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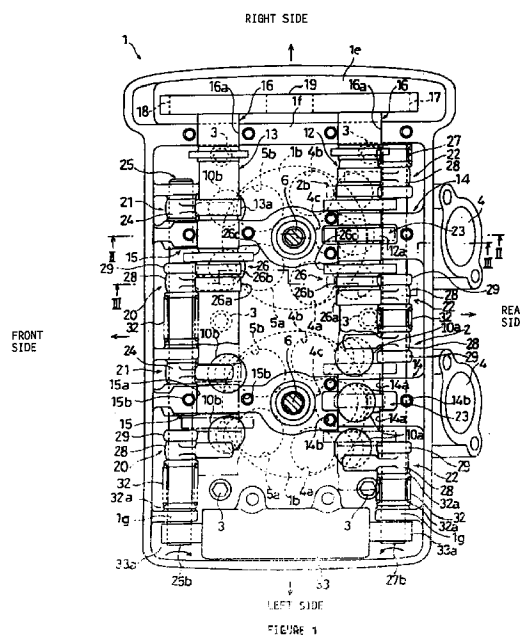
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(54) Internal combustion engine and method for controlling the valve actuation

(57) An internal combustion engine comprises a cylinder body having at least one cylinder and a cylinder head provided with a plurality of air intake and exhaust valves. These intake and exhaust valves are actuatable via air intake and exhaust camshafts in cooperation with respective rocker arms mounted at respective exhaust and intake rocker shafts and associated with said cylinder. Further, there is provided a dynamic valve apparatus being capable to variably control the valve opening and closing timing, the valve lift, and the shut down of at least some of said air intake and exhaust valves. The dynamic valve apparatus comprises a moving mechanism for moving respective rocker arms between an operational position in which a cam nose of each of said camshafts is in sliding contact with said rocker arms and a non-operational position in which said rocker arm is offset of said cam nose in axial direction of said exhaust and intake rocker shafts in accordance with detected engine operational conditions.



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Description

The present invention relates to an internal combustion engine comprising a cylinder body having at least one cylinder, a cylinder head provided with a plurality of air intake and exhaust valves actuatable via air intake and exhaust camshafts in cooperation with respective rocker arms mounted at respective exhaust and intake rocker shafts and associated with said cylinder, and a dynamic valve apparatus being capable to variably control the valve opening and closing timing, the valve lift, and the shut down of at least some of said air intake and exhaust valves and to a method for controlling the valve actuation of an internal combustion engine comprising a cylinder body having at least one cylinder, a cylinder head provided with a plurality of air intake and exhaust valves actuatable via air intake and exhaust camshafts in cooperation with respective rocker arms mounted at respective exhaust and intake rocker shafts and associated with said cylinder and a dynamic valve apparatus being capable to variably control the valve opening and closing timing, the valve lift, and the shut down of at least some of said air intake and exhaust valves.

There have been dynamic valve apparatus for engines capable of performing variable control to shut down some of the plurality of valves on each cylinder, to variably control the valve opening and closing timing, and to variably control the valve lift.

An example of a variable lift control type of dynamic valve apparatus is the swing arm type that was described in the prior art, for example in Japan Patent Application Disclosure Sho 60-243310 (1985). This conventional apparatus pivotally supports the swing arms at their base end and brings the valve shaft into contact with their front end, wherein each of said swing arms would be pushed and driven by a cam nose, a second pivot also is present between the first pivot and the cam nose on said swing arm, and said second pivot can be moved up or down by a hydraulic cylinder.

With the apparatus of the prior art as described in the above application, when the engine is operating in the low speed operating range, the swing arm pivots on the first pivot, and when operating in the high speed operating range, the swing arm pivots on the second pivot. This design causes greater valve lift in the high speed operating range than in the low speed operating range.

However, in order to further improve the performance of engines, not only is it necessary to vary the valve lift between the low speed and high speed operating ranges, but it is further desirable to vary the valve timing as well. Since the foregoing conventional apparatus relies on the same cam noses, it is not possible to vary the valve timing in that design. Furthermore, it is impossible to obtain a zero valve lift, in other words, to shut down the valves.

Accordingly, it is an objective of the present invention to provide an improved internal combustion engine

as indicated above which facilitates with a simple and space saving construction the variable control of the valve opening and closing timing as well as of the valve lift and in addition to control the valve shut down.

It is a further objective of the present invention to provide an improved method for controlling the valve actuation of an internal combustion engine as indicated above which facilitates to reliably control and with a minimal time delay the variable control of the valve opening and closing timing as well as of the valve lift and in addition to control the valve shut down.

According to the invention, this objective is solved for an internal combustion engine as indicated above in that the dynamic valve apparatus comprising a moving mechanism for moving respective rocker arms between an operational position in which a cam nose of each of said camshafts is in sliding contact with said rocker arms and a non-operational position in which said rocker arm is offset of said cam nose in axial direction of said exhaust and intake rocker shafts in accordance with detected engine operational conditions.

Further, according to the present invention, this objective is solved for a method for controlling the valve actuation of an internal combustion engine as indicated above by the steps of moving said rocker arms by means of said dynamic valve apparatus having a moving mechanism between an operational position in which a cam nose of each of said camshafts is in sliding contact with said rocker arm and a non-operational position in which said rocker arm is offset of said cam nose in axial direction of said exhaust and intake rocker shafts in accordance with detected engine operational conditions.

In order to further enhance the controllability of the internal combustion engine, it is advantageous when said moving mechanism comprises sliders slidably mounted on the exhaust and intake rocker shafts and being movable by a transmission pin guidable by respective drive slots formed in said exhaust end intake rocker shafts for pushing said rocker arms from a first position to a second position, a spring for urging said rocker arms back to the first position when said sliders are released from said rocker arms, and an actuator rotating said exhaust and intake rocker shafts to actuate said sliders.

When said internal combustion engine comprises three intake air valves and two exhaust valves symmetrically arranged to both sides of a plane containing a central axis of said cylinder, it is advantageous when at least said air intake valves arranged at both sides of said plane and at least one of said exhaust valves are operable by said moving mechanism.

According to an advantageous embodiment of the present invention, all exhaust and all intake valves are operable by said moving mechanism.

According to an advantageous embodiment of the inventive method for controlling the valve actuation, it is advantageous when at least two of said air intake valves and at least one of said exhaust valves are moved by

said moving mechanism.

It is possible to further enhance the controllability when an engine control unit controls said moving mechanism.

According to one embodiment of the invention, when the rocker arm is positioned in the operational position, the rotational movement of the cam nose is transmitted to the valve by the rocker arm; when the rocker arm is in the non-operational position, the rotational movement of the cam nose is transmitted directly to the valve, and it is possible to vary the amount of valve lift depending on the axial position of the rocker arm.

According to another embodiment of the invention, the cam nose is composed of a high speed nose and a low speed nose, so that, when the rocker arm is positioned in the operational position, the rotational movement of the high speed nose is transmitted by the rocker arm to the valve, and when the rocker arm is in the non-operational position, the rotational movement of the cam nose is transmitted directly to the valve. As a result, depending on the shapes of the low speed nose and high speed nose and the amount of lift in the designs, it is possible to variably control the valve lift and the opening and closing timing. In this case, by setting the low speed nose to have approximately zero lift, it is possible to shut down the valve when the rocker arm is placed in the non-operational position.

According to a further embodiment of the invention, the above described shifting system is installed for one of the exhaust valves and for the left and right side intake valves, and the foregoing low speed nose is shaped to virtually shut down the opening and closing operations of the valve. Accordingly, during low speed operations, one of the foregoing exhaust valves, and the left and right side air intake valves are virtually shut down, while only the remaining exhaust valve and the center air intake valves are operated. During mid-speed operations, either the foregoing left or right side air intake valve is shut down while both exhaust valves and two air intake valves are operated. Further, in high speed operating ranges, all the valves are operated, thereby making it possible to shut down valve operations in three stages according to the operating state of the engine.

Further, since only the center air intake valve, from among the three air intake valves, is left operational in the low speed operating range, it is possible to direct the air intake flow in the axial direction of the cylinder, thereby generating a tumbling action which facilitates stable combustion at lean air/fuel ratios.

According to still another embodiment of the invention, since the transfer speed of the rocker arm from the non-operational position to the operational position is higher than the transfer speed in the reverse direction, during rapid acceleration, for example, the number of valves operating can be immediately increased, thereby improving acceleration response.

Further, according to a still further embodiment of

the invention, the rotation of the inner rocker shaft to the non-operational position causes the rocker arms to be shifted to the non-operational position by the drive surface of the inner rocker arm which drives it in the non-operational direction when rotated, and the retaining members on the outer rocker shaft retain the rocker arms in said non-operational position. On the other hand, when the inner rocker shaft is rotated into the operational position, the rocker arms are released from the foregoing retainer position by the return drive surface on the inner rocker shaft, and the foregoing holding force immediately returns the rocker arms to the operational position. This feature allows the movement of the rocker arms from the non-operational position to the operational position to be quicker than their movement in the opposite direction.

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

In the following, the present invention is explained in greater detail with respect to several embodiments thereof in conjunction with the accompanying drawings, wherein:

Figure 1 is a top view of the dynamic valve apparatus for an engine according to a first embodiment incorporating the inventions of Claims 1 - 3;

Figure 2 is a sectional view along line II-II of Figure 1;

Figure 3 is a sectional view along line III-III of Figure 1;

Figure 4 is a side view of the cylinder head of the foregoing embodiment,

Figure 5 is a diagram showing the shape of the cam nose in the foregoing embodiment;

Figure 6 is a diagram showing the drive mechanism for the rocker arms in the foregoing embodiment;

Figure 7 is a diagrammatic sectional view showing the drive slots on the rocker shafts in the foregoing embodiment;

Figure 8 explains the operation of the foregoing embodiment;

Figure 9 explains the operation of the foregoing embodiment;

Figure 10 explains the operation of the foregoing embodiment;

Figure 11 is a top view of a modification around the center air intake valve of the foregoing first embodiment;

Figure 12 is a sectional side view of a modification around the center air intake valve of the foregoing first embodiment;

Figure 13 is a top view of the dynamic valve apparatus of a second embodiment that incorporates the inventions of Claims 4 and 5;

Figure 14 is a diagram showing the drive slots of the foregoing second embodiment;

Figure 15 is a diagram used to explain the operation of the foregoing second embodiment;

Figure 16 is a diagram used to explain the operation of the foregoing second embodiment;

Figure 17 is a diagram used to explain the operation of the foregoing second embodiment; and

Figure 18 is a diagram of the drive slots of the foregoing second embodiment.

Examples of the present invention will be described below with reference to the attached Figures.

Figures 1 - 10 will be used to explain a first embodiment of dynamic valve apparatus for engines according to the present invention. Figure 1 is a top view showing the cylinder head with the cover removed; Figures 2 and 3 are sectional views taken along lines II-II and III-III of Figure 1, respectively; Figure 4 is a side view of the cylinder head; Figure 5 is a diagram showing the shape of the cam nose; Figure 6 is a diagram showing the drive slot of the rocker shaft; Figure 7 is a sectional diagram of the rocker shaft drive mechanism, Figures 8 through 10 are Figures that will be used to explain the operation. In the present embodiment, the exhaust side will be the front side and the air intake side will be the rear side, and left, right and center will refer to the directions when looking toward the front side from the rear side.

In the Figures, 1 represents an engine cylinder head for a water-cooled, four-stroke cycle, in-line, twin cylinder, five-valve engine equipped with an embodiment of this invention, and it is secured to the top of the top mating surface of a cylinder body 2 that is affixed to the top of a crank case (not shown) by means of head bolts 3.

Two concave combustion zones 1b are formed in the cylinder body mating surface 1a of the foregoing cylinder head 1, which, together with the cylinder bores 2a in the foregoing cylinder body 2, form the combustion chambers. Formed in said combustion areas 1b are left and right side air intake valve openings 4a, 4b, a center air intake valve opening 4c, as well as left and right side exhaust valve openings 5a, 5b. Further there are threaded holes for spark plugs 6 positioned to approximately coincide with the axial center of the cylinder bores 2a. These hold the spark plugs 6 in a manner such that their electrodes are exposed to the inside of

the foregoing concave combustion areas 1b.

The foregoing air intake valve openings 4a - 4c converge into a single air intake port 4 which connecting them to the rear wall of the cylinder head 1. In addition, the foregoing exhaust valve openings 5a, 5b converge into a single exhaust port 5 connecting them to the front wall of said cylinder head 1.

The valve heads 7d of the air intake valves 7a, 7b and 7c are positioned, respectively, where they can open and close the foregoing air intake valve openings 4a - 4c. Valve springs 9, which hold the foregoing air intake valves 7a - 7c in the normally closed position, are located between a retainer 8 on the top surface of the valve shafts 7e and spring seats 1c formed in the cylinder head. Attached to the top ends of the foregoing air intake valves 7a - 7c are air intake lifters 10a. Said lifters 10a can freely slide in lifter guide holes 1d formed in the cylinder head 1.

