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(54) Internal combustion engine.

(57) The present invention relates to an internal combustion engine of the four-cycle type comprising a cylinder block with at least one cylinder bore defined therein, a piston reciprocating in said cylinder bore, a crankshaft rotatably journaled and driven by said piston, a cylinder head (15) affixed to said cylinder block (14) through a plurality of head bolts (50,51), an exhaust passage arrangement (33) and an intake passage arrangement (32) with a plurality of exhaust valves (31) and at least three intake valves (31) supported in said cylinder head, said exhaust valves and said intake valves being actuated by an exhaust camshaft (23) and an intake camshaft (22), respectively, and at least one of said head bolts being disposed on the intake side of the cylinder head laterally outwards with respect to the intake camshaft. The engine is improved in that the camshafts are driven from said crankshaft via an intermediate reduction gear unit (19,20,21).

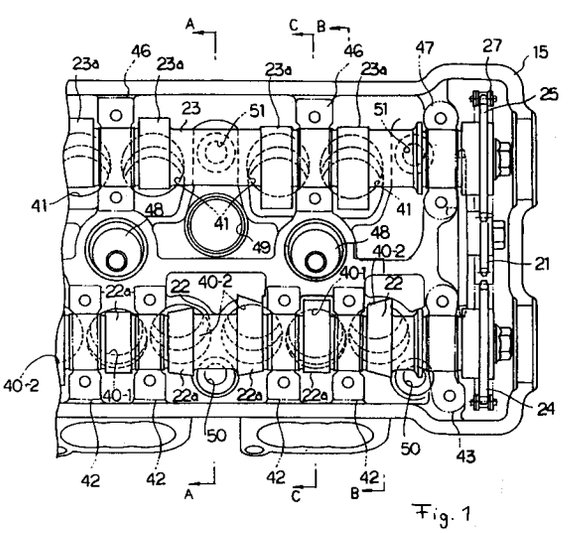

Fig. 1

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This invention concerns an internal combustion engine as indicated in the preamble of claim 1.

Recently, larger numbers of valves have been used as one means to increase the speed of 4-cycle engines. For example, the so-called 5-valve engines with three air intake valves and two exhaust valves per cylinder have appeared on the market.

However, as the number of valves increase, the more numerous the problems that result from interference between the valve lifters, the head bolts and the like in the cylinder head, so that the positioning of the head bolts has become a problem. These problems have been avoided by making cylinder heads larger, entailing dual structures, thus increasing the number of cylinder head parts and complicating the structure.

Also, since in 4 cycle engines, the camshafts are rotated at one half the speed of the crankshaft, the sprockets affixed to the camshafts have had to be of a relatively large diameter, making it difficult to reduce engine size.

The present invention was developed after reflection upon the foregoing problems and its objective is the creation of a four-cycle engine which, even with a large number of valves, allows a compact cylinder head with a single structure.

According to the present invention, the aforementioned objective is performed in that the camshafts are driven from said crankshaft via an intermediate reduction gear unit.

According to a preferred embodiment of this invention, the foregoing air intake valves are configured in a radiating manner, and moreover, positioned so that the distance between the axes of adjacent air intake valves is a minimum substantially at the mid-way position in the valve axial direction from the lower edge of the valve to the top of edge of the lifter.

According to a further preferred embodiment, the camshaft bearings are located between the air intake valve lifters on at least the air intake side of each cylinder, and since the cylinder head bolts on at least the air intake side are positioned outside the air intake valve lifters, interference among the cylinder head bolts, the lifters and camshaft bearings is avoided, thereby allowing a single cylinder head structure, fewer cylinder head parts, and a simplified cylinder head structure.

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

Hereinafter the present invention is illustrated and explained in greater detail by means of a preferred embodiment in conjunction with the accompanying drawings, wherein:

Fig. 1 is a top view of the principal parts of a cylinder head of an internal combustion engine according to an embodiment of the invention;

Fig. 2 shows the cylinder head of fig. 1 in a sectional view taken along line A-A in fig. 1;

Fig. 3 shows the cylinder head of fig. 1 including an exhaust valve and a side intake valve in a sectional view taken along line B-B in fig. 1;

Fig. 4 shows the cylinder head of fig. 1 including a center intake valve in a sectional view similar to the view of fig. 3 taken along line C-C in fig. 1;

Fig. 5 is a sectional view showing the positioning of the air intake valves in the camshaft direction;

Fig. 6 is a front view of the internal combustion engine according to the embodiment of fig. 1; and

Fig. 7 is a side view of the internal combustion engine with a part of the cover removed.

First, to describe the overall structure of this embodiment of the four-cycle engine 1, with reference to Figures 6 and 7, said four-cycle engine 1 is a multicylinder engine with the cylinders positioned side-by-side. As shown in the end view of Figure 6, the assembly comprises a pulley 3 affixed to one end of the crankshaft 2, a drive pulley 5 for the alternator 4, a drive pulley 7 for the water pump 6, a drive pulley 9 for the power steering pump 8, and a drive pulley 11 for the air conditioning compressor 10. These pulleys 3, 5, 7, 9, and 11 are connected by a V-belt 12. As shown in Figure 6, a pulley 13 is used to adjust the tension of V-belt 12.

A cylinder head 15 is affixed atop the cylinder block 14 of the four-cycle engine 1. A cylinder head cover 16 also covers the top of said cylinder head 15. An oil pan 17 is mounted under the cylinder block 14.

Also, on one side of the four-cycle engine 1, the other end of the above mentioned crankshaft 2 protrudes through a space formed at one end of the cylinder block 14, as shown in Figure 7, and a small diameter sprocket 18 is affixed there to said crankshaft 2. Also a freely rotating intermediate shaft 19 is present at the bottom of the foregoing cylinder head 15 and is parallel to the crankshaft 2. Large and small diameter sprockets 20, 21 are affixed to one end of said intermediate shaft 19.

