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[33] Japan
[31] 44/70901;
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[54] VALVE TIMING SYSTEM OF AUTOMOTIVE
INTERNAL COMBUSTION ENGINE
7 Claims, 10 Drawing Figs.

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F01I 13/00
[50] Field of Search 123/90.15,
90.16, 90.17, 90.18; 64/25; 74/568

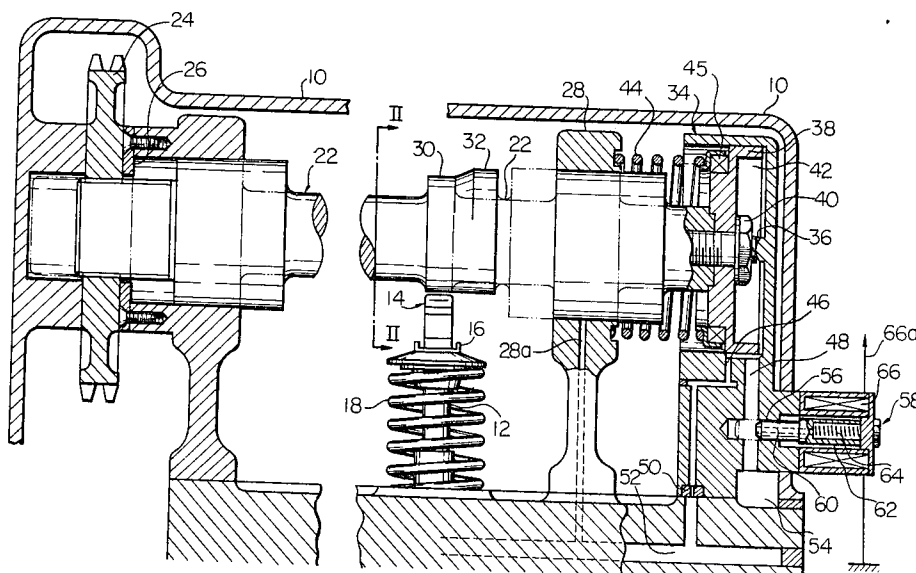
[56] References Cited
UNITED STATES PATENTS

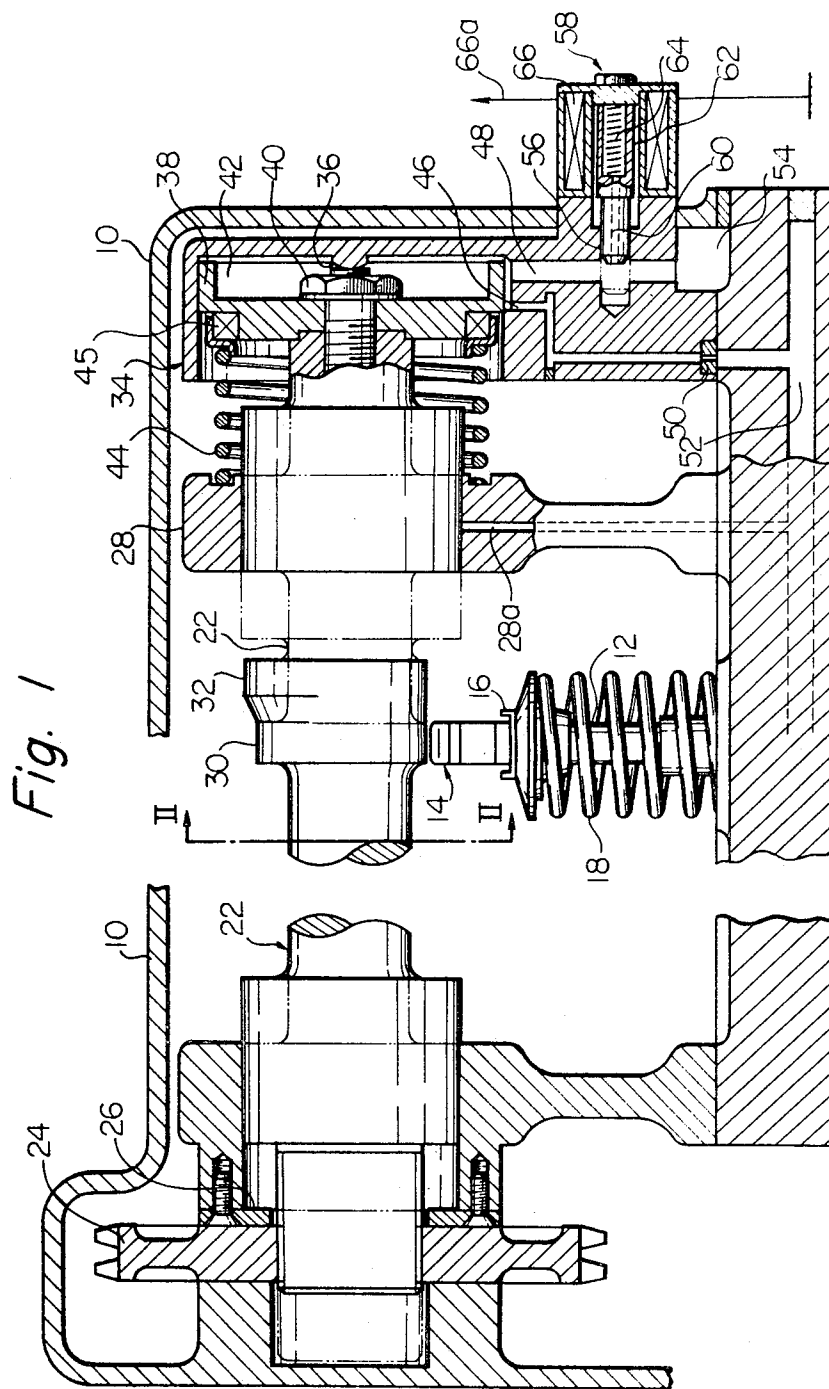
2,305,787	12/1942	Kales.....	123/90.15
2,670,594	3/1954	Crooks.....	123/90.18 X
2,804,061	8/1957	Gamble.....	123/90.18