The valve heads 11c of the left and right side exhaust valves 11a, 11b are positioned, respectively, where they can open and close the foregoing exhaust valve openings 5a, 5b. Valve springs 9, which hold the foregoing exhaust valves 11a, 11b in the normally closed position, are located between a retainer 8 on the top surface of the valve shafts 11d and spring seats 1c that were formed in the cylinder head 1. Attached to the top ends of the foregoing exhaust valves 11a, 11b are exhaust lifters 10b. Said lifters 10b can freely slide in lifter guide holes 1d formed in the cylinder head 1.

An air intake camshaft 12 and exhaust camshaft 13 are installed in parallel above the foregoing air intake lifters 10a and exhaust lifters 10b. Said air intake and exhaust camshafts 12, 13 are axially supported by air intake and exhaust center bearings 14, 15 which are located in the areas of the shafts opposite the cylinder bore axes.

The foregoing center exhaust bearings 15 are composed of receiver members 15a formed in the cylinder head 1 and of removable cam caps (not shown) attached thereto. Said cam caps are retained in place over the foregoing head receiver members 15a by cap bolts secured in two threaded bolt holes 15b.

The foregoing center air intake bearings 14 are composed of receiver members 14a formed in the cylinder head 1 and of removable cam caps (not shown) attached thereto. The foregoing head side receiver member 14a splits left and right, on either side of the air intake lifter 10a, to accommodate the center air intake valve 7c. Further, said cam caps are forked and are retained in place over the foregoing head receiver members 14a by cap bolts secured in three threaded bolt holes 14b.

The foregoing air intake and exhaust camshafts 12, 13 are supported on their right ends by the end bearings 16. Said end bearings 16 are composed of a head-side bearing 16a that is formed in the partitioning wall 1f between the cam chamber and the chain chamber 1e and the cover bearing (not shown) formed on one side of the head cover. Located inside the foregoing chain

chamber are cam sprockets 17, 18 formed on the right ends of the foregoing camshafts 12, 13, respectively, and said sprockets 17, 18 are linked to the cam sprocket on the crankshaft by means of a timing chain 19.

A variable exhaust timing mechanism 20 on the foregoing left side exhaust valve 11a and a feed exhaust timing mechanism 21 on the right side exhaust valve 11b drive the valves open and closed, respectively. Further, a variable air intake timing mechanism 22 on the foregoing left and right side air intake valves 7a, 7b, and a fixed air intake timing mechanism 23 on the center air intakes valves drive them open and closed, respectively. The left and right side exhaust valves 11a, 11b are the same length.

The foregoing fixed air intake timing mechanism 23 has a conventional structure. A center cam nose 12a formed on the air intake camshaft 12 directly drives the air intake lifter 10a to open and close the air intake valve 7. On the other hand, the fixed exhaust timing mechanism 20 has a right exhaust rocker arm 24 between the right side cam nose 13a formed on the exhaust camshaft and exhaust lifter 10b for the right side exhaust valve. This right side rocker arm 24 runs parallel to the exhaust camshaft at the front side of the exhaust lifter 10b and moreover it is slidably supported by the exhaust rocker shaft 25 which rotatably passes through it.

Further, the variable exhaust timing mechanism 20 of the foregoing right side exhaust valve 11a and the variable air intake timing mechanism 22 for the left and right side air intake valves 7a, 7b are of the same basic structure except for the symmetrical positioning of their respective drive slots which will be described below. Accordingly, the following explanation will concern the variable air intake timing mechanism 22 for the left side air intake valve 7a.

The foregoing variable air intake timing mechanism 22 is structured so that the side cam nose 26 on the air intake camshaft 12 corresponding to the left side air intake valve 7a is shaped in a manner such that the side air intake lifter can be directly driven or be driven by means of the rocker arm 28.

As is primarily shown in Figure 5, the foregoing side cam nose 26 is composed of a guide circle 26a which is of slightly greater diameter than the casting skin area 26d of the camshaft, of a high speed nose 26b which is of the same diameter of the base circle but has a lift amount *a* appropriate for the opening timing (operating angle) during high speed operations, and *a* of low speed nose 26c which has lift *c* and which has a base circle diameter that is slightly greater by the dimension *b* (1 mm or less) than that of said high speed nose 26b. The approximate center of the foregoing air intake lifter 10a is between the foregoing guide circle 26a and the low speed nose 26c.

The air intake rocker shaft 27 rotatably passes through the rear side of the foregoing air intake lifter 10a and it runs parallel to the camshaft 12. In the areas on this air intake rocker shaft 27 corresponding to the left

and right air intake lifters 10a, 10a, as will be described further below, are left and right drive slots 31, 31', and there are a left drive slot 31 and a left side right drive slot 31' for the left side air intake valve which is shaped differently than that for the right drive slot 31'.

Also, in the area of the foregoing left and right drive slots 31, 31' on the foregoing rocker shaft 27 are fitted, annular left and right sliders 29 that can slide in the axial direction. Each of the sliders 29 has a transmission pin 30 that projects radially. The inside ends of said pins 30 are held in the foregoing drive slots 31, 31', and the outside ends are held in guide holes 1h formed parallel to the rocker shaft in the cylinder head 1. With this structure, when the rocker shaft 27 is rotated, the foregoing sliders 29 move in the axial direction.

The foregoing left drive slots 31, 31' are composed of a slot area 31a that slants to the axial line of the rocker shaft, and a retention area 31b which is at right angles to the axial line of the rocker shaft, as is shown in Figure 6. Accordingly, when the rocker shaft 27 is rotated in the direction of arrow *a* shown in Figure 6, during the first half of the rotation, the foregoing transmission pin 30 moves in the left drive slots toward the cylindrical axis, but it does not move further during the second half. On the other hand, on the drive slot 31 side, there is no movement during the first half, but during the second half of the rotation there is movement toward the cylinder axis.

The structure for the rocker shaft 25 drive slot on the exhaust side is similar to that of the foregoing left side drive slot 31, the first half of the rotation of the rocker arm causes the slider to move but will be held stationary through the second half of the rotation.

Attached to the foregoing rocker shaft 27 is the above-mentioned rocker arm 28, which is in contact with the end surface of the foregoing slider 29, and said rocker arm 28 is free to slide and to move in the axial direction. There is a spring 32 held by a spring receiver 32a in contact with the anti-slider end surface of said rocker arm 28, and the other end of the spring is in held by a spring receiver 32a in the support boss 1g formed in the cylinder head 1. In this manner, the rocker arm 28 is normally held on the side of the high speed nose 26b.

Thus, the rocker arm 28 with the foregoing structure follows the movement of the foregoing slider 29; when said rocker arm 28 is positioned farther away from the cylindrical axis by the slider 29, then it lies between the foregoing guide circle 26a and the lifter 10a (in the non-operational position), and when it is positioned closer to the cylindrical bore (the inside end) it lies between the foregoing high speed cam nose 26b and the lifter 10 (the operational position).

There is a pinion unit 25b, 27b formed on the left ends of the foregoing exhaust and air intake rocker shafts 25, 27, and these pinion units engage a rack unit formed on the output shaft of a hydraulic actuator that is located in the left end of the cam chamber. A control signal is fed into a switching oil pressure valve in an oil pressure circuit for the foregoing hydraulic actuator 33

by an ECU (not shown). The control will be described in detail for the valve shutdown control, variable valve opening and closing timing, and variable valve lift control. To wit, the foregoing ECU functions as a positioning means for the rocker arms in this invention.

Next, the operational effects of the embodiment's apparatus will be explained.

When the engine is operating at low speeds, the air intake and exhaust rocker shafts 25, 27 are held in the low speed position, and the transmission pins 30 on the sliders 29 lie in the low speed position (the outside end) in the various drive slots 31, 31', to position the sliders toward the outside. Accordingly, the rocker arm 28 lies in the non-operational position between the guide circle 26a and the lifter 10a. As a result, the rocker arm 28 does not swing, and the low speed cam nose 26c directly drives the lifter 10a. Accordingly, the left side exhaust valve 11a and the left and right side air intake valves 7a, 7b are lifted only slightly by the low speed cam nose 26c to a lift height c which keeps the valves virtually in a shutdown condition.

The center air intake valve is always opened and closed at a fixed timing and lifts according to the nose shape and nose height of the center cam nose 12a which opens and closes the center air intake valve opening no matter what the engine RPM range, while the exhaust rocker arm 24, based upon its rocker ratio, opens and closes the right side exhaust valve opening 5b at a fixed timing and lift.

When a change is made from low speed to mid-speed engine operations, the rocker shaft 27 is rotated to the mid-speed position and the transmission pins 30 move to the mid speed position in the drive slots 31, 31'. In this case, transmission pin 30 for the drive slot 31' for the right side air intake valve is not displaced in the axial direction, so that the right side valve 7b remains virtually shut down just as it was during the above described low speed operations.

On the other hand, the transmission pins 30 are moved axially in the drive slot 31 for the foregoing left side exhaust valve 11a and the left side air intake valve 7a to advance their rocker arms 28 to between the high speed nose 26b and the lifter 10a or 10b, thereby driving the left side exhaust valve 11a and the left side air intake valve 7a opened and closed by means of the high speed cam nose 26b and the rocker arms 28. As a result, the two exhaust valves, and two of the air intake valves are operating, while one air intake valve is shut down.

The above described switching operation is performed as follows. When, in response to a switching signal, the foregoing hydraulic actuator rotates the rocker shafts 25, 27 as shown in Figure 6 from the low speed position to the mid-speed position, the slider 29 moves toward the inside and the cylindrical axis due to the transmission pin 30 moving in the drive area 31a of the drive slot 31. At this time, when the camshaft rotates from the position (shown in Figure 2) where the side surface of the high speed cam nose 26b is sliding

against the side surface of the rocker arm 28 (the side facing the cam nose) to the position corresponding to where the foregoing opposite surfaces are at the base circle position, the spring force against the foregoing rocker arm 28 will cause it to slide toward the slider 29, advancing it to the position between the high speed cam nose 26b and the lifter 10a.

After that, the rotational action by the high speed cam nose is transmitted to the lifter 10a, or lifter 10b by means of the rocker arm 28 with the result that the foregoing left side exhaust valve 11a and the left side air intake valve 7a are opened and closed, respectively, according to the nose shape and height of the high speed cam nose 26b and the rocker ratio of the rocker arm 28.

When a transition is made from mid-speed to high speed operations, the rocker shaft 27 is rotated to its high speed position and the rocker pins 30 move to the high speed positions in the drive slots 31, 31'. In this case, the transmission pins 30 for the left side exhaust valve and the left side air intake valve do not move. On the other hand, the transmission pin for the right side air intake valve moves toward the inside in the drive area 31a of the drive slot 31', thereby causing the right side air intake valve 7b to begin operating. As a result, all the valves are operational.

Also, when making the transition from high speed to mid-speed and then to low speed operations, the transition is made from all the valves being operational to shutting down one of the air intake valves, followed by a condition where two of the air intake valves and one of the exhaust valves are shut down. Making the transition from operational to shutdown occurs by rotating the rocker shafts 25, 27 in the reverse direction as described above. In this case, the sliders 29 directly slide the rocker arm 28 from the position shown in Figure 10 to the position shown in Figure 9 or Figure 8 without respect to the angular position of the camshaft.

Thus in the current embodiment, since there is a high speed cam nose 26b and a low speed cam nose 26c with a larger diameter base circle, the rocker arm 28 can be advanced into an operational position between the high speed cam nose 26c and the lifter 10a or withdrawn into the non-operational position, thereby making it possible to shut down two air intake valves and one exhaust valve during low speed operations, and to shut down one exhaust valve during mid-speed operations, thereby shutting down valves on the basis of the operating state of the engine.

Here, since the low speed cam nose 26c has but a slight nose height c , even when the foregoing valves are in a shutdown period, the foregoing valves 11a, 7a, and 7b are opening and closing slightly, eliminating the possibility of fuel remaining in the vicinity of the valve opening and preventing the buildup of carbon and other deposits in the area of the exhaust valve opening.

Further, with regard to the switching structure that switches from low speed to mid-speed to high speed operations, because the rocker shaft 27 forcibly slides

the slider 29, and the spring 32 pressing against the rocker arm 38 causes it to follow the movement of the slider, so-called synchronized movement has been made possible, and the movement of a plurality of rocker arms 28 can be performed unobstructed in multi-cylinder engines.