Further, long, mutually parallel camshafts 22 and 23 are present on the top of the cylinder head 15 on the air intake and exhaust sides and run perpendicularly to the plane of the paper of Figure 7. Sprockets 24 and 25 are affixed to one end of each of these camshafts 22, 23, respectively and are larger in diameter than the foregoing sprocket 21.

A chain 26 spans the foregoing sprockets 18 and 20, while a chain 27 spans sprockets 21, 24 and 25. These chains 26 and 27 are maintained at the required tension by tensioners 28 and 29.

The details of the foregoing cylinder head 15, will be explained below with reference to Figures 1 through 5.

The four-cycle engine 1 as shown is of the 5-valve type, with three exhaust valves, 30-1, 30-2 (see Figures 3 and 4) on the air intake side and two exhaust valves 31 (see Figure 3) on the exhaust side. Three air intake passages 32-1, 32-2 (see Figures 3 and 4) and two exhaust passages 33 (see Figure 3) are present in the cylinder head 15. These air intake passages 32-1, 32-2 are opened and closed by the foregoing air intake valves 30-1, 30-2 at the appropriate timing, as are the exhaust passages 33 by the foregoing exhaust valves 31.

The above mentioned air intake valves 30-1, 30-2 and the exhaust valves 31 are inserted and retained in valve guides 34, 35 so that they are free to slide. Above them are valve lifters 36, 37 respectively. These air intake valves 30-1, 30-2, and exhaust valves 31 are held in the normally closed position by springs 38, 39, respectively.

Furthermore the above mentioned valve lifters 36 are slidably fitted into three round holes 40-1, 40-2 present at the air intake side of each cylinder in the cylinder head 15. Valve lifters 37 are slidably fitted into two round holes 41 on the exhaust side of each cylinder in the cylinder head 15. However, as shown in Figure 5, the thickness of the material between adjacent round holes 40-1, 40-2, which are positioned in a radiating manner and which contain the foregoing air intake valves 30-1, 30-2, is at its minimum in the mid-way position in the axial direction of the valves. Accordingly, the distance between the adjacent air intake valves 30-1, 30-2 has been shortened, providing space for the cam shaft 22 journal and allowing to increase the diameter of the lifters 36.

The foregoing camshafts 22, 23 run parallel to each other on the air intake and exhaust sides on top of the cylinder head 15. The air intake side camshaft 22 is supported so that it is free to rotate in the journal areas on bearings held by the bearing cap 42 between the valve lifters 36 (between the round holes 40-1 and 40-2) in the cylinder head 15, and on bearings at both ends of the cylinder head 15 held by bearing caps 43. Also, the exhaust side camshaft 23 is supported in such manner by bearings 44 that it is free to rotate in the areas between valve lifters 37 (holes 41) in the cylinder head 15, said bearing 44 being held in place by bearing cap 46 and bolts 45 (see Figure 4), as well as by bearings at both ends of the cylinder head 15, which are held by bearing caps 47.

The camshafts 22, 23 and the cams 22a, 23a sliding against the above mentioned valve lifters 36, 37, are each formed integrally as single units.

Here, as is shown in Figure 5, the centers of the various cams 22a on the air intake side in the width direction have been offset to the left in Figure 5 from the center of the air intake side valve lifters 36 by the amount of e_1, e_2 and e_3. Accordingly, when the cams 22a drive the valve lifters 36, said valve lifters 36 rotate around those centers (the axial centers of air intake valves), precluding uneven wear of said valve lifters.

As shown for the embodiment in Figure 5, the offset e_1 and e_3 on both sides is taken on the inside of the centers of the cams 22a, while the offset e_2 of the center is taken on the left side of the center of cam 22a. Accordingly, The distance from the center l_1 of the left side two cams 22a, is greater than the distance l_2 on the right side two cams 22a ($l_1 > l_2$), so that the thickness b_1 of the journal area between the left side two cams 22a is greater than the thickness b_2 of the journal area between the right side two cams ($b_1 > b_2$). The offset e_2 may be used on either side of the center of cam 22a, and if the offset e_2 had been taken on the right side with respect to the center of the cam 22a in Figure 5, then the above described relationships would be reversed: they would be $l_1 < l_2$, $b_1 < b_2$, respectively.

Also, as is shown in Figures 1 and 4, the plug holes 48, one for each cylinder, in the central area of the cylinder head 15 are such that they tilt toward the exhaust side. Again, as shown in Figures 1 and 4, the holes 49 in the cylinder head 15 are sand drain holes used for the casting process.

As shown in Figure 4, if the distances from the center of the cylinder bore to the centers of camshafts 22, 23 are L_1 and L_2, respectively, and if the distances from the center of the plug hole 48 to the camshafts 22, 23 are L_1' and L_2', respectively, the relationships of $L_1 < L_2$, $L_1' \leqq L_2'$ hold true.

In this embodiment, the cylinder head 15 has been cast as a single unit, and it is held onto the foregoing cylinder block 14 (see Figure 6) by means of cylinder head bolts 52, 53 (see Figure 2) which pass though the bolt insertion holes 50 present at an appropriate pitch on the air intake side, and bolt insertion holes 51 present at an appropriate pitch on the exhaust side of the cylinder head 15. However, as is shown in Figure 1, the bolt insertion holes 50 on the air intake side are outside the valve lifters 26 (round holes 40-1, 40-2).

