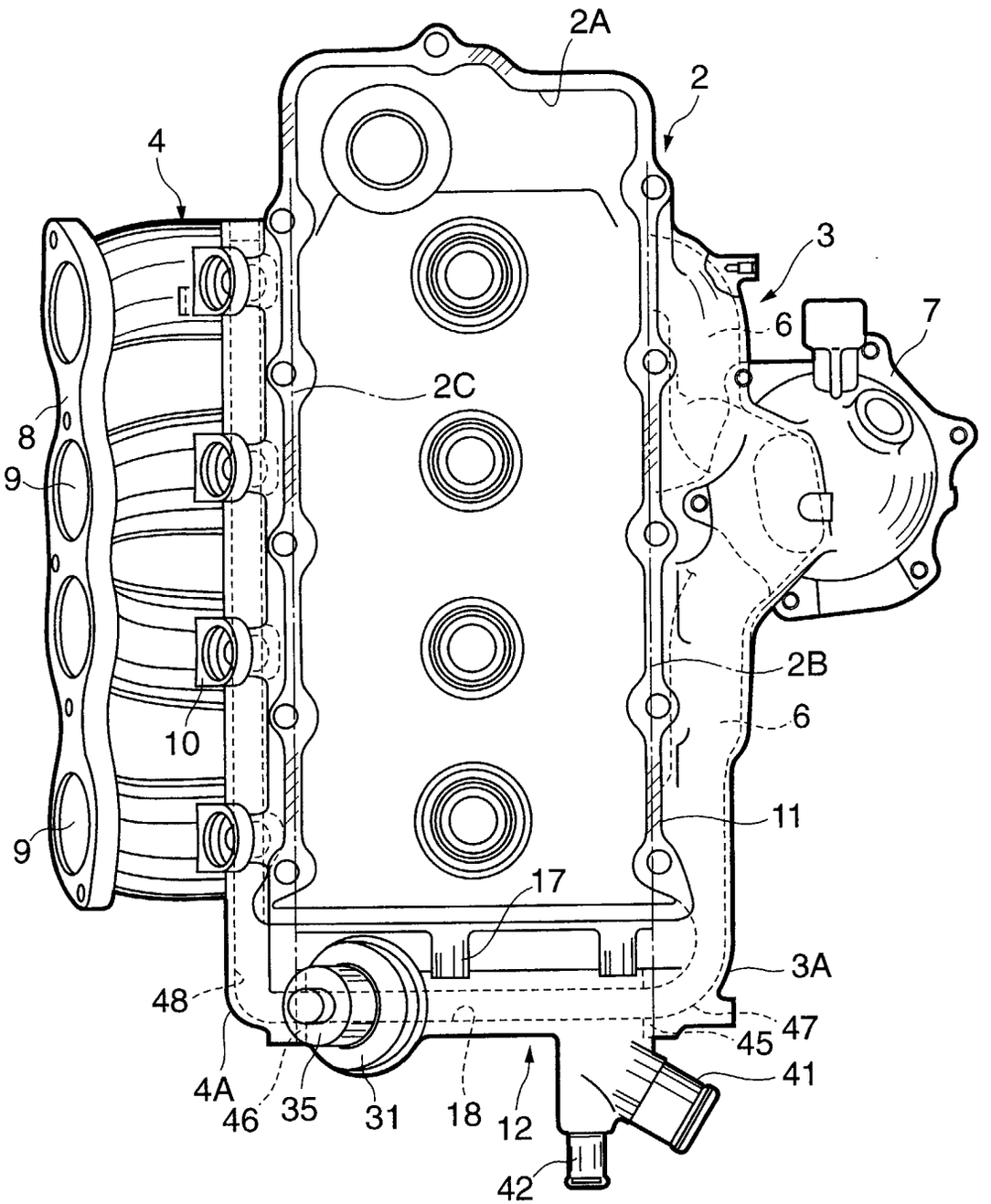

FIG. 1

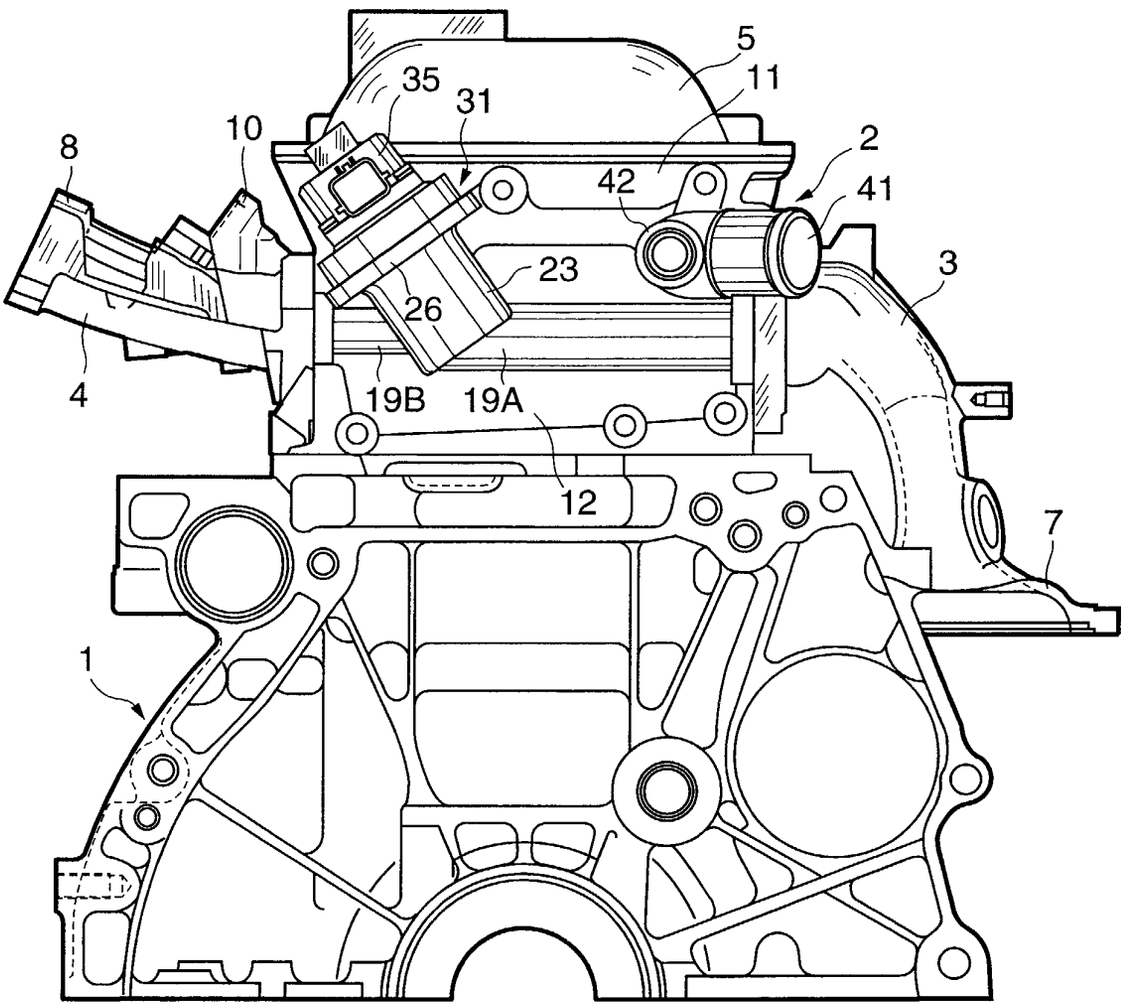

FIG. 2