Incidentally, in the case where the structure is such that the rocker arms are directly moved by the rocker shaft without using any springs, the rocker arm must move at the point when the rocker's side surface is positioned at the base circle of the cam nose. However, in the case of a four-cylinder engine, it is normally the case that the valve opening timing for each of the cylinders is different, and it would usually be impossible to set the timing for the rocker arms of all four cylinders to move to the base circle of the cam nose at the same time. Accordingly, in the case of four-cylinder engines, it is difficult to adopt a direct moving structure for the rocker arms, although it would be possible for a single-cylinder engine, and even possible for two-cylinder engines if the movement could be set between the combustion intervals.

Further, in the rocker arm 28's non-operational position (shutdown position), since the present embodiment uses a guide circle 26a which is formed to the same diameter as the base circle of the high speed cam nose 26b, there can be a smooth transition from the shutdown position of the rocker arm 28 to the operational position. Even if the guide circle 26a is designed to be of somewhat larger diameter (10 μ m for example) than the base circle of the high speed nose 26b, there is almost no impediment to the foregoing transition.

Further, since the present embodiment continues the normal operation of the center air intake valve 7c while two of the three air intake valves are shut down, and because the left and right side exhaust valves 7a, 7b are shut down and put on variable timing, not only is it easy to secure the space required for said shifting mechanism, but in addition, since the center air intake valve 7c is the only valve imparting direction to the air intake during low speed operations, which directs it in the axial direction of the cylinder, the resulting tumbling action stabilizes lean combustion.

While the foregoing first embodiment allows one air intake valve to operate during low speed operations, two to operate during mid-speed operations and three to operate during high-speed operations, it is possible to select the number of operating valves by the shape of the foregoing drive slots 31, 31'.

Further, while the present embodiment uses a nose of 1 mm or less for the low speed nose 26c that virtually shuts down the valve, it is of course possible to employ any nose shape and height appropriate to low speed operations for said low speed nose 26c, thereby allowing different opening and closing timing and lift between low speed operations and mid-/high speed operations.

Further, in the present embodiment, the rocker arms are shifted between an operational position between the high speed nose and the lifter, and a non-

operational position outside that position, and the freedom in design of the shape of the nose can be further broadened by using a structure that makes the rocker arm slidable between a high speed nose and a lifter and between a low speed nose and a lifter.

The foregoing embodiment describes the case where the center cam nose 12a presses against the lifter 10a to directly drive the center air intake valve 7c open and closed, but this drive could equally well be performed through a rocker arm.

Figures 11 and 12 show an example where the center air intake valve 7c is driven by a rocker arm 28'. In this example the center bearing 14', composed of the bearing 15a formed in the head and the cam cap, has been divided into two parts which sandwich, on the left and right sides, the air intake lifter 10a, and a center rocker arm 28' is positioned between the left and right sections. The foregoing head cap is removably held in place by four bolts that thread into the head side bearings 14a.

Figures 13 through 18 will be used to explain a second embodiment. In the Figures, parts that are the same as those in Figures 1 through 12 bear the same reference numbers. This second embodiment is an example wherein the transition time for the rocker arm to move from the non-operational position to the operational position is much greater than the transition time for the movement in the opposite direction.

The engine used in this second embodiment is the same engine used in the foregoing first embodiment, and the basic structure of the dynamic valve apparatus is the same as that of the first embodiment, except that the rocker shafts have a double walled pipe structure composed of an inner rocker shaft and outer rocker shaft. To wit, the inner rocker shaft 41 on the air intake side is rotatably and axially supported by the support boss 1g and the center bearings 14, but it is incapable of movement in the axial direction. It can be rotated by means of the actuator 33.

An outer rocker shaft 42 is installed coaxially around the outside circumference of the foregoing inner rocker shaft 41 and is rotatable with respect to it. The ends of said outer rocker shaft 42 are in contact with the foregoing support boss 1g and with the end surface of the center bearing 14 and it cannot move in the axial direction.

Left and right drive slots 43, 44 are formed in the areas of the foregoing inner rocker shaft 41 and outer rocker shaft 42 that correspond to the left and right side air intake valves, as shown in Figure 14. Said left drive slot 43 is composed of inner and outer left drive slots 45, 46 formed in the inner and outer rocker shafts 41, 42, respectively. The right drive slot 44 is composed of the inner and outer right drive slots 47 and 48 formed in the inner and outer rocker shafts 41, 42, respectively.

The foregoing inner left drive slot 45 is composed of: a holding slot 45a, which extends at right angle (in the circumferential direction) with respect to the axial line *a* of the rocker shaft to form the operational position

holding slot which holds the foregoing transmission pin 30 and the slider in the operational position; a non-operational direction angular drive surface 45b that continues from said operational position retention slot 45a and runs at an angle with respect to the rocker shaft axis *a*, and which, in conjunction with the rotation of said inner rocker shaft 41, causes the slider to move to the non-operational position; and a return drive surface 45c, which is formed parallel to the rocker shaft axis *a*, continuing from the foregoing operational position slot 45a, so that the slider can return from the above described non-operational position to the operational position without rotating the inner rocker shaft 41. Furthermore, the above mentioned outer left drive slot 46 has a non-operational position retention slot 46a which holds the foregoing slider in the non-operational position, and a guide slot 46 b, which extends in parallel to the rocker shaft axis *a* and which guides the movement of the foregoing slider 29 between the operational and non-operational positions.

The foregoing inner right drive slot 47 is composed of: a non operational direction angular drive surface 47a, which is formed at an angle with respect to the rocker shaft axis *a*, and which with the rotation of the inner rocker shaft 41 causes the foregoing slider to move to the non-operational position; and a return drive surface 47b which is formed parallel to the rocker shaft axis and which, without the rotation of the inner rocker shaft 41, allows the slider 29 to return from the foregoing non-operational position to the operational position. Furthermore, the foregoing outer right drive slot 48 has a non-operational position retaining slot 48a that extends perpendicularly with respect to the rocker shaft axis *a* and which holds the foregoing slider in the non-operational position, and a guide slot 48b which extends in parallel to the rocker shaft axis.

The exhaust rocker shaft is composed of an inner rocker shaft 52 which can be rotated by the foregoing actuator 33, and an outer rocker shaft 52, which can rotate with respect to the inner rocker shaft 51 but which cannot move axially. As is shown in Figure 18, an inner drive slot and outer drive slot are formed in both of said rocker shafts 51, 52. Said inner drive slot 53 is formed at an angle with respect to the rocker shaft axis and it has a non-operational direction slanted drive surface 53a that drives the foregoing slider 29 to the non-operational position and a return drive surface 53b that is formed parallel to the rocker axis. Further, the foregoing outer drive slot 54 has a non-operational position retention slot which retains the foregoing slider in the non-operational position, and a guide slot which runs parallel to the rocker shaft and which guides the movement of the foregoing slider between the operational and non-operational positions, parallel to the rocker shaft.

Next, the operation of the present embodiment will be explained.

First, the operation on the air intake side will be explained. In Figures 15 and 16, the drive slots 45 for the left and right side air intake valves have been flipped

upside-down from the position shown in Figure 14 for the purpose of seeing the action of the transmission pins for the left and right side air intake valves.

When the engine is operating in the high speed range as shown in Figure 15 (a), the inner rocker shaft is at the right side position (the high speed operating position), and the transmission pins 30, in other words, the sliders 29, are positioned in the inner left and right drive slots 45, 47 in the left edge of the Figure, as well as in the left and right outer drive slots in the lower part of the Figure. This positions the left and right side air intake rocker arms 28 in the operating position, and as a result, the three intake valves, including the left and right side air intake valves 7a, 7b, and the center air intake valve 7c, are all being driven by the high speed nose through the rocker arms.

When the engine is operating in the mid-speed range as shown in Figure 15 (b) - (e), the inner rocker shaft 41 is rotated to the middle position (the mid-speed operations position), which is to the left with respect to the Figure, whereupon the slider 29 for the right side air intake valve is moved by the non-operational direction slanted drive surface 47a in the axial direction and upward to the non-operational position side, while the rocker arm 28 for the right side is pushed into the non-operational position against the force of the spring 32 (see the position in Figure 13). This design causes the right side air intake valve 7b to be driven open and closed by the low speed nose 26c, thereby setting it into a virtually shutdown condition.

In this case, since the slider 29 for the left side air intake valve 7a is maintained in the operating retention slot 45a of the inner left drive slot 45, even when the inner rocker shaft 41 is rotated, it does not move axially, but rather, the left side air intake valve 7a continues to operate.

On the other hand, when the engine is in the low speed operating range, as shown by Figure 15 (f) - (i), the inner rocker shaft 41 is rotated to its left side position (the low speed operating position) and the slider 29 for the left side air intake valve is moved axially and upwardly as shown in the Figure (downward in Figure 13) by the non-operational position direction slanted drive surface 45b of the inner left drive slot 45 that moves the slider 29t and the rocker arm 28 for the left side air intake valve into the non-operational position. This feature causes the left side air intake valve to be driven by the low speed nose 26c, setting it into a virtual shutdown state. Also, the transmission pin 30 for the left side air intake valve is held in the non-operational position retention area 46a of the outer left drive slot 46.

When the foregoing inner rocker shaft 41 is rotated to the left side in Figure 15, the transmission pin 30 of the right side air intake valve moves further to the left due to the inner left drive slot 47, but at this time, since it remains within the non-operational position retention slot 48a of the outer left drive slot 48, the left side air intake valve maintains a virtually shutdown state.

In the above described low speed operating range,

only the center air intake valve remains operational, while the left and right side air intake valves are virtually shut down, but, as shown in Figure 15 (j)- (l) when the inner rocker shaft 41 is rotated to the right side shown in the Figure to the low speed operation holding position. In other words, when the inner rocker shaft 41 is rotated to the right from the foregoing left side position to just before the foregoing middle position, this feature causes the transmission pin 30 for the right side air intake valve to come into contact with the return drive surface 45c of the inner drive slot 45, and it is held in this position

Then, when the engine again reaches the mid-speed operating range, as shown in Figure 15 at steps (m), (n), rotating the inner rocker shaft 41 just slightly to the right achieves the foregoing mid-speed operating position. When this event happens, the return drive surface 45c of the inner left drive slot causes the transmission pin 30 to be pushed to the right side shown in the Figure, away from the retention slot 46a of outer left drive slot 46. This design causes the transmission pin 30 to be immediately moved to the operating position by the foregoing spring force, to immediately render the left side air intake valve operational.

Also, when returning to low speed operations, as shown in Figure 15 at steps (o) - (r), the inner rocker shaft 41 is rotated to the left to the low speed operating position, and the transmission pin 30 for the left side air intake valve is moved in the axial direction to once again put the left side air intake valve into a virtually shutdown condition, and further rotation brings it into the low speed operation holding position (Figure, steps 16 (a) - (c)).

Further still, when moving toward the mid-speed operational state, the left side air intake valve becomes operational immediately (Figure 15, (d), (e)). In this mid-speed operating range, the center air intake valve 7c and the left side air intake valve 7a are operating, while the right side air intake valve 7b remains virtually shut down. However, when the inner rocker shaft 41 is rotated to the mid-speed operation holding position as shown in Figure 16 in steps (f) - (i), the latter valve remains holding in that position. To wit, when the inner rocker arm 41 is rotated from the foregoing middle position to just before the foregoing right side position, the transmission pin 30 for the right side air intake valve is in contact with the return drive surface 47b of the inner right drive slot 47, and it is held in this position.

Then, for high speed operations, as shown in Figure 16 in steps (j), (k), the slight rotation of the inner rocker shaft 41 to the right causes the foregoing far-right, high speed operations position to be assumed. This feature causes the transmission pin 30 to be pushed to the right by the return drive surface 47b of the inner right drive slot 47 from the retaining slot 48a of the outer right drive slot 48, whereupon the foregoing spring force causes the transmission pin 30 to be immediately returned to the operating position, thereby bringing the right side air intake valve into immediate operation.

With regard to the exhaust side, during high and

mid-speed operating ranges, as shown in Figure 17a, the inner rocker shaft 51 is positioned in the high and mid-speed operating position on the right side shown in the Figure, and the transmission pin 30 is in its operating position so that both the left and right side exhaust valves 11a, 11b are operating.

When the engine is changed to a low speed operating state, the inner rocker shaft 51 is rotated to the left as shown in the Figure to the low speed operating position, and the non-operational direction slanted drive surface 53a of the inner drive slot 53 causes the transmission pin 30 to move to the non-operational position, and said transmission pin 30 is retained in the retention slot 54a of the outer drive slot 54 (Figure 17 (b) - (f)), thereby putting the left exhaust valve in a shut-down condition.

Then, during the foregoing low speed operations, when the inner rocker shaft 51 is rotated to just before the foregoing right side high and mid-speed operating position, the transmission pin 30 comes into contact with the return drive surface 53b of the inner drive slot 53 which is a holding position (Figure 17, steps (g) - (j)), so that if a transition is made once again to high speed operations, the inner rocker shaft 51 can be rotated to the right slightly, causing the transmission pin 30 to be pushed from the foregoing retention slot 54a and immediately returned to the operating position by the above described spring force. As a result, the shut down left exhaust valve 11a is immediately returned to operation.