When a four-cycle engine with the above described configuration is running and rotates the crankshaft 2, this rotation is transmitted from the sprocket 18 shown in Fig. 7 through the chain and sprocket 20 to the intermediate shaft 19 to set it into rotation, thereby transmitting the rotation of the crankshaft 2 by a first-stage speed reduction in the proportion of the ratio of the diameters of the

sprocket 18 to sprocket 20 to the intermediate shaft 19. Next the rotation of this intermediate shaft -- already reduced by the first-stage reduction -- is transmitted through the chain 27 to the sprockets 24 and 25 to drive into rotation their resp. camshafts 22 and 23, the ratios of the diameters of the sprocket 21 on the intermediate shaft 19 to the sprockets 24 and 25 on the camshafts 22 and 23 implementing the second-stage speed reduction, as a result of which said camshafts 22 and 23 rotate at half the speed of the crankshaft 2.

When the camshafts 22, 23 are rotatably driven as described above, the above mentioned cams 22a, 23a are caused to rotate, thereby pushing the foregoing intake and exhaust valve lifters 36, 37 downward at an appropriate timing, overcoming the force of springs 38, 39 for the intake and exhaust valves 30-1, 30-2, and 31, whereby, as described above, the intake and exhaust passages 32-1, 32-2, and 33 are opened and closed at the appropriate timing by the intake and exhaust valves 30-1, 30-2 and 31.

As described above, in this embodiment the rotational speed of the crankshaft is reduced in two stages when transmitted to the camshafts 22, 23, thereby enabling the sprockets 24, 25 affixed to camshafts 22, 23 to be of a lesser diameter, allowing a reduction of the distance between the camshafts 22 and 23, which further reduces the size of this four-cycle engine 1.

This embodiment comprises bearings for the camshaft 22 which are positioned between the valve lifters 36 for the three air intake valves 30-1, 30-2 on the air intake side, the bolt insertion holes 50 (for cylinder head bolts 52) on the air intake side being positioned outside the air intake side valve lifters 36 (round holes 40-1, 40-2), while avoiding interference among the cylinder head bolts 52, the valve lifters 36 and the bearings. As a result the cylinder head may be a single structure; one which is simpler and which offers a reduced number of parts for the cylinder head 15.

As is clear from the foregoing description, the shown embodiment simplifies the cylinder head structure, even enabling a single cylinder head structure for multi-valve engines and the achievement of more compact four-cycle engines of the type having three air intake valves per cylinder and overhead air intake and exhaust camshafts, by using a cylinder head with a single structure, a two stage speed reduction in the transmission of the rotation of the crankshaft to the foregoing camshafts, and further, by positioning camshaft bearings between the air intake valve lifters, and by positioning the cylinder head bolts outside the air intake valve lifters on the air intake side of the head.

Furthermore, it is to be noted that the provision and arrangement of the sand drain holes 49 is advantageous particularly with respect to the casting process. This is, of course, not restricted to sand drain holes provided in combination with the intermediate reduction gear unit or the head bolts disposed laterally outwards with respect to the intake camshaft.

Claims

1. Internal combustion engine of the four cycle type comprising a cylinder block (14) with at least one cylinder bore defined therein, a piston reciprocating in said cylinder bore, a crank shaft (2) rotatably journaled and driven by said piston, a cylinder head (15) affixed to said cylinder block (14) through a plurality of head bolts (52, 53), an exhaust passage arrangement (33) and an intake passage arrangement (32-1, 32-2) with a plurality of exhaust valves (31) and at least three intake valves (30-1, 30-2) supported in said cylinder head (15), said exhaust valves (31) and said intake valves (30-1, 30-2) being actuated by an exhaust camshaft (23) and an intake camshaft (22), respectively, and at least one of said head bolts (52) being disposed on the intake side of the cylinder head (15) laterally outwards with respect to the intake camshaft (22), **characterised in that** the camshafts (22, 23) are driven from said crankshaft (2) via an intermediate reduction gear unit (19, 20, 21).

2. Internal combustion engine according to claim 1, **characterised in that** said intermediate reduction gear unit comprises an intermediate shaft (19) rotatably journaled by the cylinder head (15) and a large diameter sprocket (20) and a small diameter sprocket (21) connected for rotation with said intermediate shaft (19), said large diameter sprocket (20) being driven from the crankshaft (2) via a first chain means (26) and said small diameter sprocket (21) driving the intake camshaft (22) and exhaust camshaft (23) via a second chain means (27).

3. Internal combustion engine according to claim 2, **characterised in that** the axis of rotation of the intermediate shaft (19) and the sprockets attached thereto is laterally offset towards the exhaust side of the cylinder head (15), while a tightening device (29) for tightening the second chain (27) is disposed on the intake side between the small diameter sprocket (21) and the intake camshaft (22).

4. Internal combustion engine according to at least one of claims 1 to 3, **characterised in that** the intake camshaft (22) and exhaust camshaft (23) are provided with a plurality of cams (22a, 23a) for actuating the intake valves (30-1, 30-2) and exhaust valves (31), respectively, through respective valve lifters (36, 37) slidably received within respective lifter holes (40-1, 40-2, 41) formed in the cylinder head (15).

5. Internal combustion engine according to claim 4, **characterised in that** the lifter holes (40-1, 40-2) on the intake side of the cylinder head (15) are disposed inwardly with respect to the head bolts (52) on the intake side of the cylinder head (15), while the head bolts (53) on the exhaust side are disposed between lifter holes (41) on the exhaust side of the cylinder head (15).

6. Internal combustion engine according to at least one of claims 1 to 5, **characterised in that** a center of each of the cams (22a) of the camshaft (22, 23) is offset in the direction of the camshaft axis by an amount (e_1, e_2, e_3) with respect to a center of the respective valve lifters (36, 37).