2,969,051	1/1961	Webster	123/90.18
2,980,089	4/1961	Sampietro	123/90.18 X
3,019,776	2/1962	Clavell	123/90.18 X
3,401,572	9/1968	Bailey.....	123/90.15 X
3,481,314	12/1969	Le Crenn.....	123/90.18
2,528,983	11/1950	Weiss	123/90.18 X
2,871,837	2/1959	Kerby.....	123/90.18

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ABSTRACT: A valve timing system for an internal combustion engine of a motor vehicle, including a camshaft which is hydraulically axially movable and which has first and second cam lobes which are positioned and configured relative to the rocker arm for the exhaust valve of the engine cylinder, the first and second cam lobes being selectively aligned with the rocker arm so that the valve is timed in different manners depending upon the driving conditions of the motor vehicle. The hydraulic fluid for axially moving the camshaft is controlled by a solenoid operated discharge valve in response to an engine speed actuated switch and an intake manifold vacuum actuated switch. The valve timing system is adapted for the elimination of air pollution in urban areas without impairing the performance quality of the engine. Such cam lobe configurations may be applied to the cam lobes associated with the intake valve so that not only the exhaust valve but the intake valve can be timed in relation to the driving conditions of the motor vehicle.





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Fig. 2

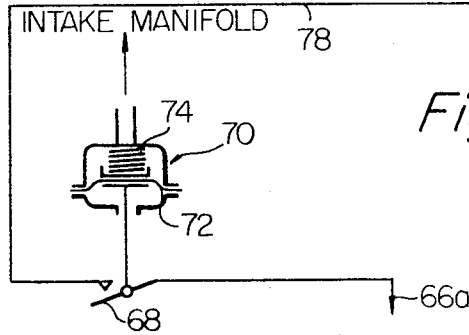
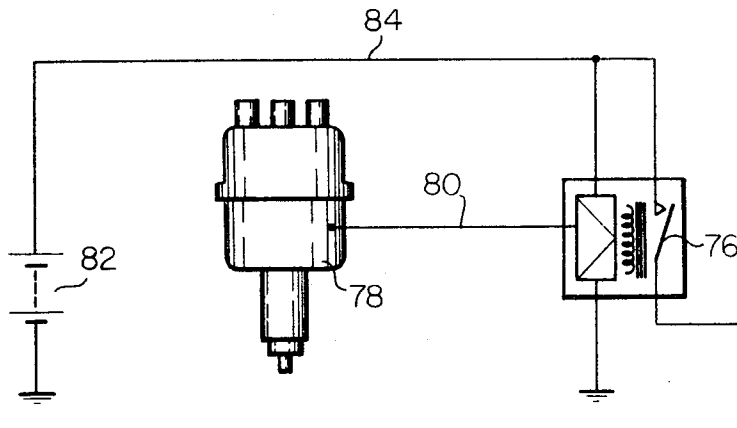
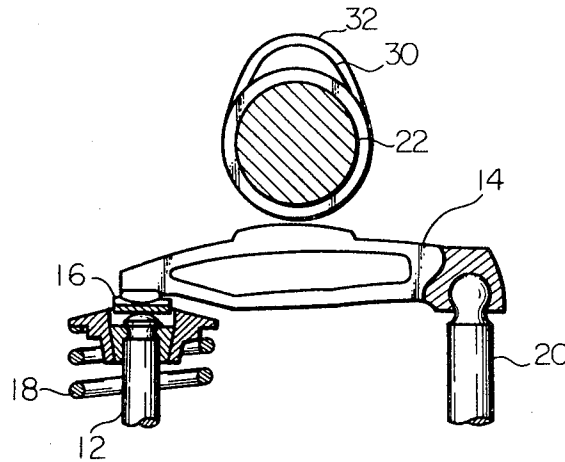