Thus, in this second embodiment, when the air intake valve(s) and exhaust valve are shut down (to a non-operational state) from an operating state, the inner rocker shafts 41, 51 must be rotated through the entire angular length of the slanted drive surfaces 45b, 47a, and 53a, but on the other hand, when making a transition from a shutdown state to an operational state, the inner rocker shafts 41, 51 need only to be slightly rotated, thereby making the switch from a shutdown state to an operational state instantaneous.

For example, as is shown in Figure 14b, the change from an operational state to a non-operational state (reducing the number of operational valves) takes 0.7 second, while the switch from a non-operational state to an operational state (increasing the number of operating valves) takes only 0.1 second. Although there might be some concerns over diminished acceleration response when valves are shut down, the present embodiment avoids this potential problem by immediately restoring shut down valves to operation, thereby avoiding the foregoing diminished acceleration response.

In the present embodiment, the time when the rocker arms can be moved axially into the operating position is restricted to the time interval when the base circle of the high speed cam 26b is positioned on the rocker arm side, and the higher the RPM, the shorter this interval. However since the present embodiment requires but a short interval for switching to the operational position, it is advantageous from this perspective

as well.

The present embodiment further sets the engine RPM at which switching is made to the non-operational state to be lower than that at which switching is made to the operational state. In other words, there is hysteresis involved in the number of switchings, and avoiding frequent switching between operational and non-operational states avoids the problem of so-called hunting.

In the foregoing embodiments, the left and right side air intake valves were shut down during low-speed operations, and one was returned to the operational state during mid-speed operations, and the remainder was rendered operational in the high speed operating range, thereby achieving valve shut down in stages, but the invention may also be applied of course to the shutting down and restorations of a single valve, or, a plurality of valves may be shut down at one time.

According to the dynamic valve apparatus in one embodiment of the invention, when the rocker arms are in the operating position, the rotational movement of the cam nose is transmitted to the valves by the rocker arms, and when they are in the non-operational position, the valves are operated directly by the rotational movement of the cam nose, thereby allowing variable control of valve lift based upon the axial position of the rocker arms.

According to another embodiment of the invention, by constituting the cam nose of a high speed nose and a low speed nose, by putting the rocker arm into the operational position so that the rotational movement of the high speed cam nose is transmitted to the valve by the rocker arm, and by directly transmitting the rotational movement of the low speed cam nose to the valves when the rocker arm is in the non-operational position, it is possible to vary the amount of lift and the opening and closing timing according to the nose shapes of the low speed nose and the high speed nose and according to the lift height. Further, by setting the lift of the low speed nose to approximately zero, it is possible to place valves into a shutdown state using a very simple structure.

According to a further embodiment of the invention, by installing the foregoing variation apparatus on one of the exhaust valves and upon the left and right side air intake valves, and by setting the foregoing low speed nose shape to virtually shut down the opening and closing operation, it is possible during low speed engine operations, to virtually shut down one of the foregoing exhaust valves, and the left and right side air intake valves and leave the other exhaust valve and the center valve operational, and, during mid-speed engine operations, it is possible to shut down the right or the left side air intake valve and leave the other two, as well as the two exhaust valves operational, and further, during high speed engine operations, to have all the valves operational, thereby achieving a three-stage valve shutdown control that corresponds to the operating state of the engine.

Further, during low speed operations, since only

the center air intake valve from among the three intake valves is left operational, the air entering the cylinders is directed in the axial direction of the cylinders to generate a tumbling action, which is effective in stabilizing the combustion at lean air/fuel ratios.

According to still another embodiment of the invention, because of the displacement speed of the rocker arms from the non-operational to the operational position is higher than in the reverse direction, it is possible to immediately increase the number of operational valves during rapid acceleration, which is effective in improving acceleration response.

According to a still further embodiment of the invention, since on the one hand the amount of rotation of the inner rocker shaft causes a proportional movement of the rocker arm from the operational position to the non-operational position, while on the other, the rocker arms may be moved from the non-operational to the operational position without the rotation of the inner rocker shaft, it is possible to make a speedier transition in moving the rocker arm from the non-operational to the operational position than is in the reverse direction.

Claims

1. Internal combustion engine comprising a cylinder body (2) having at least one cylinder (2a), a cylinder head (1) provided with a plurality of air intake and exhaust valves (7a, 11a) actuatable via air intake and exhaust camshafts (12, 13) in cooperation with respective rocker arms (28) mounted at respective exhaust and intake rocker shafts (25, 27) and associated with said cylinder (2a), and a dynamic valve apparatus (20, 22) being capable to variably control the valve opening and closing timing, the valve lift, and the shut down of at least some of said air intake and exhaust valves (7a, 11a), **characterized in that** the dynamic valve apparatus (20, 22) comprising a moving mechanism (29-33) for moving respective rocker arms (28) between an operational position in which a cam nose (26) of each of said camshafts (12, 13) is in sliding contact with said rocker arms (28) and a non-operational position in which said rocker arm (28) is offset of said cam nose (26) in axial direction of said exhaust and intake rocker shafts (25, 27) in accordance with detected engine operational conditions.
2. Internal combustion engine according to claim 1, **characterized in that** said cam (26) comprises a guide circle (26a) engagable by said rocker arm (28) and constituting said non-operational position and a high speed nose (26b) engagable by said rocker arm (28) and constituting said operational position.
3. Internal combustion engine according to claim 2, **characterized in that** said cam (26) further comprises a low speed nose (26c) contacting said

respective air intake valve (7a) or exhaust valve (11a), respectively, when the rocker arm (28) is in the non-operational position.

4. Internal combustion engine according to claim 3, **characterized in that** said low speed nose (26c) has a larger rotational diameter than said high speed nose (26b). 5
5. Internal combustion engine according to at least one of claims 1 to 4, **characterized in that** said moving mechanism comprises sliders (29) slidably mounted on the exhaust and intake rocker shafts (25, 27) and being movable by a transmission pin (30) guidable by respective drive slots (31, 31') formed in said exhaust end intake rocker shafts (25, 27) for pushing said rocker arms (28) from a first position to a second position, a spring (32) for urging said rocker arms (28) back to the first position when said sliders (29) are released from said rocker arms (28), and an actuator (33) rotating said exhaust and intake rocker shafts (25, 27) to actuate said sliders (29). 10 15 20
6. Internal combustion engine according to at least one of claims 1 to 5, whereby said internal combustion engine comprises three air intake valves (7a-7c) and two exhaust valves (11a, 11b) symmetrically arranged to both sides of a plane containing a central axis of said cylinder (2a), **characterized in that** at least said air intake valves (7a, 7b) arranged at both sides of said plane and at least one of said exhaust valves (11a, 11b) are operable by said moving mechanism (29-33). 25 30 35
7. Internal combustion engine according to claim 6, **characterized in that** said moving mechanism (29-33) is capable of moving the respective rocker arms (28) of said two air intake valves (7a, 7b) and said one exhaust valve (11a, 11b) into the non-operational position in a low speed condition of said engine. 40
8. Internal combustion engine according to claim 7, **characterized in that** during a mid-speed condition of said engine only one air intake valve (7a, 7b) is movable into the non-operational position. 45
9. Internal combustion engine according to at least one of claims 1 to 8, **characterized in that** said moving mechanism (29-33) is capable to move said respective rocker arms (28) from the non-operational position to the operational position with a higher speed than from the operational position to the non-operational position. 50 55
10. Internal combustion engine according to at least one of claims 1 to 9, **characterized in that** said moving mechanism (29-33) is controllable by an

engine control unit (ECU)

11. Internal combustion engine according to at least one of claims 5 to 10, **characterized in that** said moving mechanism (29, 30, 32, 33) further comprises inner rocker shafts (41, 51) provided with respective inner drive slots (45, 47, 53), outer rocker shafts (42, 52) coaxially aligned with said inner rocker shafts (41, 51) and provided with respective outer drive slots (46, 48, 54) in such a manner that they are rotatable with respect to each other.
12. Internal combustion engine according to at least one of claims 6 to 11, **characterized in that** all exhaust and air intake valves (11a, 11b, 7a-7c) are operable by said moving mechanism (29-33).
13. Method for controlling the valve actuation of an internal combustion engine comprising a cylinder body (2) having at least one cylinder (2a), a cylinder head (1) provided with a plurality of air intake and exhaust valves (7a, 11a) actuable via air intake and exhaust camshafts (12, 13) in cooperation with respective rocker arms (28) mounted at respective exhaust and intake rocker shafts (25, 27) and associated with said cylinder (2a), and a dynamic valve apparatus (20, 22) being capable to variably control the valve opening and closing timing, the valve lift, and the shut down of at least some of said air intake and exhaust valves (7a, 11a), **characterized by** the steps of moving said rocker arms (28) by means of said dynamic valve apparatus (20, 22) having a moving mechanism (29-33) between an operational position in which a cam nose (26) of each of said camshafts (12, 13) is in sliding contact with said rocker arm (28) and a non-operational position in which said rocker arm (218) is offset of said cam nose (26) in axial direction of said exhaust and intake rocker shafts (25, 27) in accordance with detected engine operational conditions.
14. Method according to claim 13, whereby said engine comprises three air intake valves (7a-7c) and two exhaust valves (11a, 11b), **characterized in that** at least two of said air intake valves (7a-7c) and at least one of said exhaust valves (11a, 11b) are moved by said moving mechanism (29-33).
15. Method according to claim 14, **characterized in that** during a low speed condition of said engine, said two air intake valves (7a, 7b) and said one exhaust valve (11a, 11b) are moved to said non-operational position.
16. Method according to claim 14 or 15, **characterized in that** in a mid-speed condition of said engine only one air intake valve (7a, 7b) is moved to said non-operational position.

17. Method according to at least one of claims 13 to 16,
characterized in that an engine control unit (ECU)
controls said moving mechanism (29-33).