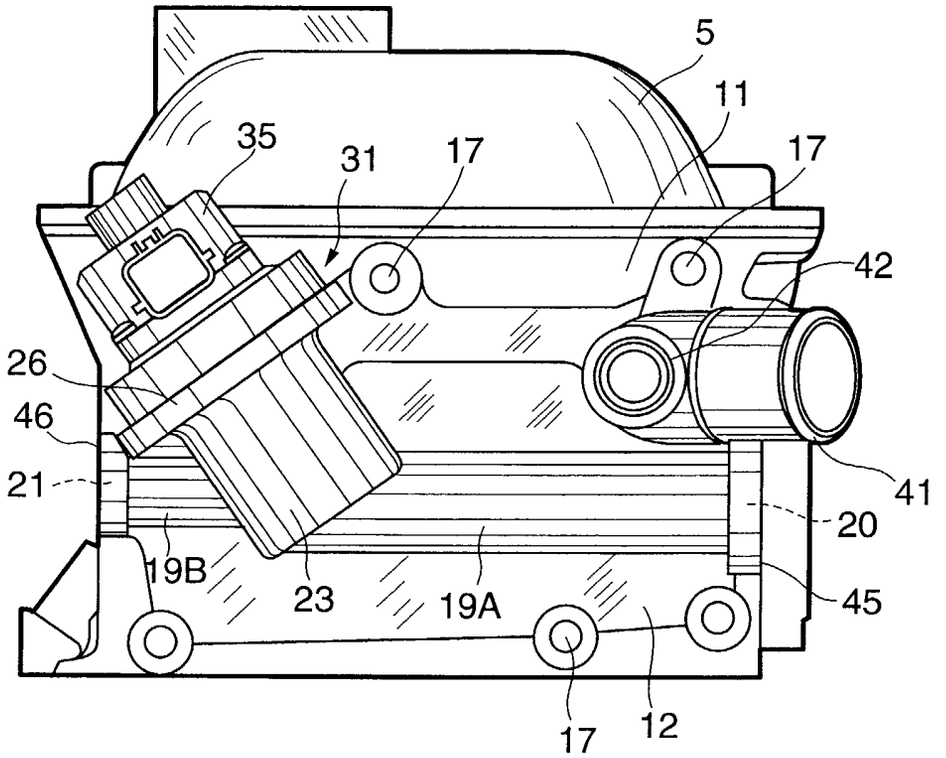
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FIG. 3