Fig. 3

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Fig. 4

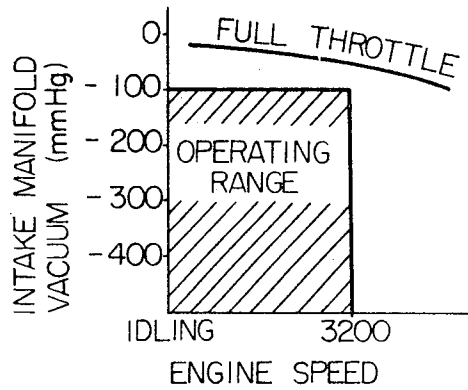
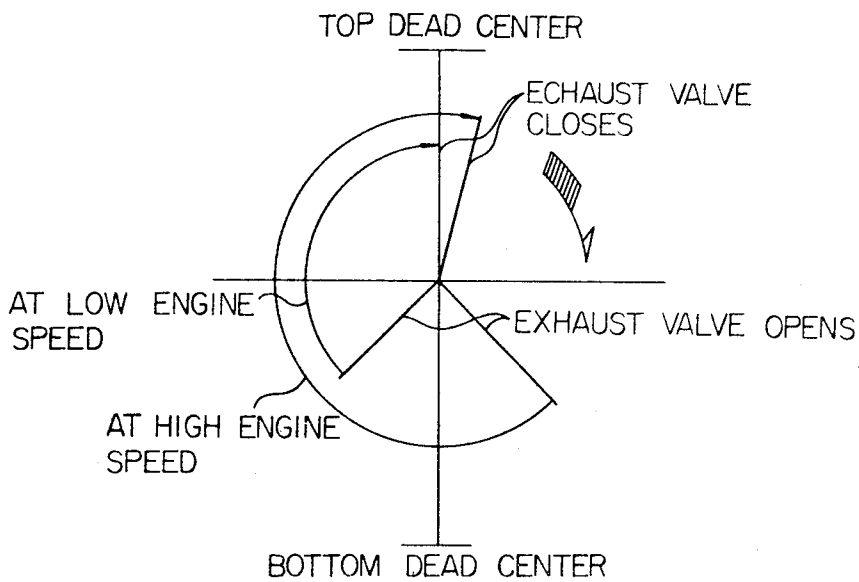


