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## (54) Four-cycle engine

(57) The present invention relates to a four-cycle engine, specifically to a cooling arrangement thereof, said engine comprising a cylinder block and a cylinder head, a chain drive means for driving at least one camshaft from a primary drive shaft and a chain cover extending along a side of the engine wherein in said chain cover forms part of a case for the water pump which, therefore, can be integrated smoothly into the engine allowing to drive the water pump in common to the other auxiliary equipment and to avoid hoses or the like for cooling other components of the engine.

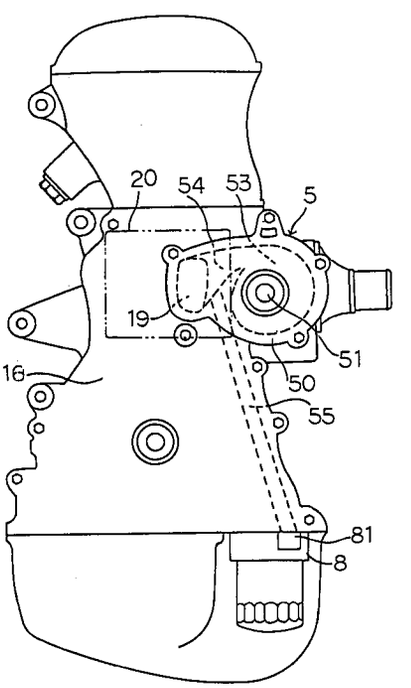


Fig. 8

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## Description

The present invention relates to a four-cycle engine comprising a cylinder block and a cylinder head, a chain drive means for driving at least one camshaft from the primary drive shaft, a chain cover extending along a side of the engine and a cooling arrangement including a water pump for circulating cooling water through the engine.

Conventionally, in four-cycle engines for automobiles, a water jacket surrounds the outside of the cylinders, and coolant from the radiator is circulated through this jacket to cool the engine. A water pump and its drive propel this coolant, which has become heated after cooling the engine, back to the radiator, where it is cooled, and then, to return the coolant to the water jacket.

In general, the water-pump impeller-housing is mounted on the cylinder block so that said impeller housing connects to a coolant passage linking it with the opening of the water jacket, and a pulley on the rotating shaft of the impeller is driven by belt from a crankshaft pulley. Part of the coolant supplied by the water pump is circulated to the oil cooler.

However, when attaching the water pump to the engine as a part of the above described conventional cooling structure for four-cycle engines, if the side of the engine is covered by a chain cover, then the cover must go around this area, leaving the water pump to protrude from the side of the engine. Not only does the water pump protrude substantially from the engine unit, but attachment of a separate hose to the coolant passage is required in order that it be able to supply coolant to the oil cooler.

An engine according to the preamble of claim 1 is know from US-A-2 852 009 which discloses liquid conduits outside the cylinder block and the chain cover.

Accordingly, it is an objective of the present invention to provide a four-cycle engine as indicated above having a cooling liquid circulation system improved in respect of compact engine design and the arrangement of a water pump in particular.

In order to perform said objective, the four-cycle engine according to the present invention comprises the chain cover and closure means defining a cooling water passage extending substantially downwardly and leading to an oil cooler.

Thus, not only the water pump of the cooling arrangement circulating the cooling water through the cylinder block and cylinder head of the engine but also parts of the cooling conduits are integrated into a chain cover area itself, which improves the layout and compactness of the engine.

Moreover, the present invention allows the water pump to be located in close proximity to an opening for the water jacket in the cylinder block, so that water can be very efficiently supplied from the water pump housing to the water jacket inside the cylinder block.

A coolant passage to a cylinder block water jacket opening and the passage to the oil cooler can be formed in the chain cover and the closure means, thus eliminating the need for extra parts such as hoses in order to circulate the cooling water to more remote parts of the engine to be cooled.

Furthermore, parts of the cooling conduits can be integrated in the cylinder block for communicating an impeller housing of the water pump to the oil cooler.

Preferrably the present invention is useful for a high performance five-valve engine having three intake valves and two exhaust valves per cylinder.

Other preferred embodiments of the present invention are laid down in the further subclaims.

In the following the present invention is explained in greater detail by means of embodiments thereof refering a multi-cylinder four-cycle engine, wherein:

Fig. 1, shows a front side view of a multi-cylinder four-cycle engine viewed along a row of cylinders, indicating the location of the auxiliary equipment positioned around the engine,

Fig. 2, is a view similar to that of Figure 1 but without the auxiliary equipment affixed to the engine,

Fig. 3, is a view similar to that of Figures 1 and 2 with the chain cover of a camshaft timer chain drive system removed,

Fig. 4, is a partial sectional view along the line A-A of Figure 2,

Fig. 5, is a partial sectional view along the line B-B of Figure 2,

Fig. 6, is a partial sectional view along the line C-C of Figure 2,

Fig. 7, is a diagram of the cooling circuit and cooling water circulation from the water pump shown in Figure 5,

Fig. 8, is a partial side view of the engine similar to Figures 1 to 3 showing the engine with another embodiment of the water pump attached thereto,

Fig. 9, is a partial side view of the engine similar to Figure 8 with yet another embodiment of the water pump attached to the engine,

Fig. 10, is an exploded side view of the engine according to Figure 1 showing the affixation thereof with an assembly bracket.

Embodiments of the cooling structure of this invention will be described below as a part of the multi-cylinder four-cycle engine shown in the attached figures.

Figure 1 shows the location of the auxiliary equipment positioned around the engine, which is a multi-cyl-

inder four-cycle engine, viewed along the line of cylinders. Located around the engine 1 are the alternator 2, the power steering pump 3, the air conditioning compressor 4, etc. These pieces of auxiliary equipment are driven at their respective rotating shafts 21, 31, 41 by a single belt 7 which connects the various pulleys 12, 22, 32, 42, 52 to that of the engine crankshaft 11. An oil cooler 8 equipped with a filter unit is mounted at the bottom of the engine 1.

Figure 2 shows the engine 1 of Figure 1. At the top, the engine 1 is covered by head cover 13, mounted over the cylinder head 14; on the side, a chain cover 16 covers the cylinder block 15 (which, in this embodiment, consists of a cylinder block unit and a crankcase) and on the bottom, an oil pan 17 is mounted under the cylinder block 15. A water pump 5 is affixed to the surface of chain cover 16.

Figure 3 shows the engine 1 of Figure 2 with the chain cover 16 removed. An inlet 18 is present on the upper part of the side of the cylinder block 15 where the water pump 5 introduces the coolant, and an inlet 19 is located nearby through which coolant is introduced into the water jacket, and below is an oil passage 83 through which oil is introduced into the oil cooler 8. Sprockets 60 are affixed parallel to each other on the crankshaft 11, and chains 61, 62 engage the teeth on these sprockets, respectively.