7. Internal combustion engine according to claim 6, **characterised in that** the center of the cams (22a) for the side intake valves (30-2) are offset in opposite diverging directions such that the distance (l_1) between one of the side intake valve cams (22a) and the center intake valve cam (22a) is greater than the distance (l_2) between the other one of the side intake valve cams (22a) and said center intake valve cam (22a).

8. Internal combustion engine according to at least one of claims 1 to 7, **characterised in that** the intake valves (30-1, 30-2) are arranged in a radiating manner, such, that the distance between the axes of two adjacent intake valves (30-1, 30-2) reaches a minimum at a point between a top edge of the valve lifters (36) and a bottom of the intake valves (30-1, 30-2).

9. Internal combustion engine according to at least one of claims 1 to 8, **characterised in that** the intake camshaft (22) and/or the exhaust camshaft (23) are rotatably supported by camshaft bearings (44) formed, at least partially, in the cylinder head (15) between adjacent lifter holes (40-1, 40-2, 41).

10. Internal combustion engine according to claim 9, **characterised in that** journal caps (42, 43) are provided for holding the camshafts (22, 23) to rotate in journal areas defined by said camshaft bearing (44) formed in the cylinder head (15).

11. Internal combustion engine according to claim 9 or 10, **characterised in that** the length of a journal area formed by said camshaft bearing (44) between a first of the side intake cams (22a) and the center intake cam (22a) is greater than the length of a journal area between a second of the side intake cams (22a) and the center intake cam (22a).

12. Internal combustion engine according to at least one of claims 1 to 11, **characterised in that** the cylinder head (15) is provided with a plug hole (48) for each cylinder, said plug hole (48) being disposed between the center intake valve (30-1) and the exhaust valves (31) and tilted towards the exhaust side of the cylinder head (15).

13. Internal combustion engine according to claim 12, **characterised in that** the plug hole (48) is disposed such that a distance (L_1') between the center of the plug hole (48) and the intake camshaft (22) is smaller than a distance (L_2') between the center of the plug hole (48) and the exhaust camshaft (23).

14. Internal combustion engine according to at least one of claims 1 to 13, **characterised in that** the camshafts (22, 23) are disposed such that a distance (L_1) between the intake camshaft (22) and the cylinder bore axis is smaller than a distance (L_2) between the exhaust camshaft (23) and said cylinder bore axis.

15. Internal combustion engine according to at least one of claims 1 to 14, **characterised in that** the cylinder head (15) is provided with a sand drain hole (49) for draining sand when casting the cylinder head (15), said sand drain hole (49) being offset with respect to the cylinder bore axis and the crankshaft axis towards the exhaust side of the cylinder head (15).

16. Internal combustion engine according to at least one of claims 1 to 15, **characterised in that** the cylinder block (14) defines a plurality of cylinders arranged in line and a sand drain hole (49) is provided in the cylinder head (15) between each pair of adjacent cylinders inwardly with respect to the lifter holes (41) for the exhaust valves (31).

17. Internal combustion engine according to at least one of claims 1 to 16, **characterised in that** the intake valves (30-1, 30-2) and the exhaust valves (31) are slidably received and retained within valve guides (34, 35).

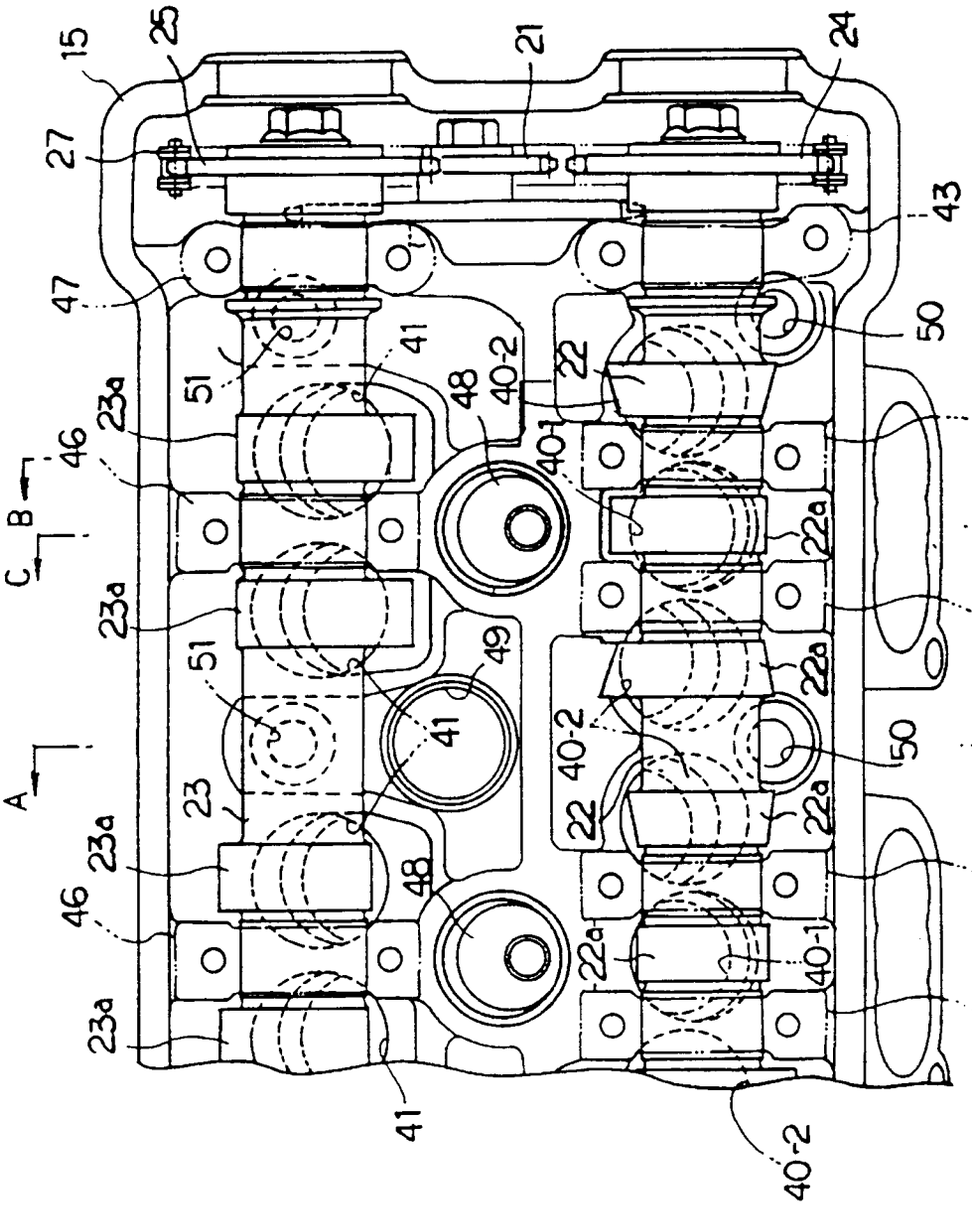
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Fig. 1