Fig. 5



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Fig. 6

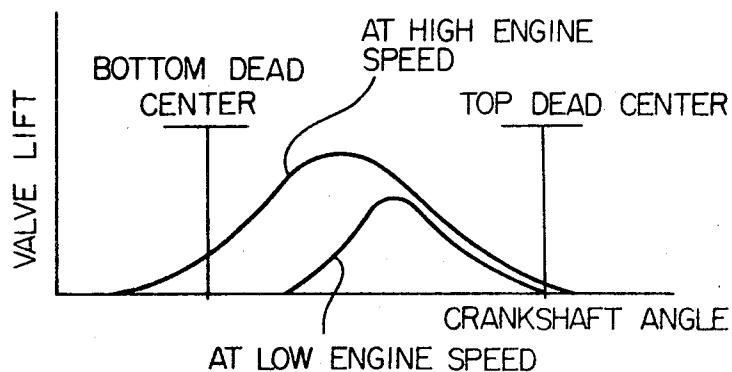
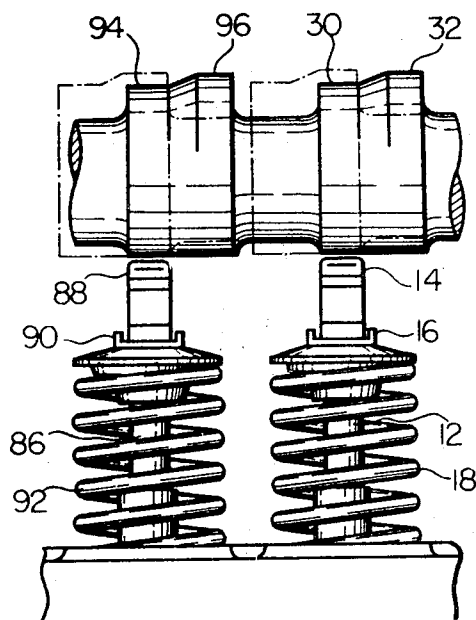


Fig. 7



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Fig. 8

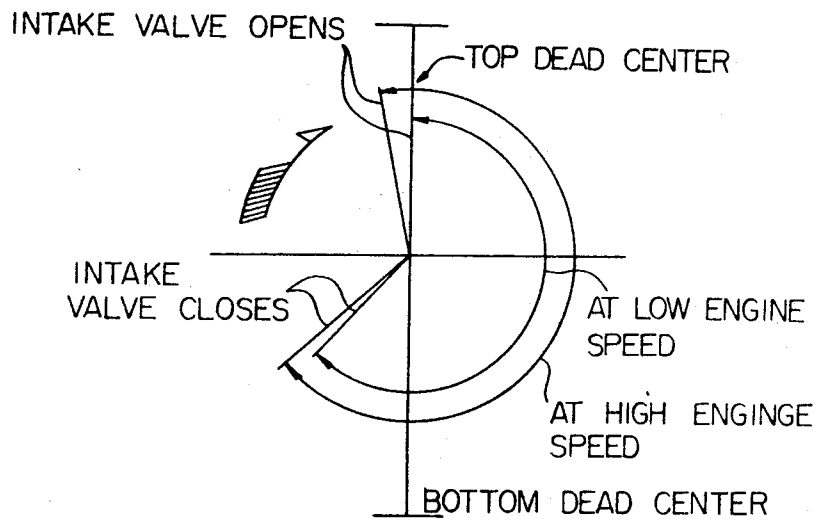
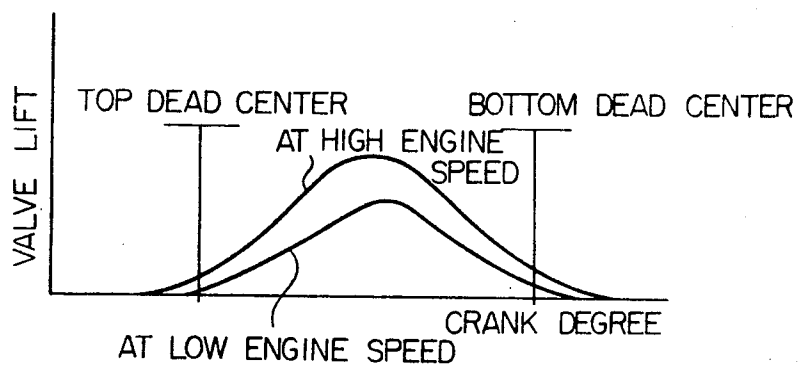
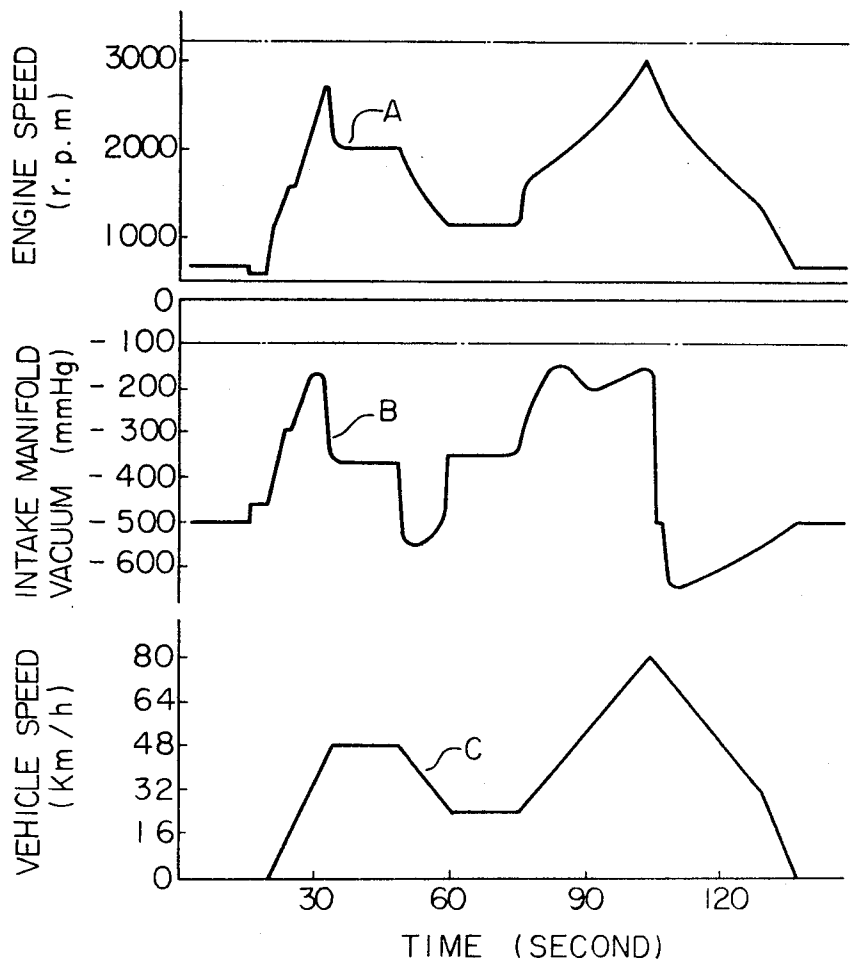