Said side of the cylinder block 15 where the timer chain transmission for driving the camshafts 64,65 and the other auxiliary equipment and the water pump 5 is positioned is disposed closer to an adjacent cylinder of the cylinder block 15 than the opposite end side of the cylinder block 15 (said side also extending inthe widthwise direction, not shown in the drawings).

A lower chain 61 transmits the drive from the rotation of crankshaft 11 to the air intake camshaft 64 and to the exhaust camshaft 65 by means of an intermediate rotating shaft 67 and an upper chain 68 at the top of the engine, which is a five valve twin cam (not shown) engine with three air intake valves and two exhaust valves per cylinder, causing the camshafts 64, 65 to rotate in this two-stage timing chain configuration. The chain 62 located near bottom of the engine transmits the drive of the crankshaft 11 to the rotating shaft 63 of an oil pump (not shown) situated inside the oil pan 17.

The twin chains which rotate the various camshafts 64, 65 of the twin cam valve system can be adjusted externally by means of a tensioner 71 for the upper chain 68 that is mounted on the cylinder head 14, and by a tensioner 72 for the lower chain mounted on the cylinder block 15.

The tensioner 71 servicing the air intake camshaft 64, the exhaust camshaft 65, and the intermediate rotating shaft 67 is located slightly farther away than usual from the center line passing through crankshaft 11 in order to make room for it to be mounted on the cylinder head 14.

Now, as shown in Figure 4, the adjoining surfaces 15a, 15b between the side of the cylinder block 16 and the chain cover are located in mutually offset and parallel planes of the cross sectional surface. The projecting adjoining surface 15a of the cylinder block comprises an integral support area 15c projecting from the cylinder block and supporting a mounting arm 23 of the alternator 2 to allow bolting said alternator at the support 15c to the affixation area 15d.

As shown in Figures 3 and 4, a mounting hole 15e passes through the cylinder block 15 below this alternator support area 15c, allowing mounting a cylinder 72c for the push rod 72b applying pressure to the tension arm 72a of the tensioner 72.

Generally, the lower chain tensioner 72 is supported at a portion of the cylinder block 15 which is correspondingly provided at the opposite end side of the cylinder block 15 (said side also extending in the widthwise direction, not shown in the drawings).

Figure 6 shows the affixation area on engine 1 for the assembly bracket 9 which allows the engine 1 to be affixed to the vehicle frame. The mounting bracket 9 is affixed as jaw-like appendage onto both the cylinder head 14 and the cylinder block 15, and there are affixation areas 90a, 90b, 90c, and 90d which correspond to the various affixation areas 10a, 10b, 10c, 10d on the engine 1 to attach the engine 1 to the frame at the affixation area 91. In addition, the top mounting arm 24 of the alternator 2 bolts onto the affixation area 92.

In addition to the mounting arm 24 being attached to the affixation area 92 of the assembly bracket 9 by means of bolts, the alternator 2 is also supported by the mounting arm 23 below, which is bolted to the affixation area 15d of the alternator support 15c that is integral with the cylinder block, thereby being attached at the top and bottom with respect to engine 1 as shown in Figure 1.

This arrangement, namely the lower mounting arm 23 for the alternator 2 increasing the strength of affixation to the engine, and the upper mounting arm 24 being affixed to the vehicle by the assembly bracket 9 minimizes engine vibrations in that area, thereby allowing the accommodation of any future change in alternator specifications by merely changing the assembly bracket 9 holding such an alternator.

As has been described above, when the side of the cylinder block 15 of engine 1 is covered by the chain cover 16 as shown in Figure 2, then the impeller housing 53, the coolant passage 54 to the water jacket opening 19, and the coolant passage 55 to the oil cooler will be integral on the outside of the chain cover 16, near the adjoining surface 15b with cylinder block 15, so that the water pump 5 shall be affixed by bolting on the cover 50.

As shown in Figure 5, the housing of the water pump 5 is integral in the chain cover and this housing area is covered by the cover 50, whereby the various coolant passages 54, 55 are made contiguous with the impeller housing 53. The impeller 57 is located inside the impeller housing 53; the extension of the shaft 51 of impeller 57 to the outside of the cover 50 allows a pulley 52 to be attached to the end of said shaft and to be be

driven by the crankshaft of engine 1 in order to recirculate coolant as shown in Figure 7.

As is shown in Figure 2, with regard to the various coolant passages 54, 55 which are contiguous with the impeller housing 53 of the water pump 5, the coolant passage 54 leading to the opening 19 for the water jacket is considerably shorter than the coolant passage 55 leading to the oil cooler 8, and these coolant passages 54, 55 are formed, respectively, in the cover 50 and in the chain cover 16 so that they are contiguous with the impeller housing 53.

Just as with the impeller housing 53, the coolant passage 55 leading to the oil cooler 8 is formed in the chain cover 16 and in the cover 50, and the cover 50 extends integrally downward from the impeller housing, along the surface of the chain cover, to the vicinity of the oil cooler 8 under the cylinder block 15.

As is shown in Figure 6, with regard to the flow path of the coolant leading to the oil cooler 8 from the coolant passage 55 of the water pump 5, the coolant is introduced into the oil cooler 8 from the end of the coolant passage 55, which is formed by the chain cover 16 and the cover 50, through the passage 55b in the chain cover 16.

With regard to the coolant passage 55 leading from the water pump 5 to the oil cooler 8, it is not only possible to form the passage in the chain cover 16 and cover 50, but as shown in Figure 8, the coolant passage 55 leading to the oil cooler 8 may equally well be formed integrally on the back side of the chain cover 16. Further, as shown in Figure 9, the coolant passage 55 to the oil cooler 8 may also be formed in the cylinder block 15, integral with the structural components of the engine, thereby eliminating the need for hoses and the like.

In any of the aforementioned cases, the cross sections of the surfaces 15a, 15b of the cylinder block 15 adjoining the chain cover are in offset and mutual parallel planes. Since the water pump 5 is integral with the side adjoining the surface 15b, compared to the case where the adjoining surface on the cylinder block side lies in the same plane as the surface on the other side, then the water pump 5, even though covered by the chain cover 16, does not project as far from the side of the engine 1. And, since it is near the opening 19 leading to the water jacket of the cylinder block 15, the structure allows the water pump 5 to be driven by engine 1 in a very compact manner.

This configuration allows the water pump 5 to be situated in such manner that the pulley 52 attached to the rotating impeller shaft 51 of the water pump 5 can be efficiently driven by the crankshaft 11, along with the other auxiliary equipment, by means of a single belt 7. In addition, this configuration simplifies the structures and improves the ease of maintenance by eliminating the need for extra parts such as hoses to provide the coolant passage to the oil cooler.

As described above, the cooling structure for four-cycle engines of this invention uses the chain cover that covers the side of the engine as a part of the water pump so that the water pump does not substantially project from the surface of the chain cover, and as a result the water pump may be located in close proximity to the opening for the water jacket in the cylinder block in a compact manner. It also reduces the number of parts, and eases engine maintenance.