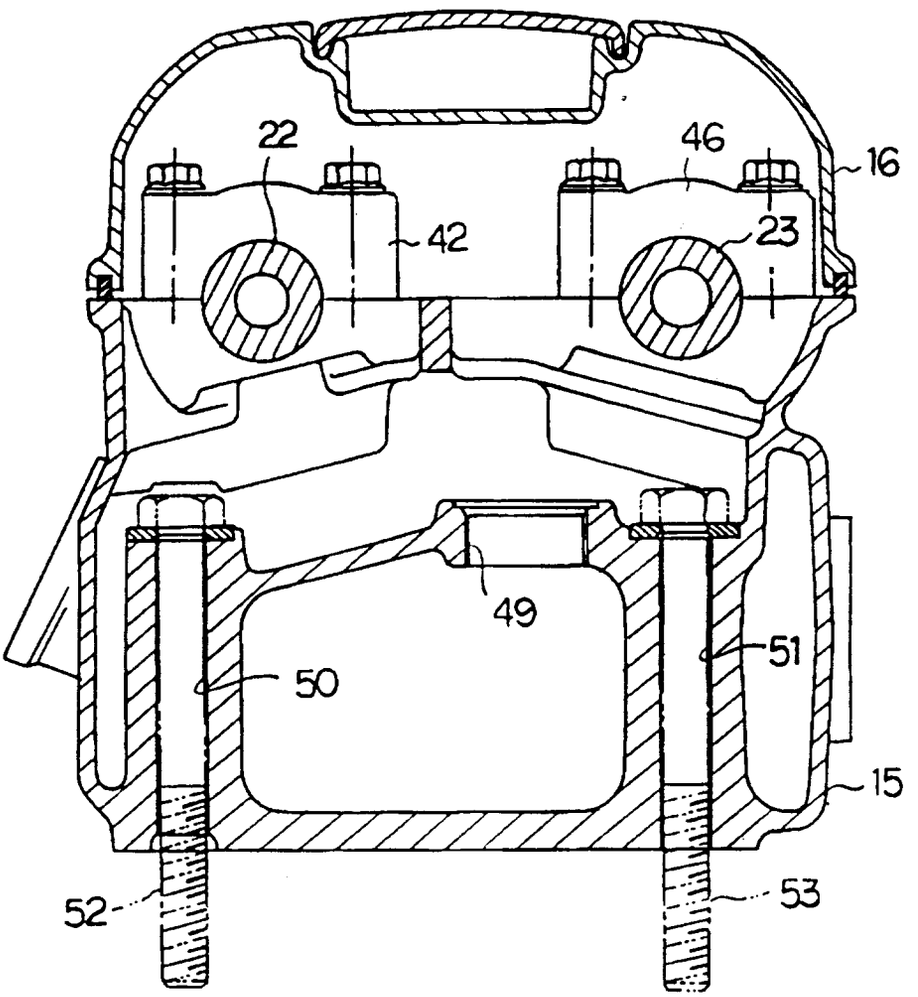

Fig. 2

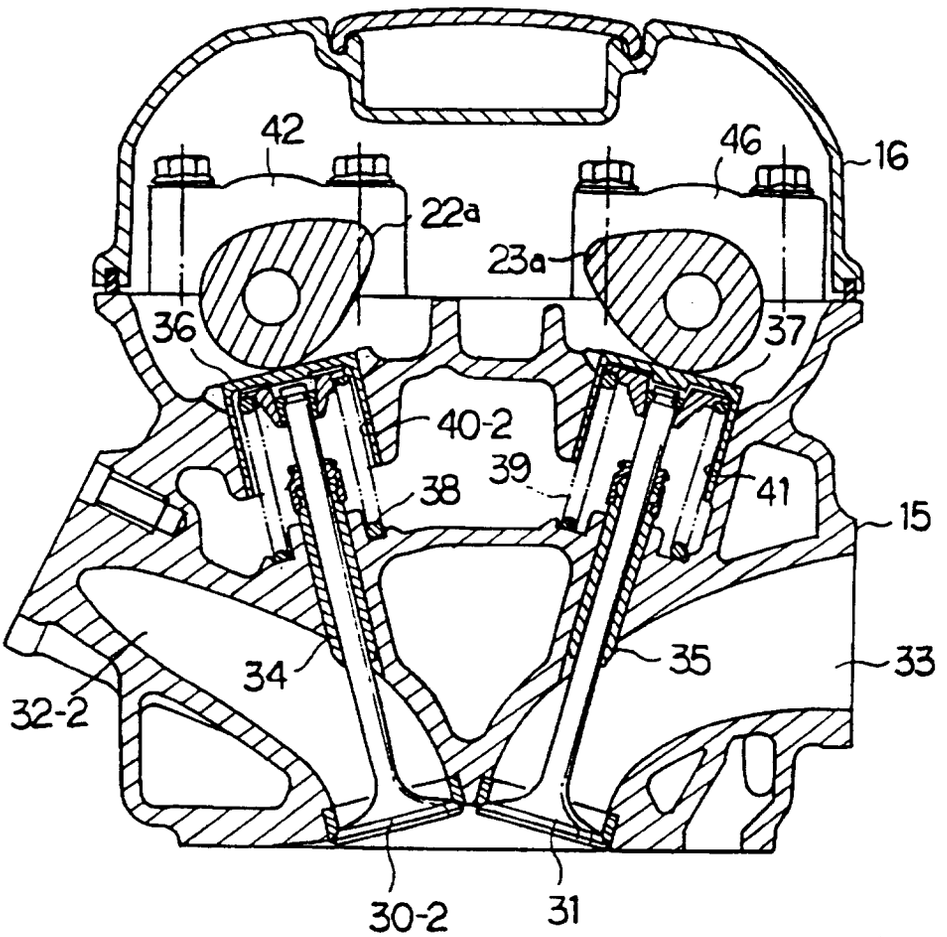

Fig. 3

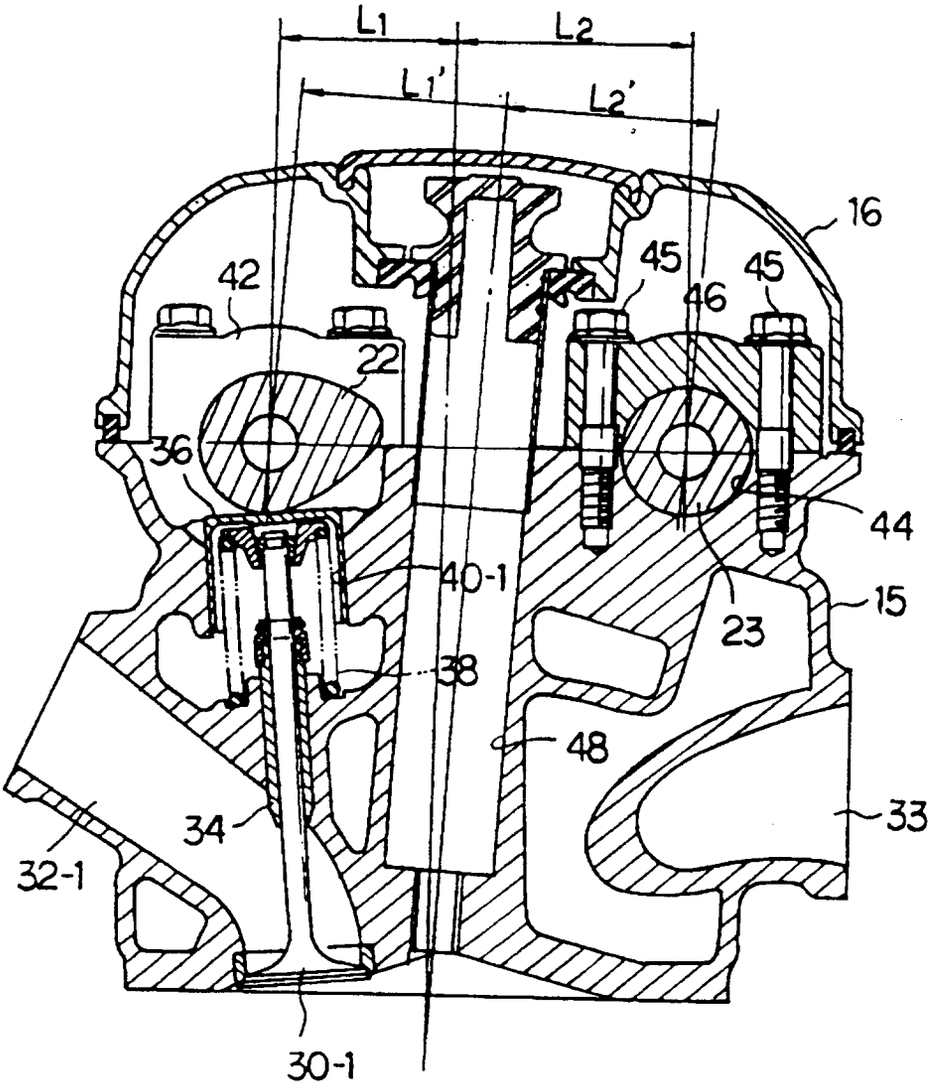