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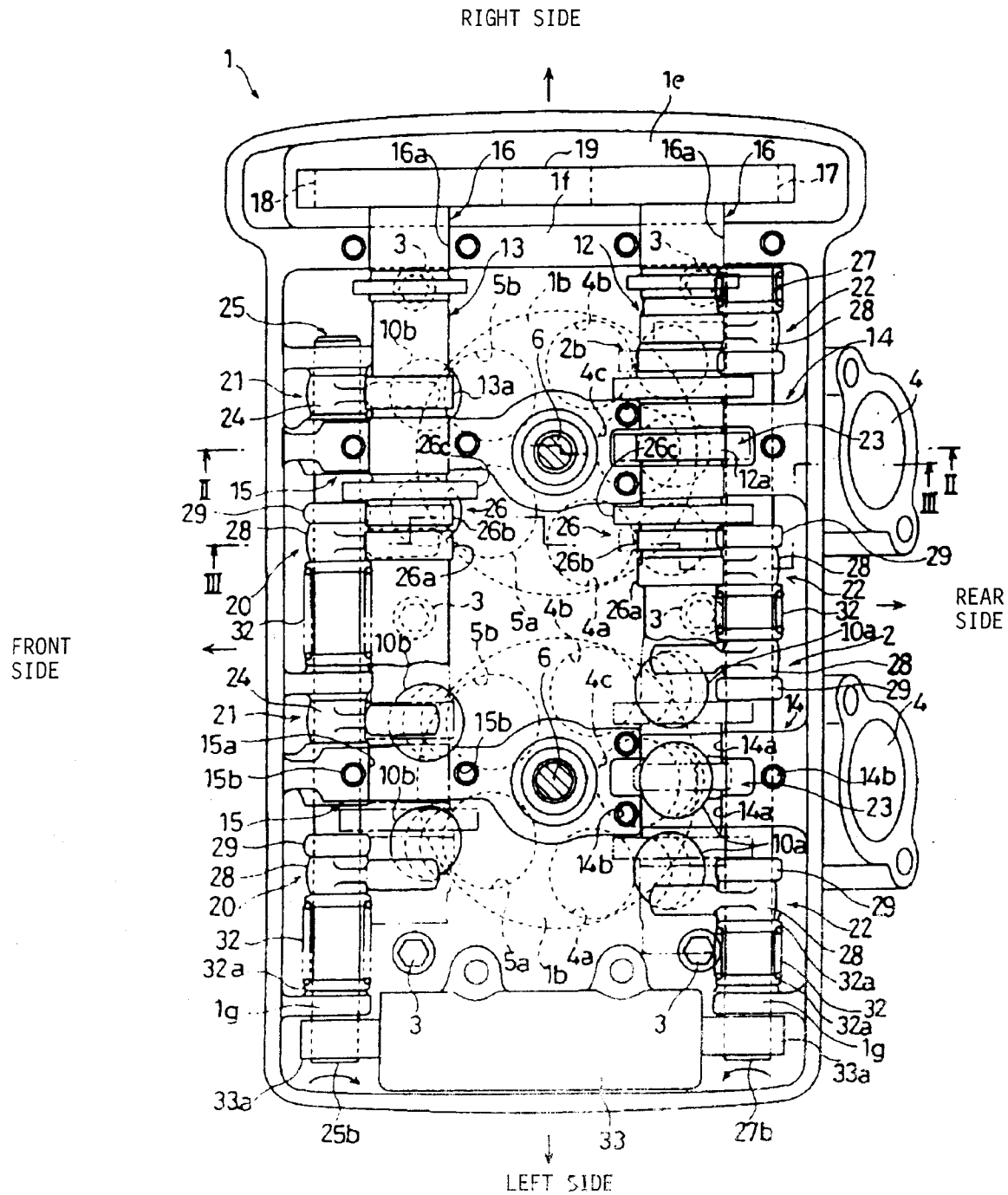
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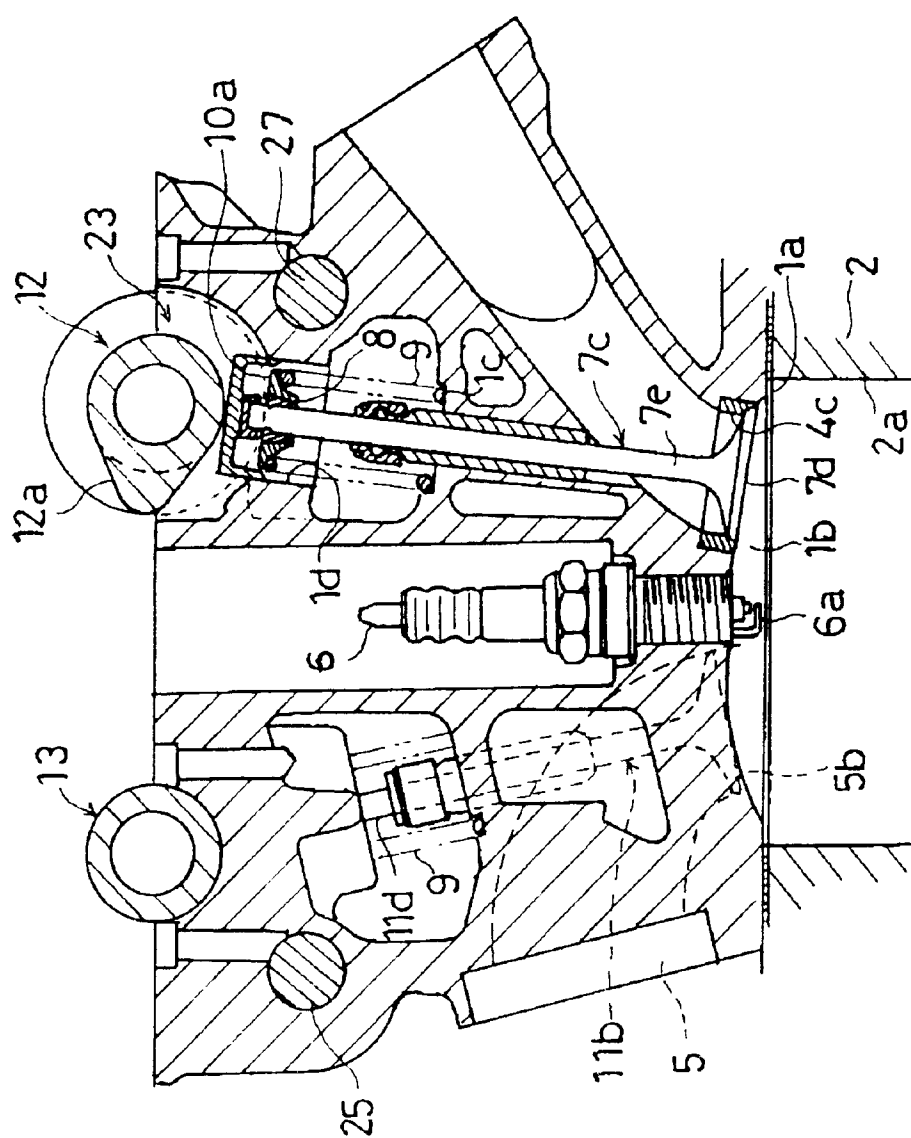
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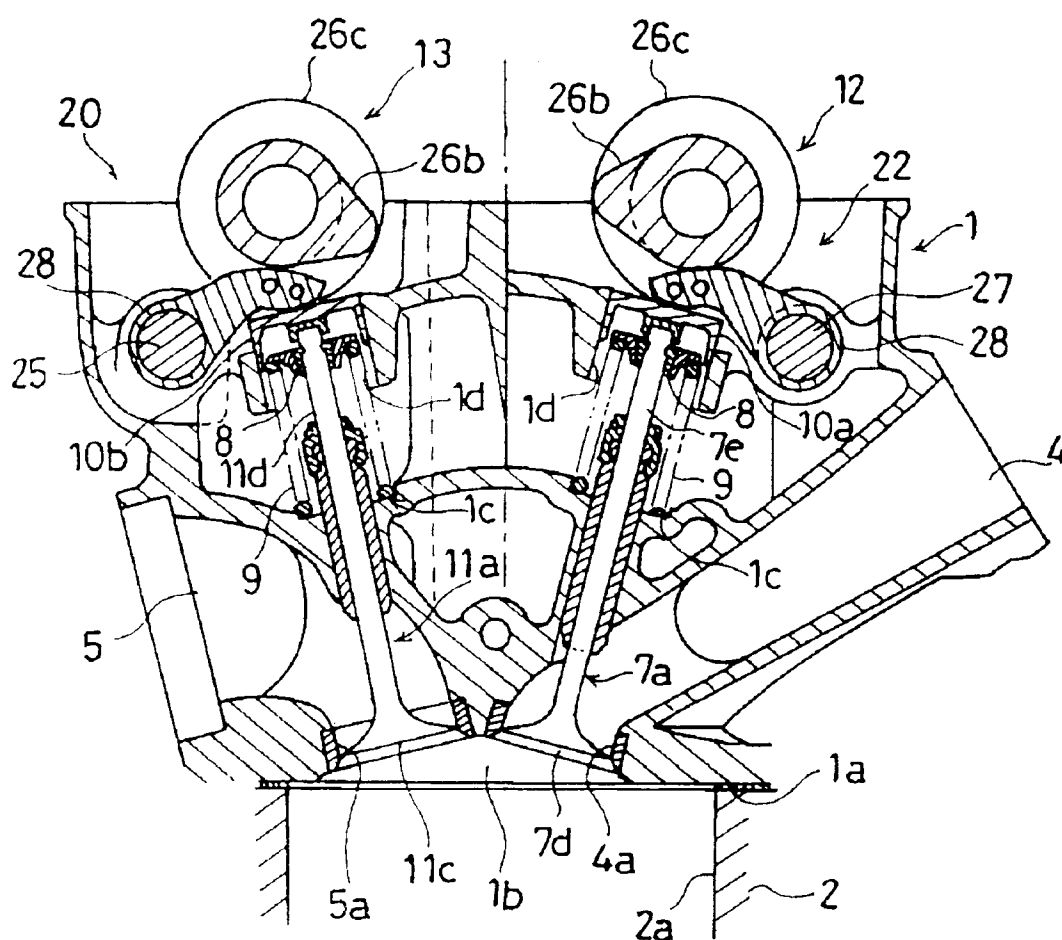
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FIGURE