## Claims

1. Four-cycle engine comprising a cylinder block (15) and a cylinder head (14), a chain drive means (100) for driving at least one camshaft (64,65) from a primary drive shaft (11), a chain cover (16) extending along a side of the engine and a cooling arrangement including a water pump (5) for circulating cooling water through the engine, said chain cover (16) defining, at least partially, a housing for the water pump (5), **characterized in that** the chain cover (16) and a closure means (50) define a cooling water passage (55) extending substantially downwardly and leading to an oil cooler (8).

2. Four-cycle engine as claimed in claim 1, **characterized in that** another closure means (50) is provided to cover the water pump and to connect to the chain cover (16).

3. Four-cycle engine as claimed in claims 1 or 2, **characterized in that** a drive shaft (51) of the water pump (5) is driven by a pulley (52) which forms part of an accessory equipment drive means.

4. Four-cycle engine as claimed in claim 3, **characterized in that** the accessory equipment drive means is a belt (7) drivingly connecting a crankshaft pulley (12) with a plurality of further accessory drive pulleys (22,32,42,52).

5. Four-cycle engine as claimed in at least one of the preceding claims 1 to 4, **characterized in that** the chain cover (16) defines part of a cooling water passage (54,55) of the cooling arrangement.

6. Four-cycle engine as claimed in at least one of the preceding claims 1 to 5, **characterized in that** the additional closure means is a cover (50) defining part of a cooling water passage (54,55) of the cooling arrangement.

7. Four-cycle engine as claimed in at least one of the preceding claims 1 to 6, **characterized in that** the cylinder block (15) comprises an integral projecting support area (15c) to which an end portion of the chain cover (16) abuts and which is adapted to support a mounting arm (23) of an alternator (2).

8. Four-cycle engine as claimed in at least one of the preceding claims 1 to 7, **characterized in that** the

water pump (5) is of the impeller type and that an impeller housing (53) of the water pump (5) is formed by the chain cover (16) and the cover means (50) which, in turn, covers the water pump (5) and an opening defined by the chain cover (16).

9. Four-cycle engine as claimed in claim 8, **characterized in that** the water pump (5) is associated to a cooling water inlet (18) provided at an upper part of the side of the cylinder block (15) where the water pump (5) introduces cooling water and that a cooling water inlet (19) is located at the area of the chain drive means (100).

10. Four-cycle engine as claimed in at least one of the preceding claims 1 to 9, **characterized in that** said oil cooler (8) is attached to a lower side of the cylinder block (15), said cylinder block (15) comprising an oil passage (83).

11. Four-cycle engine as claimed in at least one of the preceding claims 1 to 10, **characterized in that** the water pump (5) is bolted to the additional closure means (50).

12. Four-cycle engine as claimed in at least one of the preceding claims 8 to 11, **characterized in that** the impeller housing (53), a cooling water passage (54) to a cylinder block water jacket opening (19) and the cooling water passage (55) to the oil cooler (8) are formed integrally by the chain cover (16) and the closure means (50).

13. Four-cycle engine as claimed in at least one of the preceding claims 1 to 12, **characterized in that** a cooling water passage (55) is directly formed in the chain cover (16).

14. Four-cycle engine as claimed in at least one of the preceding claims 1 to 13, **characterized in that** a cooling water passage (55) communicating the impeller housing (53) of the water pump (5) to the oil cooler (8) is formed directly by the cylinder block (15).

15. Four-cycle engine as claimed in at least one of the preceding claims 1 to 14, **characterized in that** the accessories are attached to a side of the cylinder block (15) and an engine mounting bracket (9).

16. Four-cycle engine as claimed in claim 15, **characterized in that** the engine mounting bracket (9) engages both the cylinder block (15) and the cylinder head (4) of the engine.

17. Four-cycle engine as claimed in at least one of the preceding claims 1 to 16, **characterized in that** a lower drive chain (61) connects a drive sprocket fixed onto the crankshaft (11) and to a drive sprocket fixed on the intermediate drive shaft (67) which is rotatably supported through the cylinder head (4), while an upper chain (68) drives intake and exhaust camshafts (64,65) from said intermediate drive shaft (67).

18. Four-cycle engine as claimed in claim 17, **characterized in that** a lower chain tensioner (72) is supported by the cylinder block (15) while an upper chain tensioner (71) is supported by the cylinder head (14).

19. Four-cycle engine as claimed in at least one of the preceding claims 1 to 18, **characterized in that** the intermediate drive shaft (67) is disposed laterally offset with respect to the intake and exhaust camshafts (64,65).

20. Four-cycle engine as claimed in at least one of the preceding claims 1 to 19, **characterized in that** the engine comprises a plurality of intake valves per cylinder, the number of said intake valves exceeding the number of exhaust valves per cylinder and that the upper chain tensioner (71) is disposed at the intake side of the cylinder head (14).

21. Four-cycle engine as claimed in claim 20, **characterized in that** the intermediate drive shaft (67) is disposed offset towards that side of the engine opposite to the side where the upper chain tensioner (71) is disposed.

22. Four-cycle engine as claimed in at least one of the preceding claims 1 to 21, **characterized in that** the side of the cylinder block (15) supporting the water pump (5) is disposed closer to an adjacent cylinder than an opposite side of the cylinder block (15).

23. Four-cycle engine as claimed in claim 18, **characterized in that** the lower tensioner (72) is supported through a portion of the cylinder block (15) which is correspondingly provided at an opposite side of the cylinder block.