Fig. 4

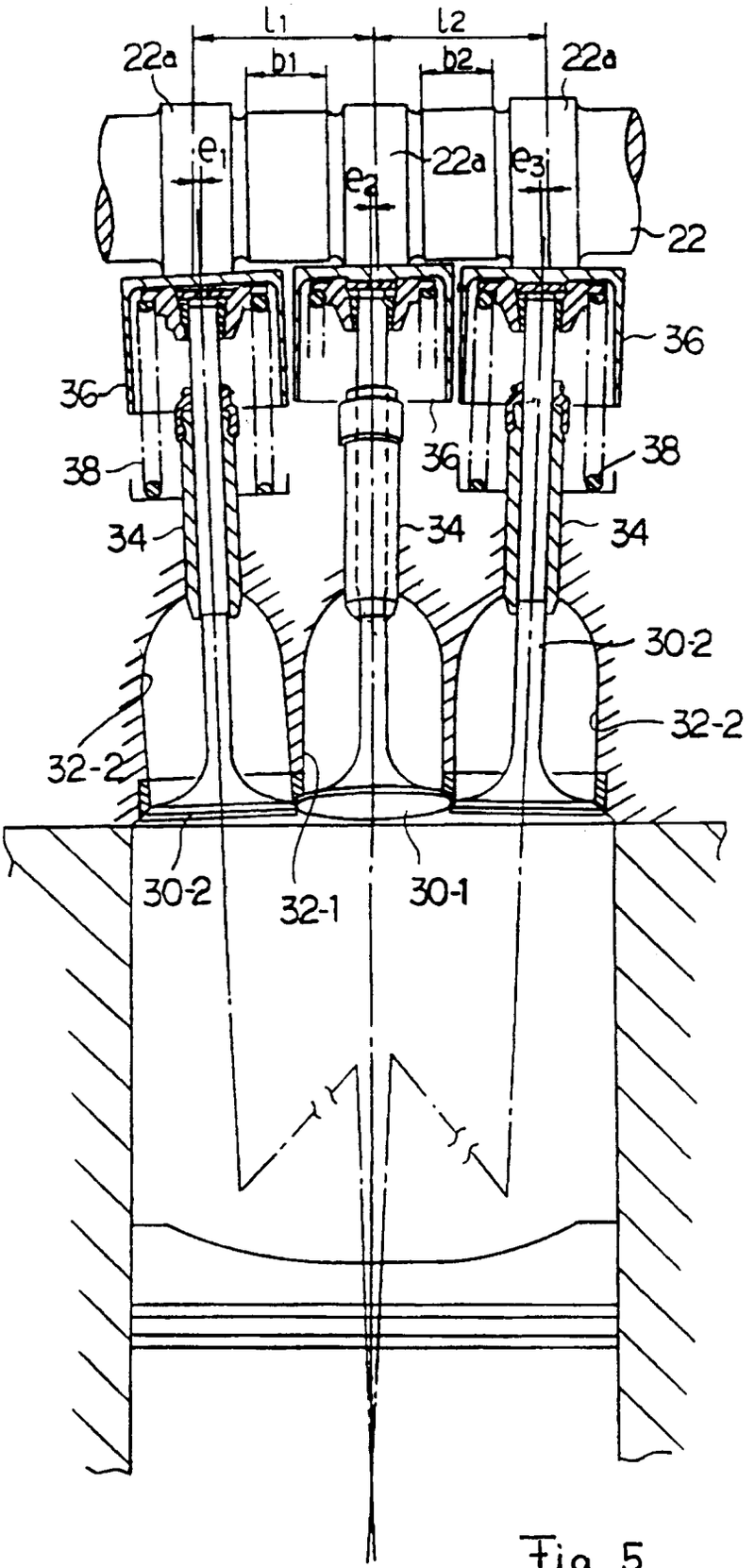
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Fig. 5