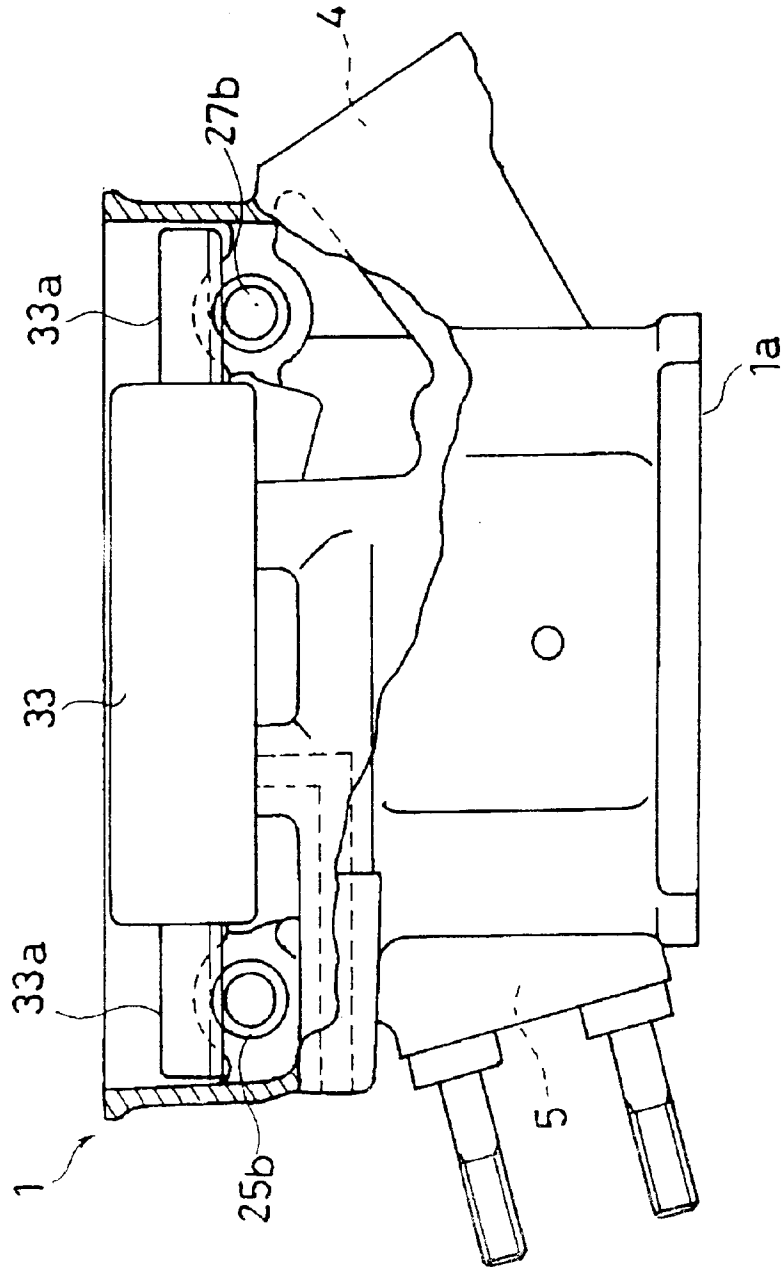


FIGURE 4

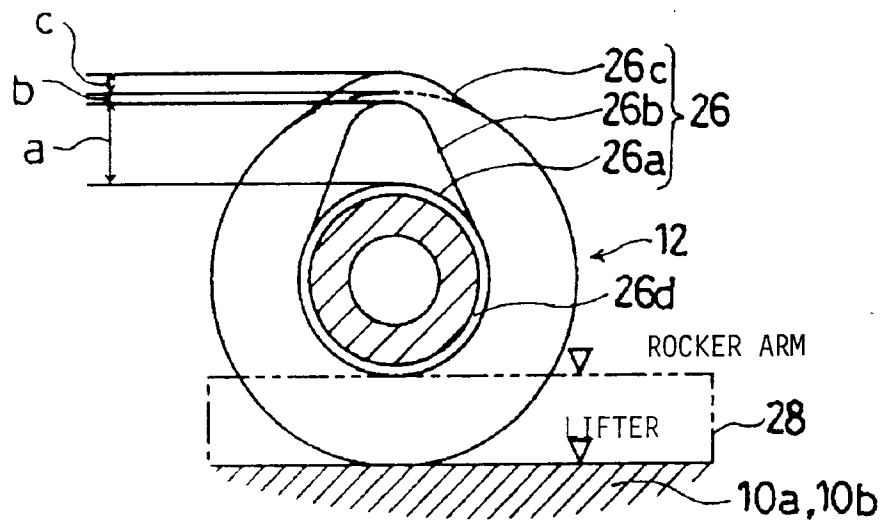


FIGURE 5

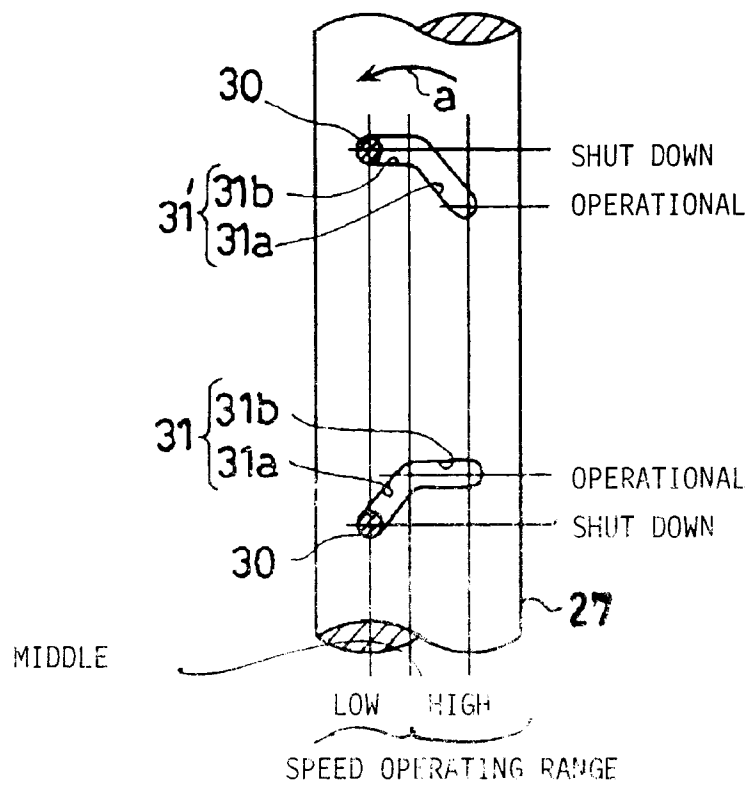


FIGURE 6

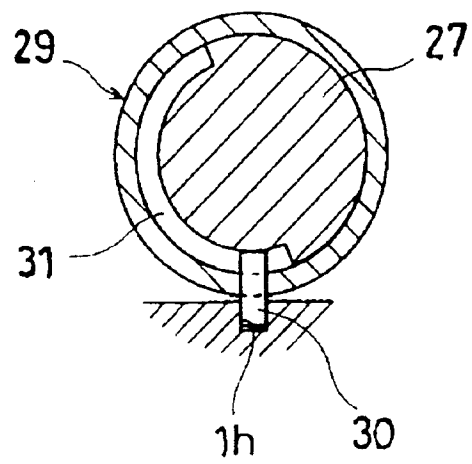


FIGURE 7

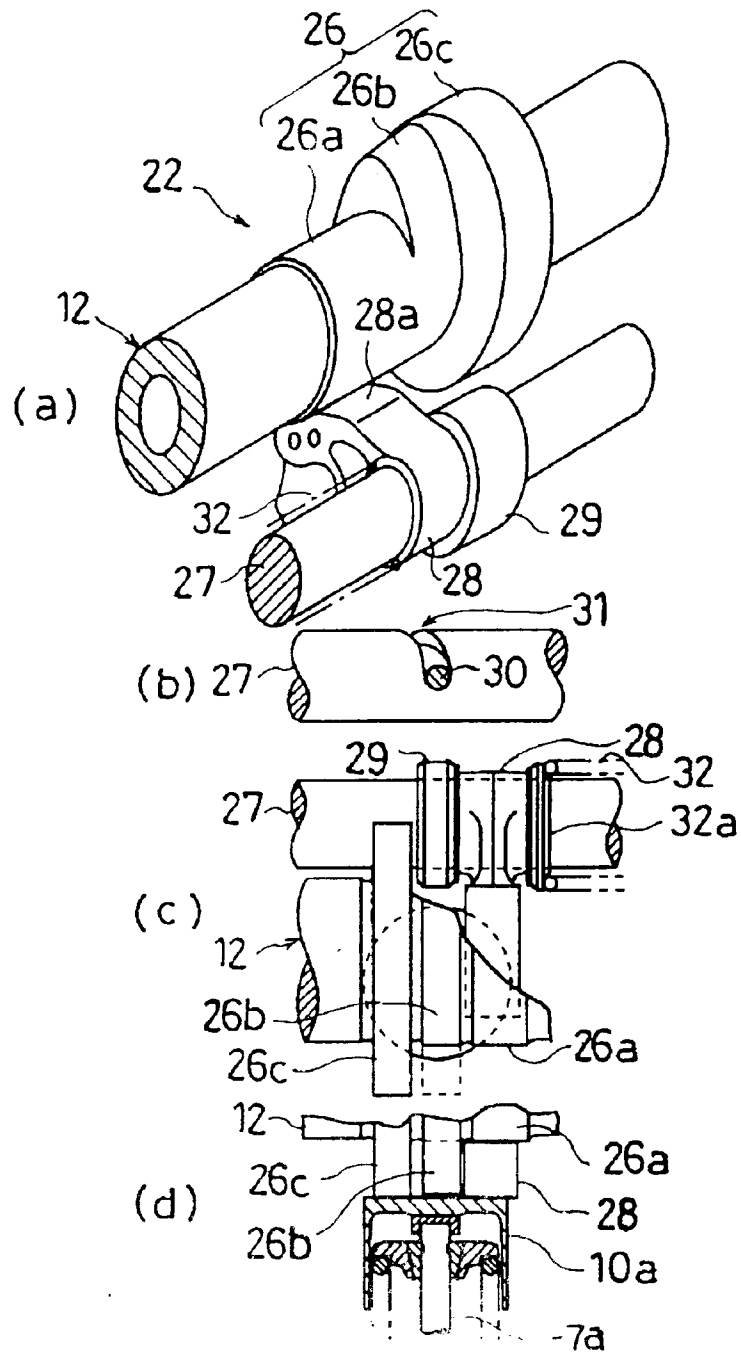


FIGURE 8

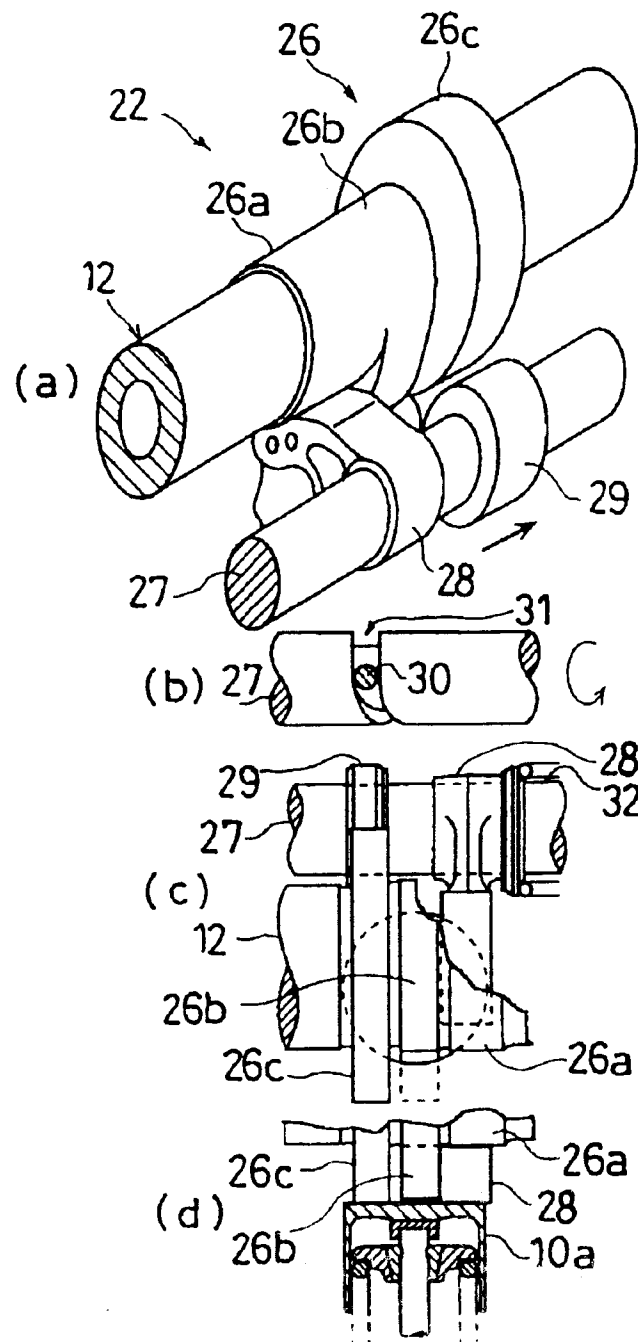


FIGURE 9

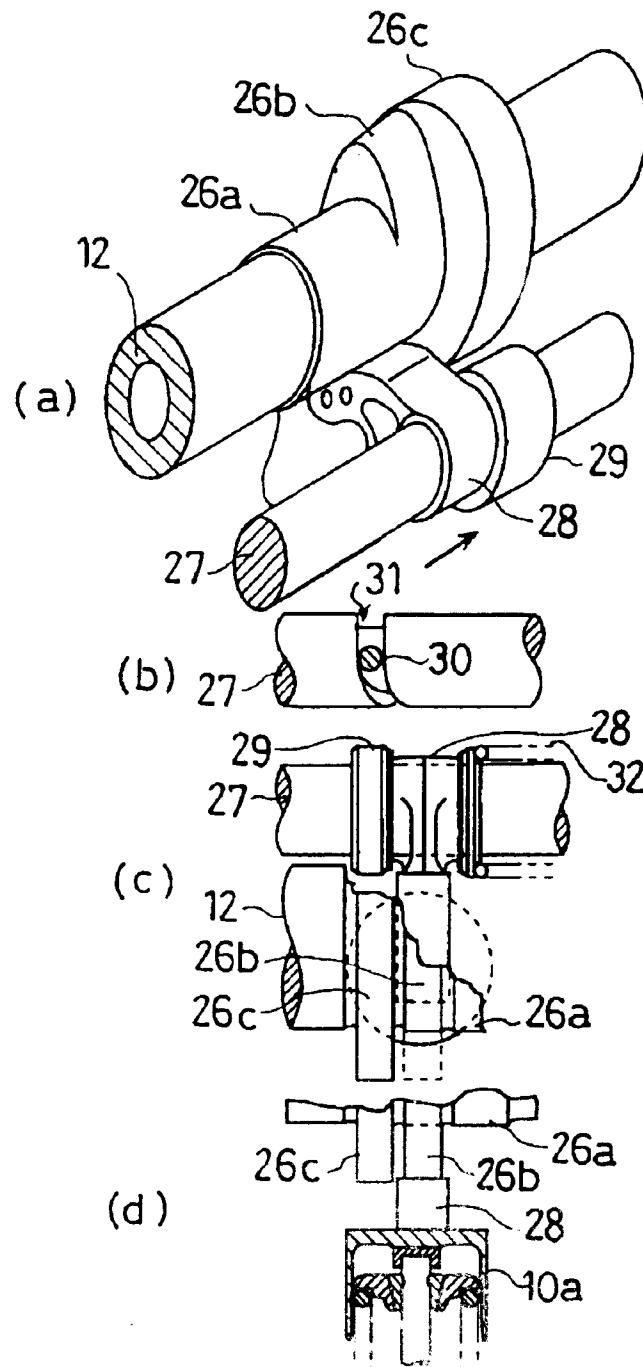


FIGURE 10

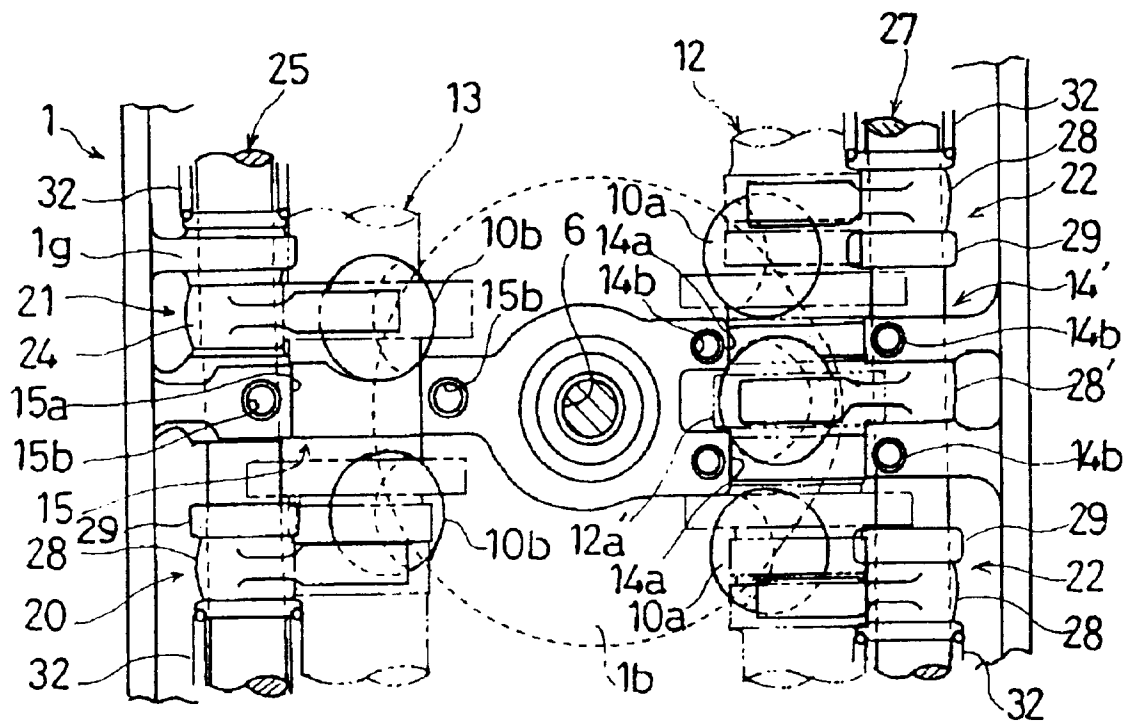


FIGURE 11

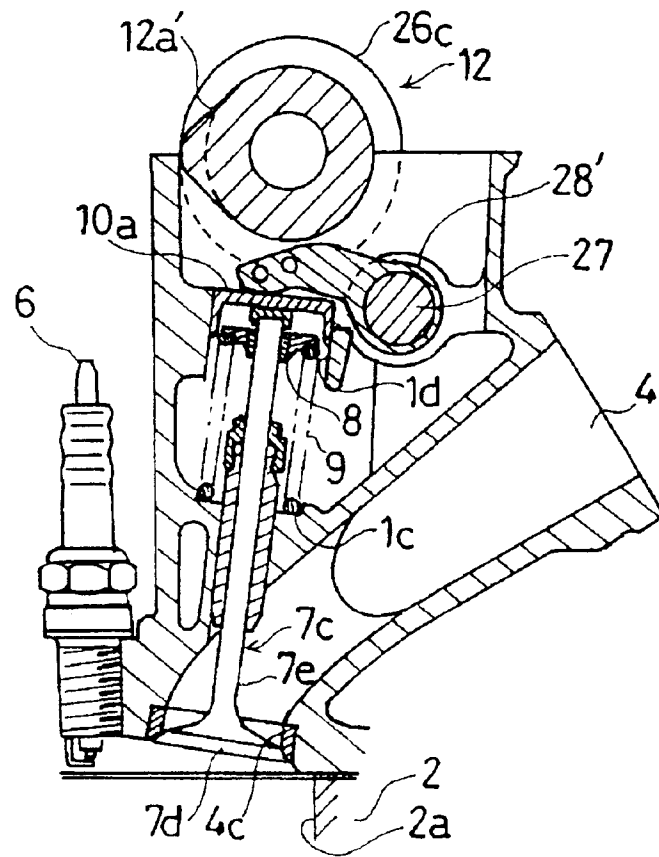


FIGURE 12

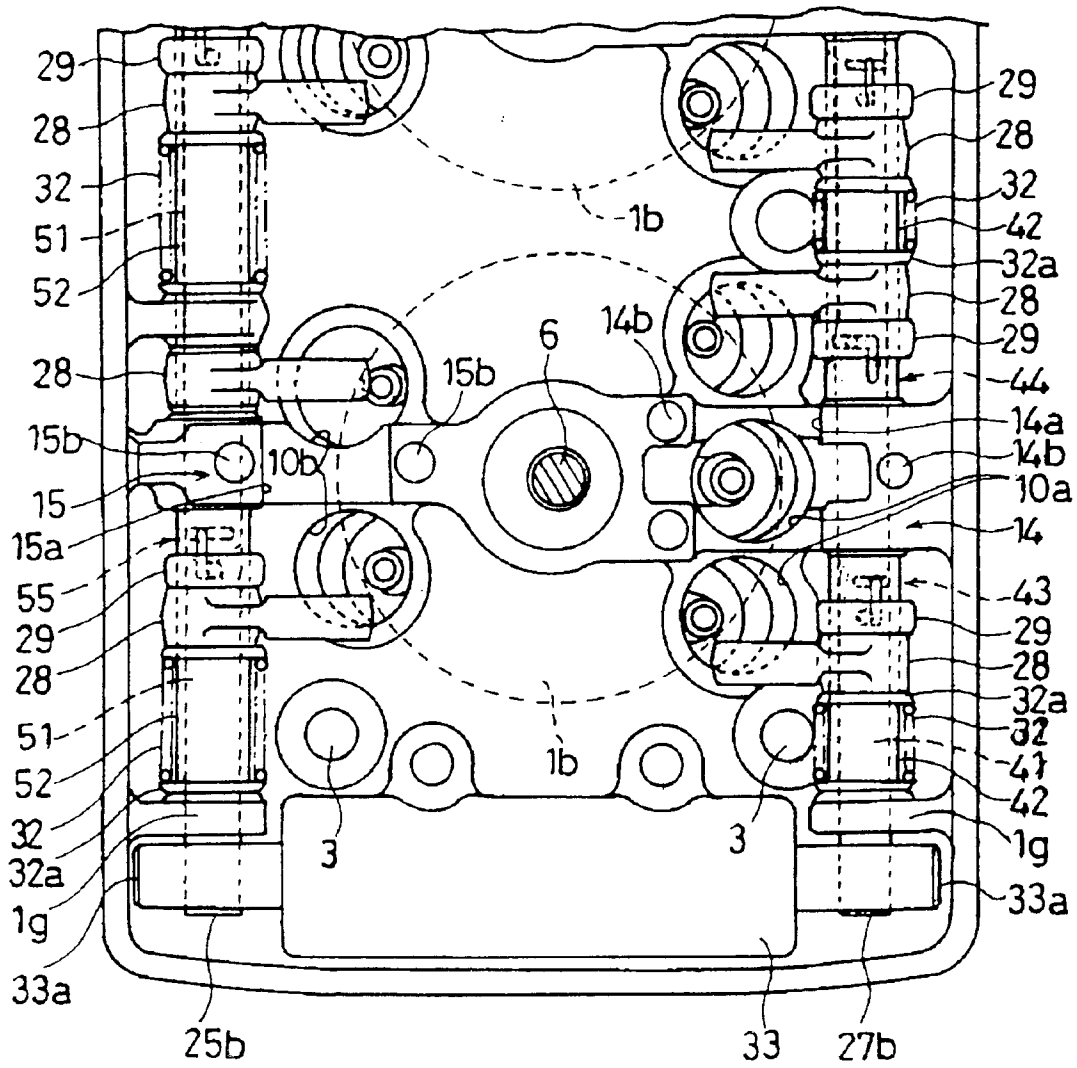