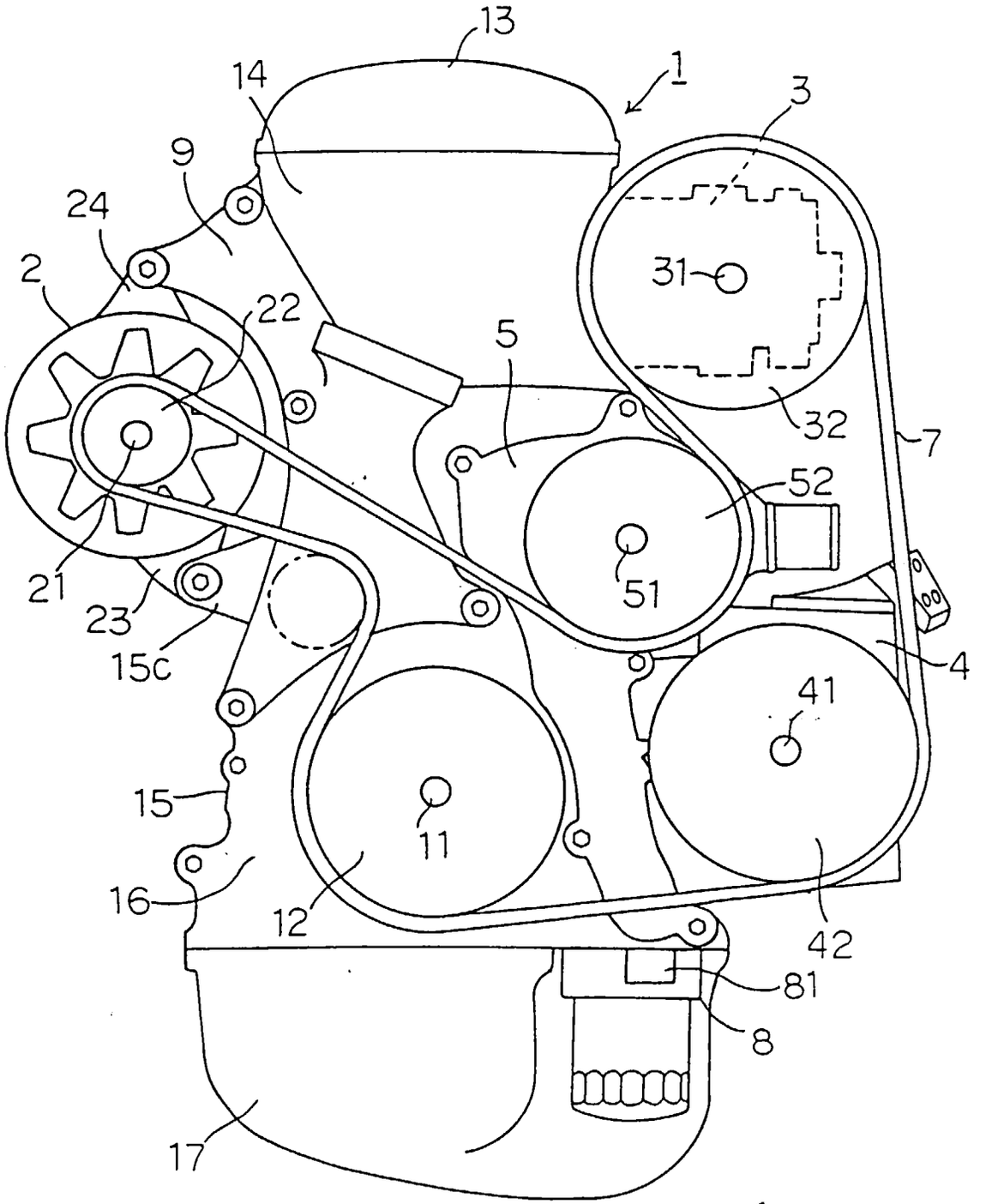



Fig. 1