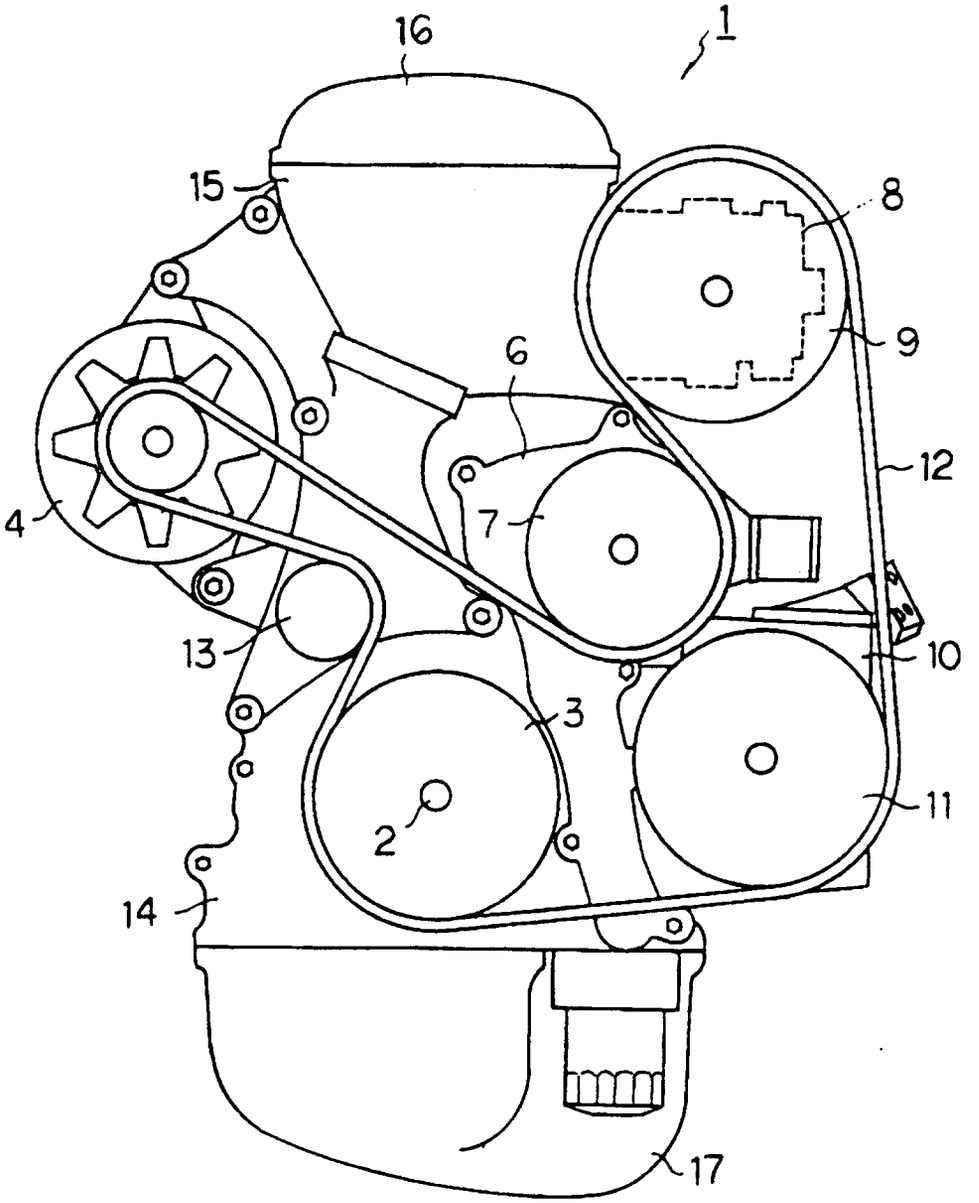

Fig. 6

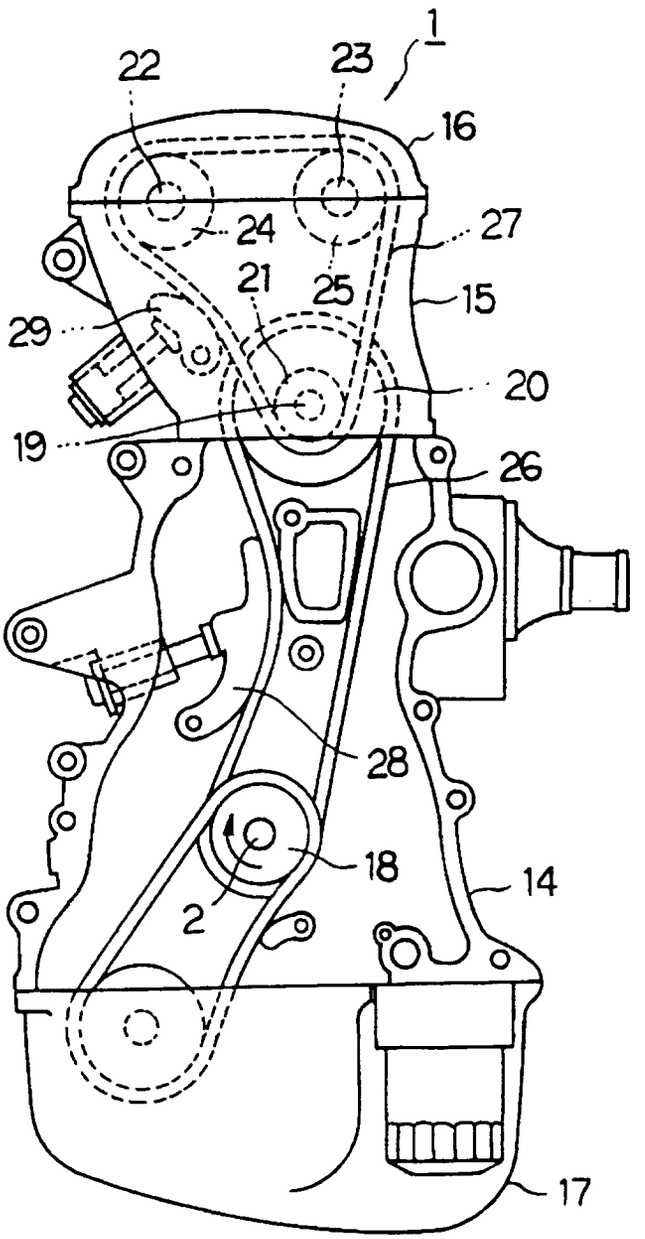

Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 94 12 0849

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	EP-A-0 474 217 (YAMAHA HATSUDOKI KABUSHIKI KAISHA) * column 11, line 42 - column 12, line 11; figures 4,5 *	1,2, 4-10,12, 14,17	F01L1/26 F02F1/24 F02F1/42 F01L1/02 F01L1/04
Y	US-A-5 099 812 (YAMAHA HATSUDOKI KABUSHIKI KAISHA) * the whole document *	1,2, 4-10,12, 14,17	
A	DE-A-38 38 305 (AUDI AG) * column 2, line 28 - column 3, line 21; figures 1-3 *	6-8	
A	US-A-5 018 497 (YAMAHA HATSUDOKI KABUSHIKA KAISHA) * figure 11 *	11	
A	PATENT ABSTRACTS OF JAPAN vol. 14, no. 545 (M-1054) 4 December 1990 & JP-A-02 230 906 (YAMAHA MOTOR CO LTD) 13 September 1990 * abstract *	1-3	TECHNICAL FIELDS SEARCHED (Int.Cl.6) F01L F02F
A	PATENT ABSTRACTS OF JAPAN vol. 14, no. 436 (M-1027) 18 September 1990 & JP-A-02 173 303 (NISSAN MOTOR CO LTD) 4 July 1990 * abstract *	1-3	
A	PATENT ABSTRACTS OF JAPAN vol. 17, no. 392 (M-1450) 22 July 1993 & JP-A-05 071 415 (YAMAHA MOTOR CO LTD) 23 March 1993 * abstract *	15	

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 February 1995	Klinger, T

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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D : document cited in the application
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EUROPEAN SEARCH REPORT

Application Number
EP 94 12 0849

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	PATENT ABSTRACTS OF JAPAN vol. 11, no. 128 (M-583) 22 April 1987 & JP-A-61 268 849 (TOYOTA MOTOR CORP) 28 November 1986 * abstract * -----	16	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)

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