FIGURE 13

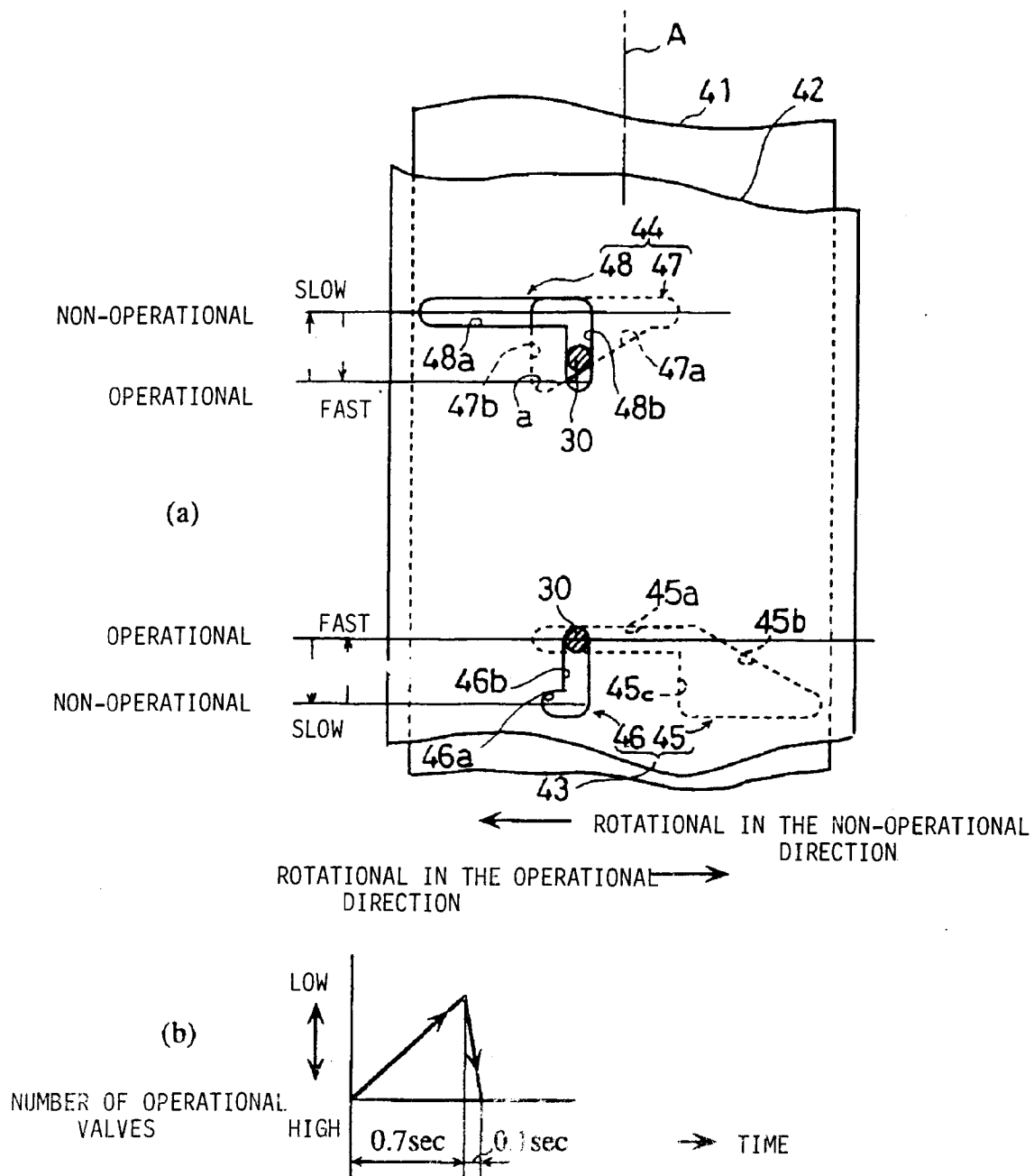


FIGURE 14

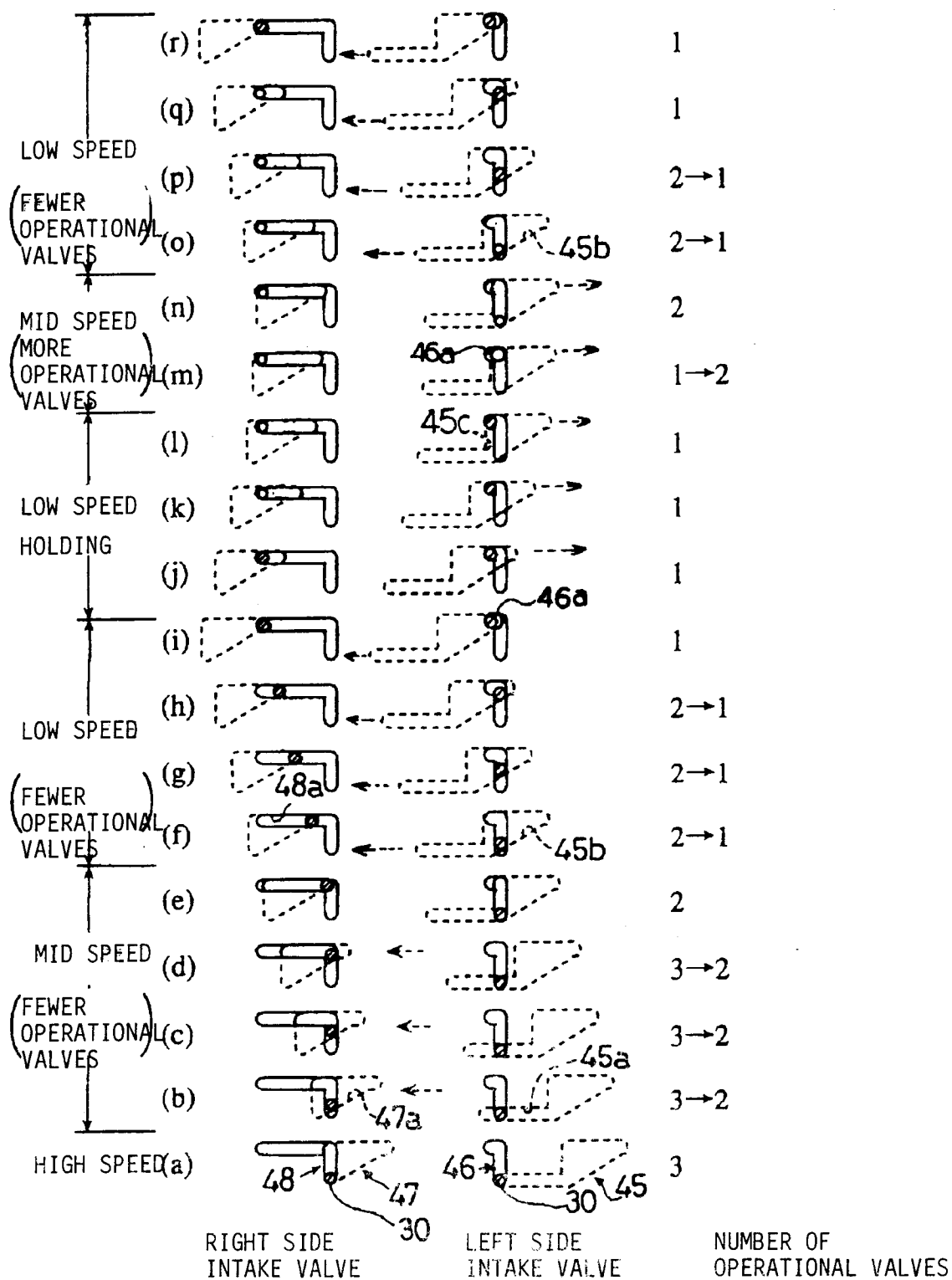


FIGURE 15

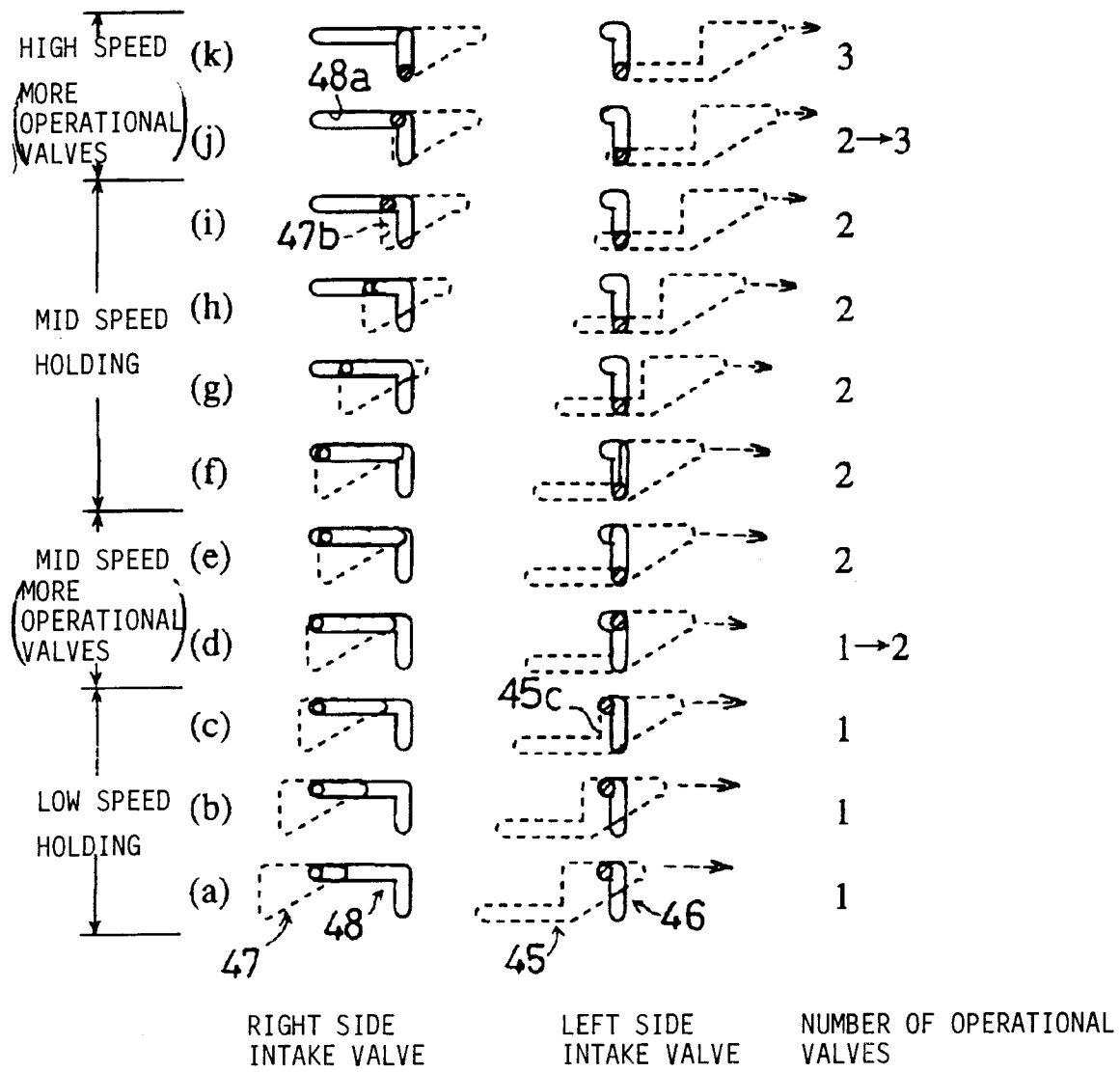


FIGURE 16

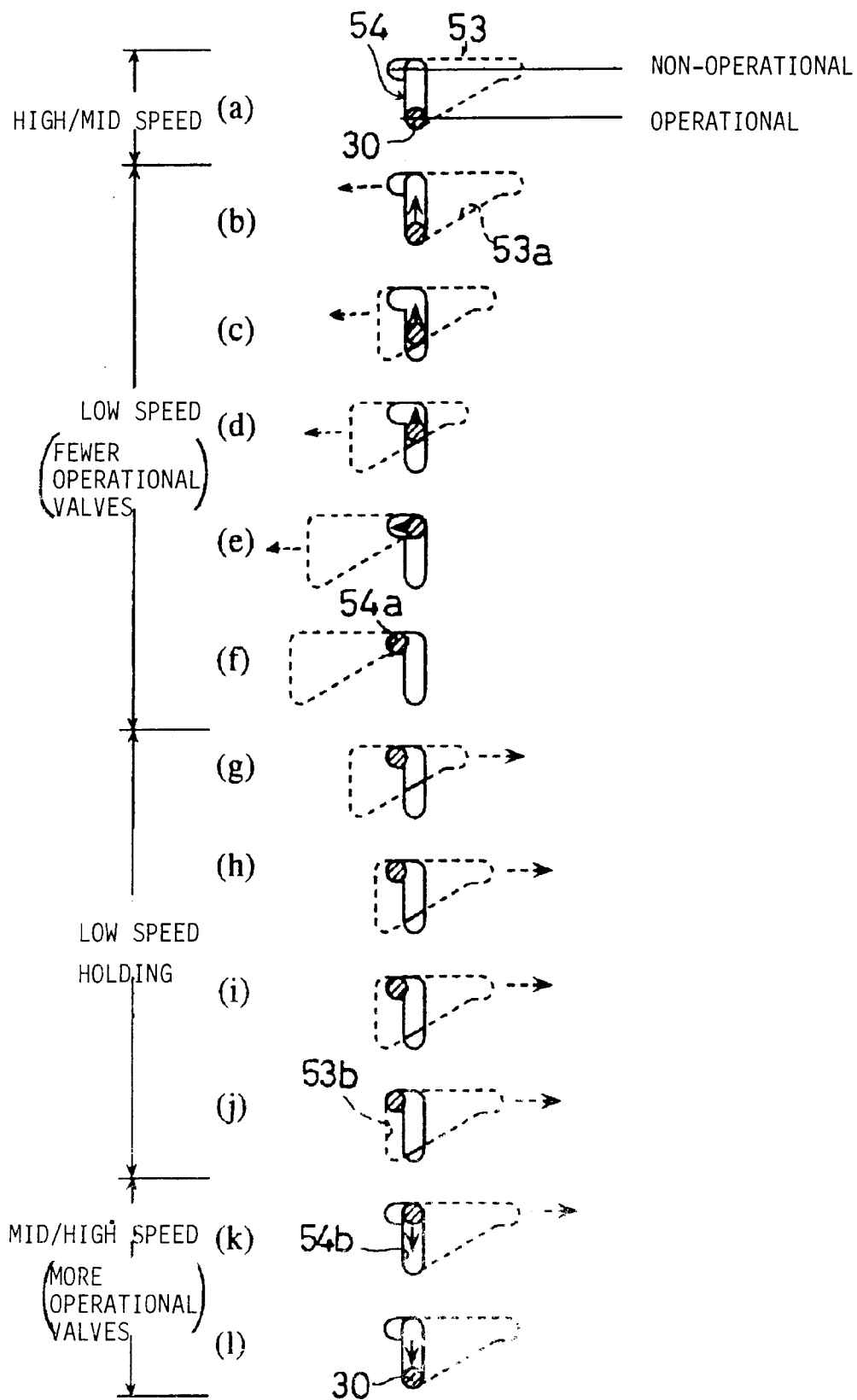


FIGURE 17

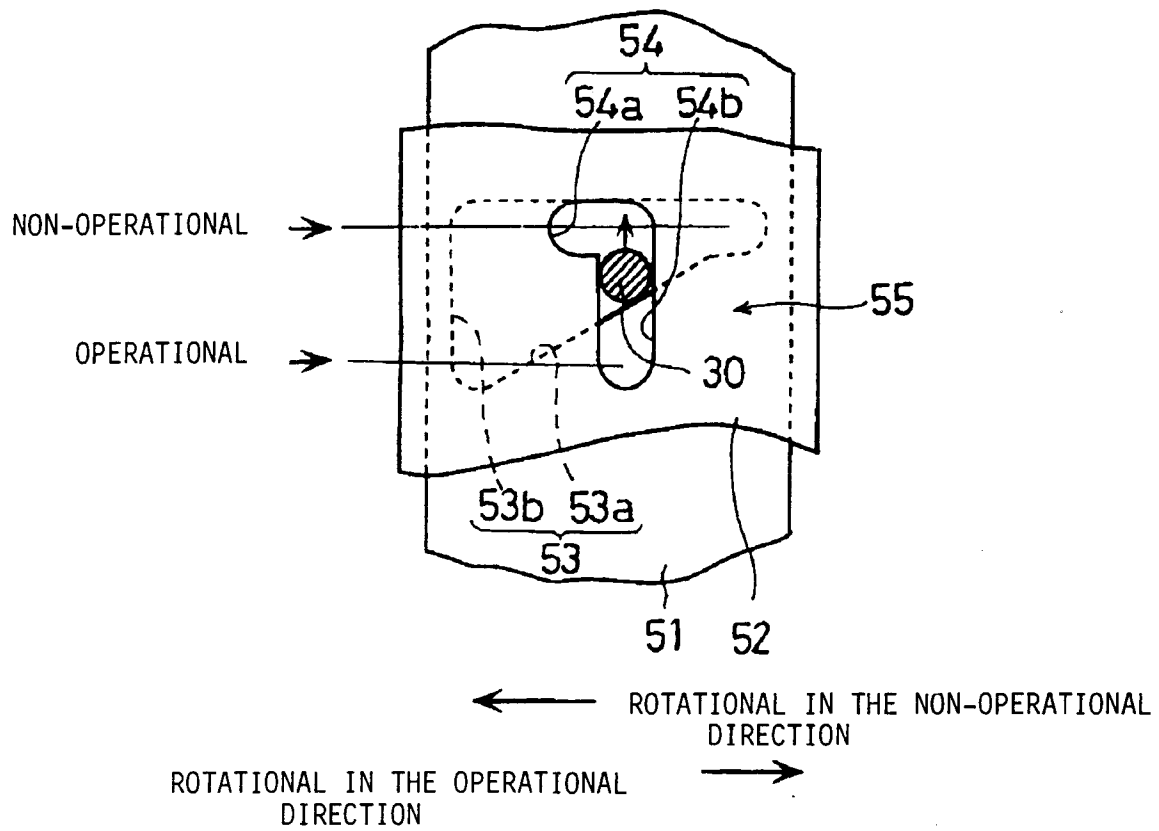


FIGURE 18



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 11 0075

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)
X,P	DE-A-195 44 242 (VOLKSWAGEN AG) * the whole document * ---	1-3,13	F01L13/00 F01L1/26 F01L1/18
A	US-A-3 878 822 (BEAL) * column 1, line 41-60 * * column 3, line 43 - column 4, line 60; figures * ---	1-3,5	
A	GB-A-2 139 283 (NISSAN MOTOR CO LTD) * the whole document * ---	1	
A	DE-A-35 21 539 (SCHMID) -----		
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int.Cl.6) F01L
Place of search THE HAGUE		Date of completion of the search 3 September 1996	Examiner Klinger, T
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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