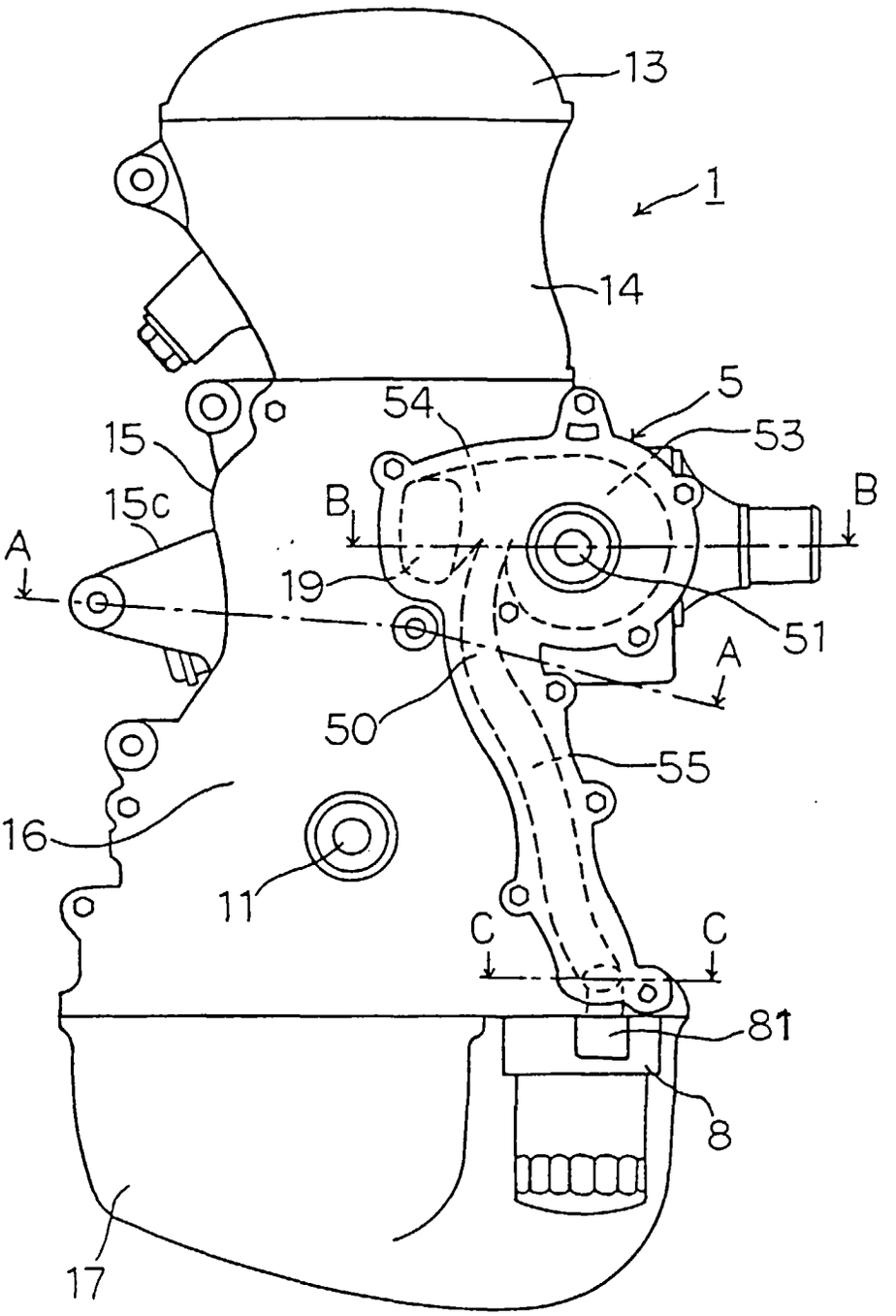
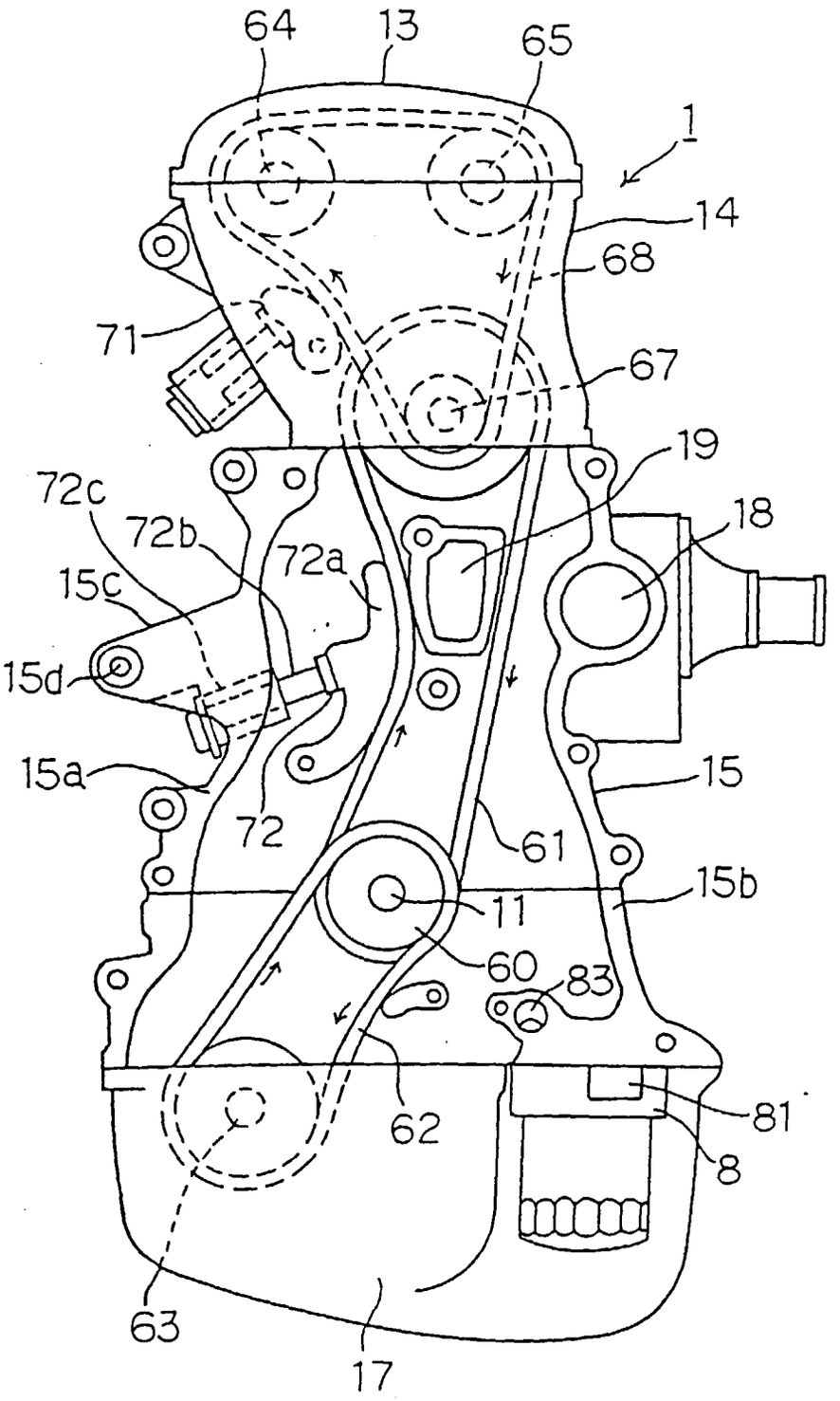