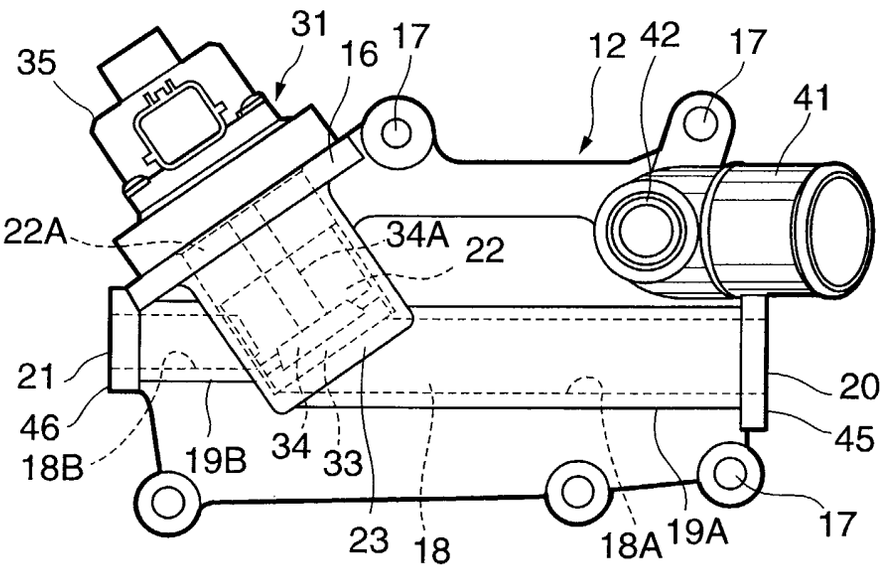
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FIG. 4

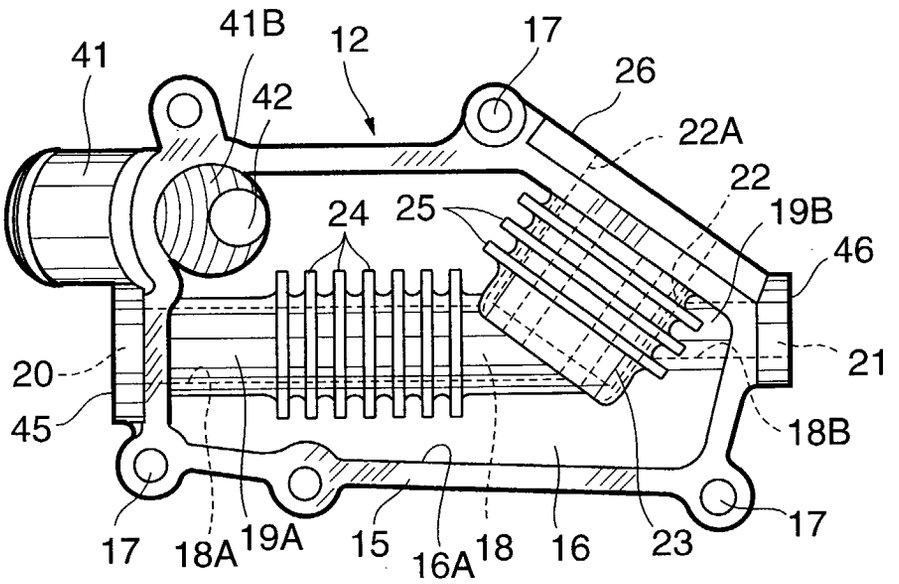
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FIG. 5