Fig. 2


64
13
65
1
14
68
71
67
19
72c
72b
72a
18
15c
15d
15a
15
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11
60
83
62
81
8
63
17

Fig. 3

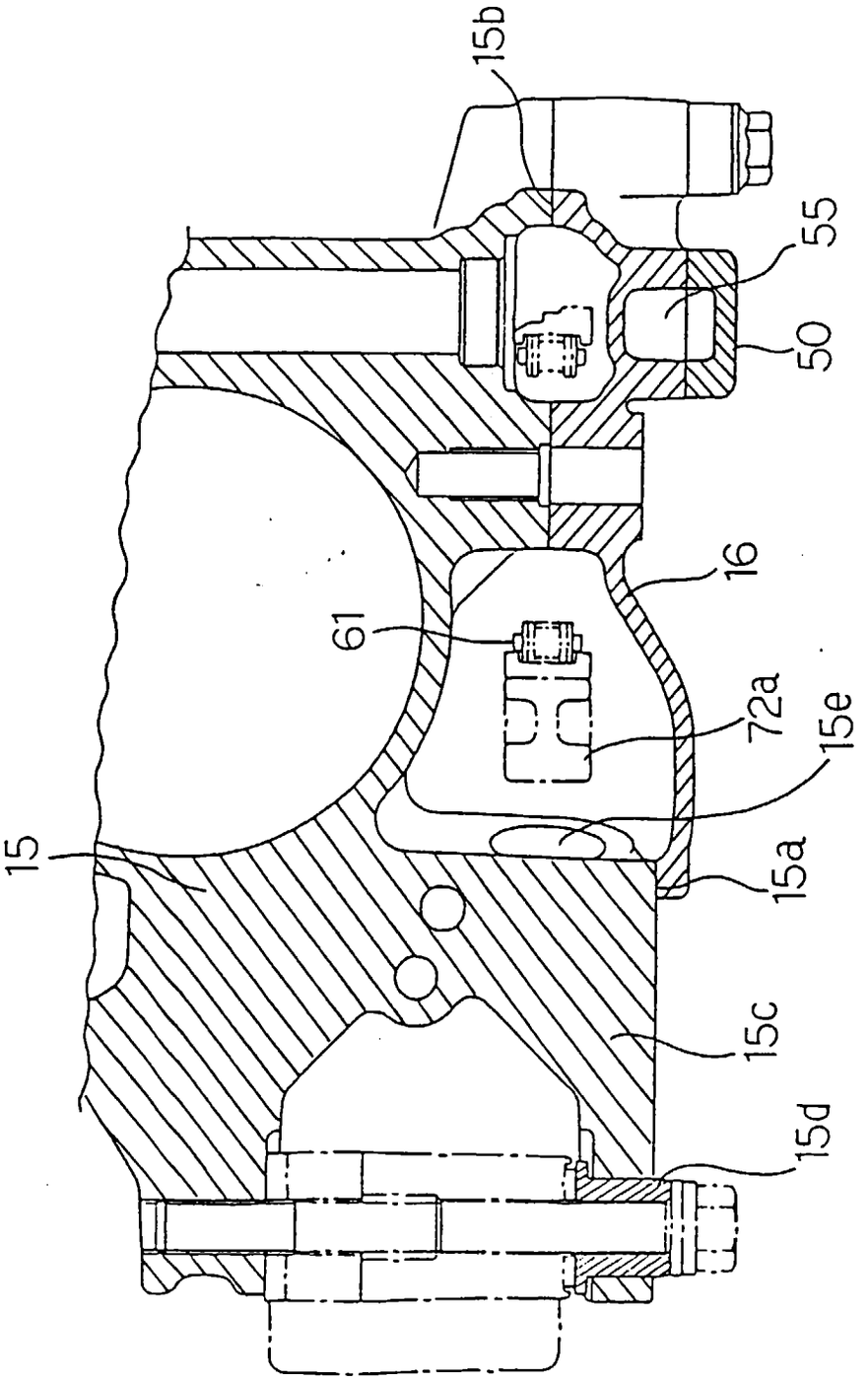
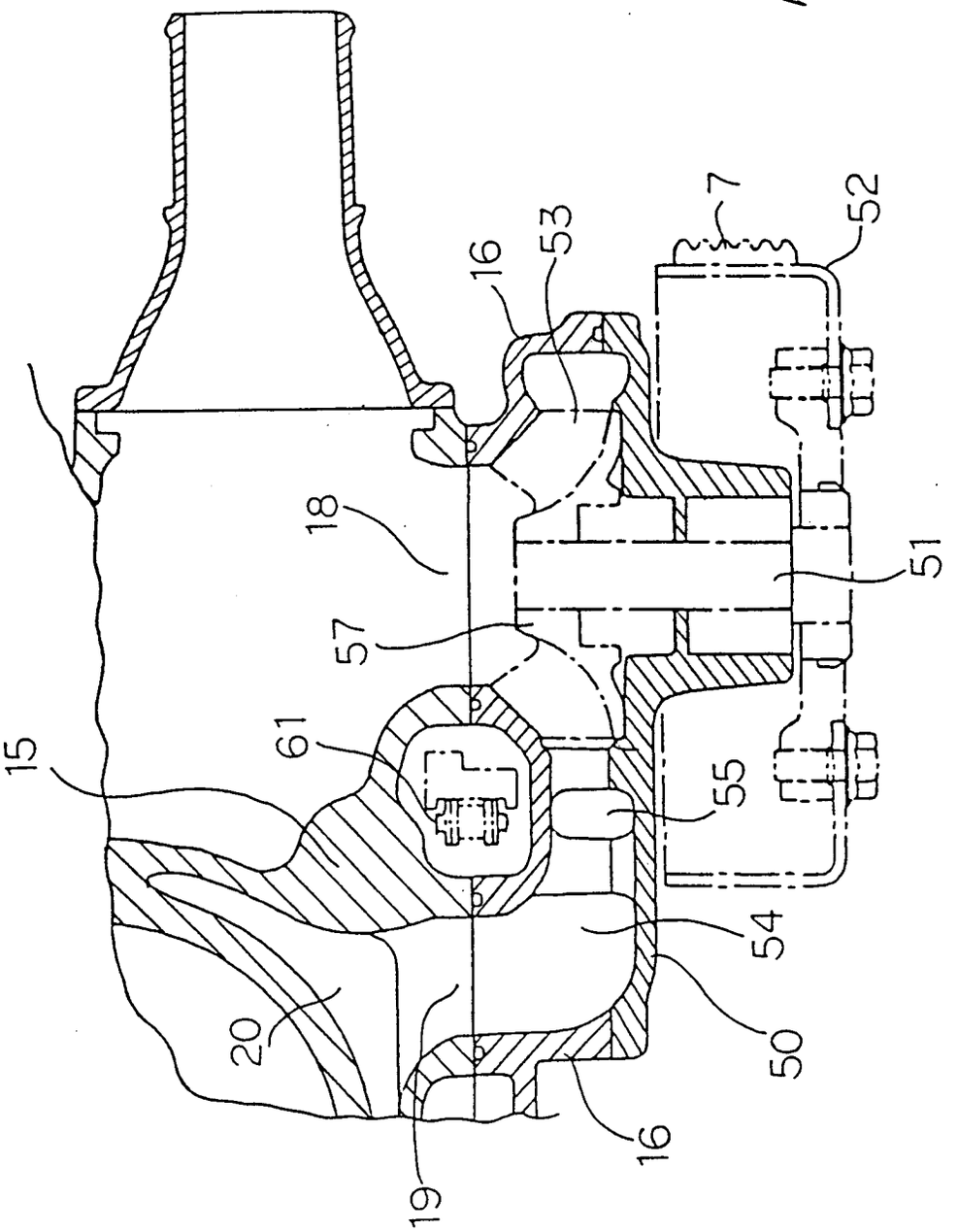



Fig. 4

Fig. 5



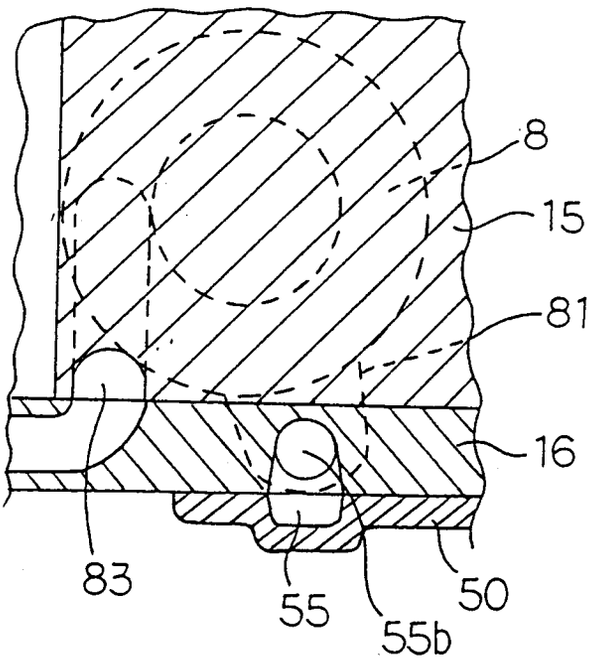



Fig. 6

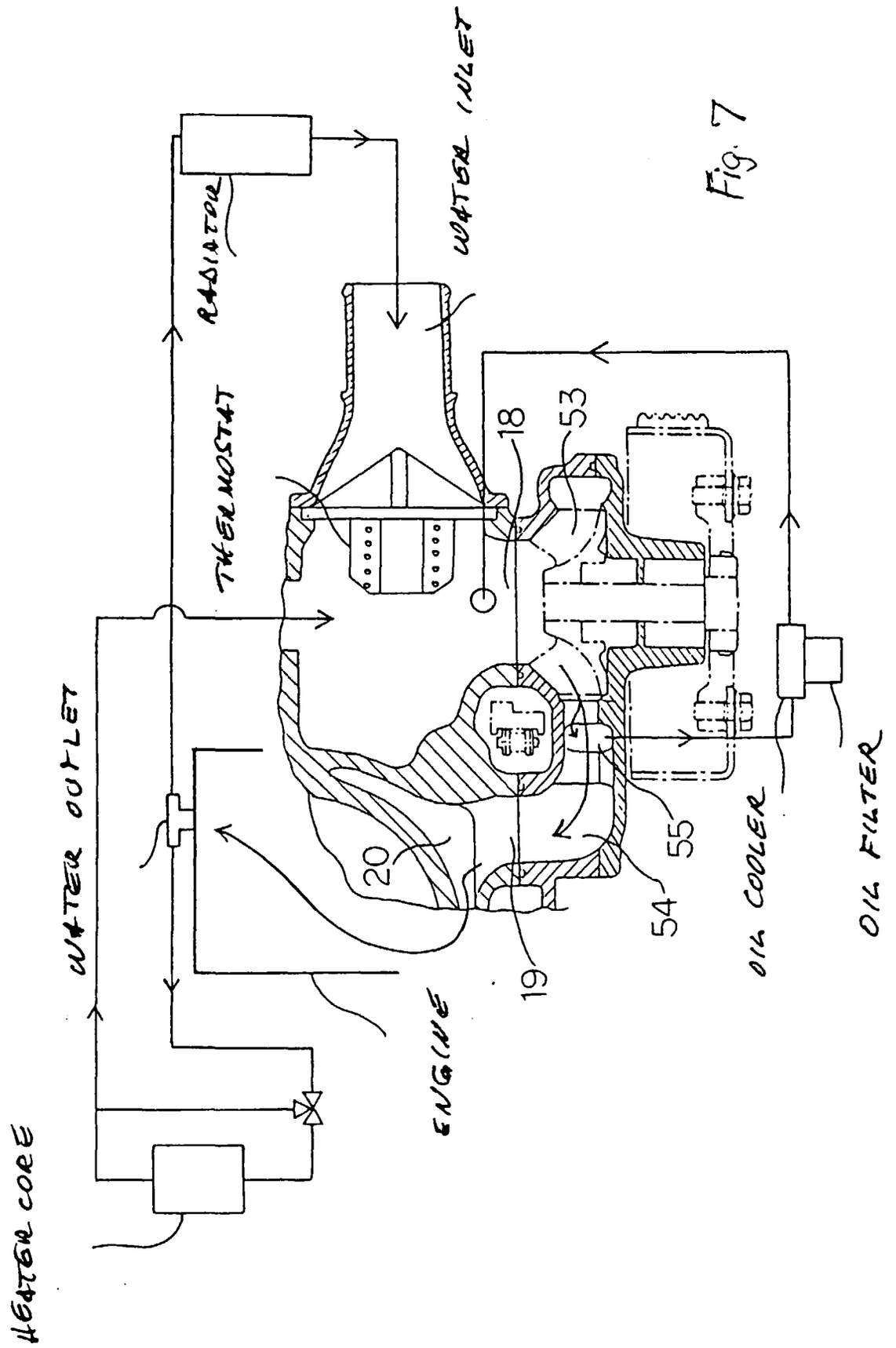

HEATER CORE
WATER OUTLET
RADIATOR
THERMOSTAT
WATER INLET
ENGINE
OIL COOLER
OIL FILTER
18
53
20
19
54
55

Fig. 7

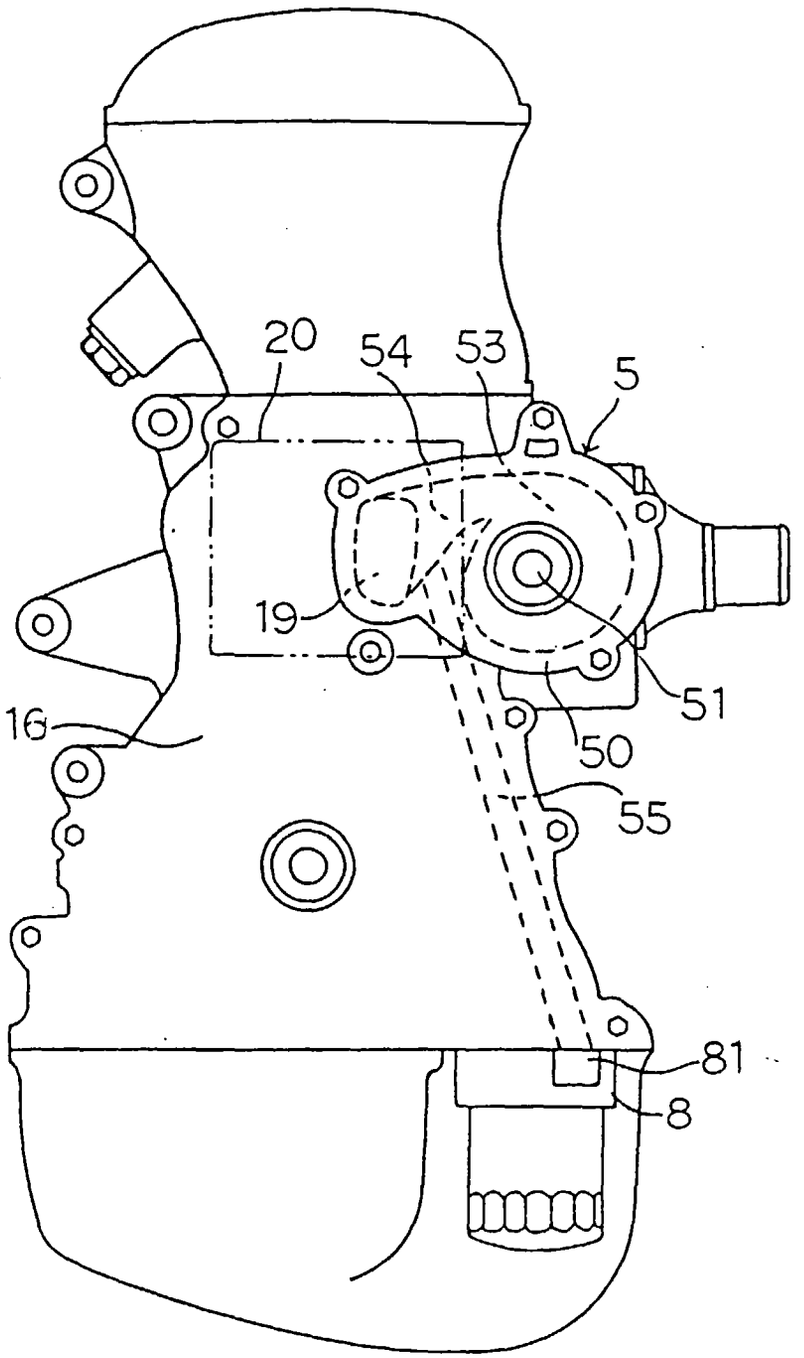



Fig. 8

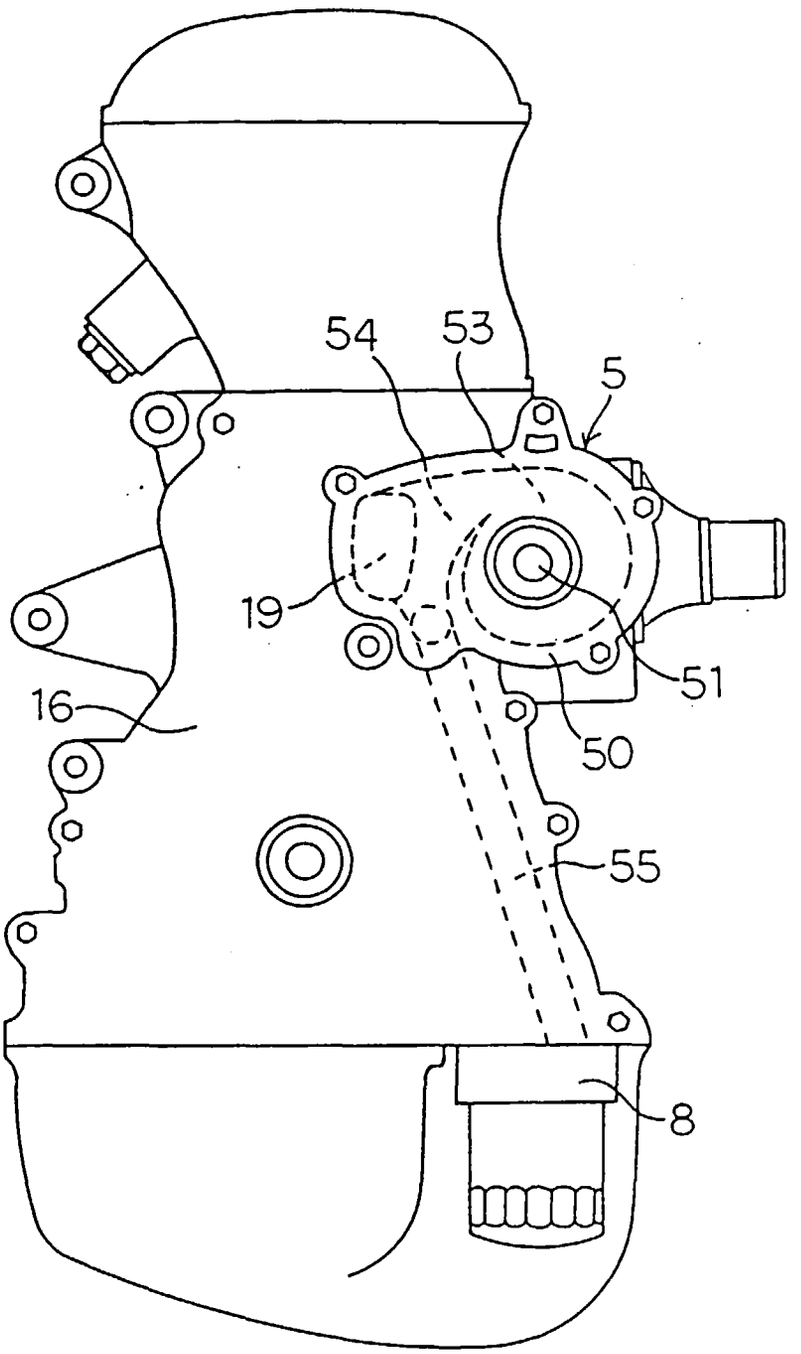



Fig. 9

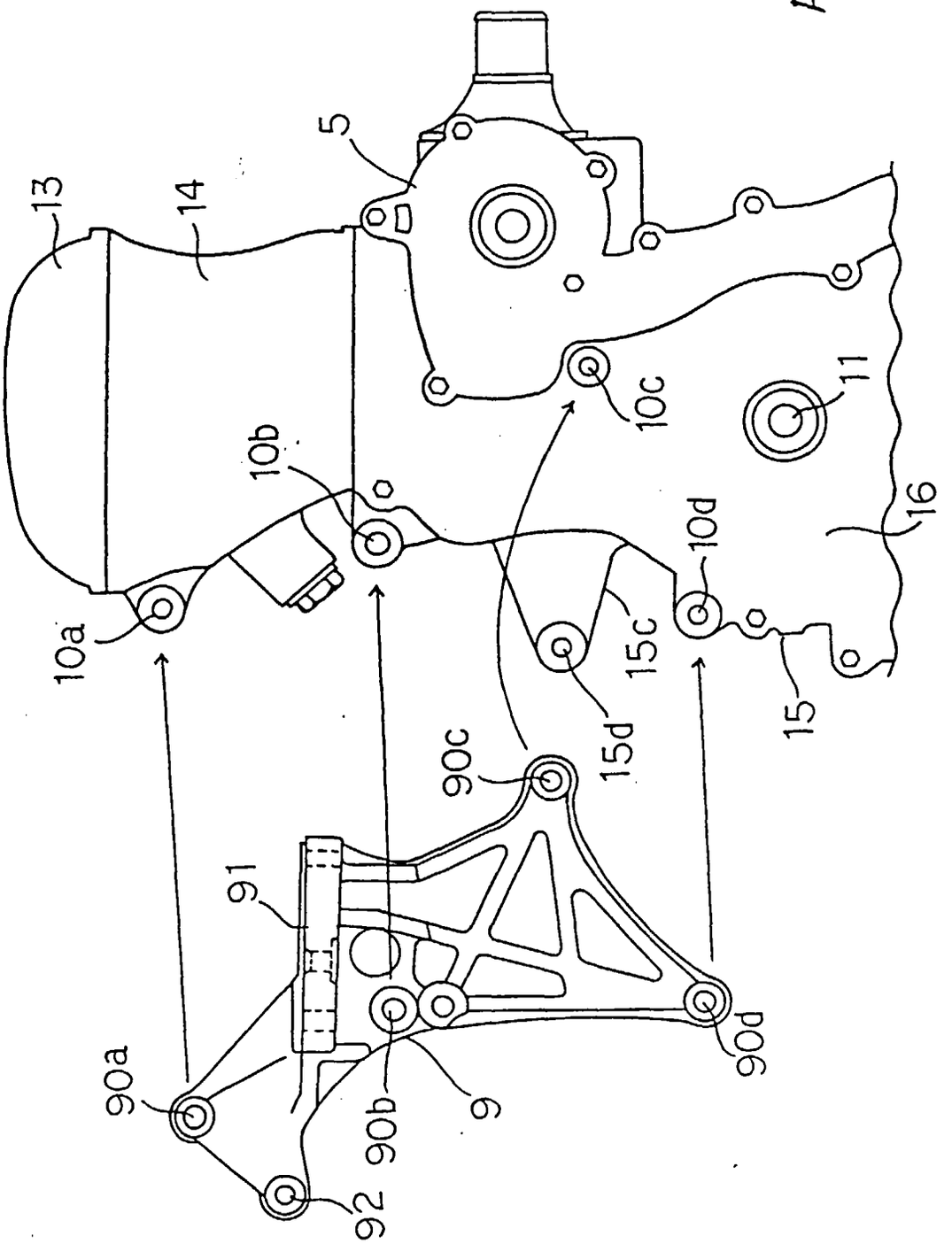



Fig. 10