Fig. 9



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Fig. 10



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VALVE TIMING SYSTEM OF AUTOMOTIVE INTERNAL COMBUSTION ENGINE

This invention relates to a valve timing system for use with an automotive internal combustion engine and, more particularly, to a valve timing system operating in relation to the driving conditions of the engine.

The opening and closing movements of intake and exhaust valves of an automotive internal combustion engine cylinder is usually timed in such a manner as to provide an optimum performance efficiency of the engine during normal cruising of the motor vehicle. When, however, the motor vehicle is driven at relatively low speeds as in city-road driving, the performance quality of the engine is more or less degraded to discharge an increased quantity of unburned or partially burned exhaust gases containing noxious compounds such as hydrocarbons and carbon monoxides, causing a serious pollution of atmospheric air in urban areas. Among the various schemes proposed to solve such air pollution problem is the practice of opening the exhaust valve at a retarded timing so that the fired gases stay in the engine cylinder for a prolonged period of time at a high temperature and at a high pressure, causing the hydrocarbons and carbon monoxides to be fully combusted. Opening the exhaust valve at a retarded timing is, although conducive to the reduction of unburned, toxic content of the exhaust gases especially during low speed and/or light load operation of the motor vehicle, reflected by a degraded performance efficiency of the engine during high speed and/or heavy load operation. This difficulty will be maintained insofar as the valve timing is controlled, or retarded, without respect to the conditions in which the engine operates.

An object of the invention is, therefore, to provide a valve timing system wherein the exhaust valve is opened at a retarded timing and closed at a slightly advanced timing during low speed and/or heavy load operation of the motor vehicle as in a city-road driving.

Another object is to provide a valve timing system in which not only the exhaust valve timing is controlled as noted above but the intake valve is controlled in such a manner as to be opened at a retarded timing and closed at a slightly advanced timing during the low speed and/or heavy load operation of the motor vehicle.

Still another object is to provide a valve timing system which is controlled in relation to any of the various operating variables, such as the engine speed and the vacuum in the intake manifold of the engine, of the motor vehicle whereby the opening and closing movements can be selectively timed without affecting the engine operation.

In the drawings:

FIG. 1 is a sectional view of an embodiment of the valve timing system according to the invention;

FIG. 2 is a view showing an essential part of the valve timing system as seen from the plane of II—II of FIG. 1;

FIG. 3 is a schematical view showing a preferred example of a control means for use with the valve timing system of the invention;

FIG. 4 is a graphical representation of an example of the range in which the system according to the invention is made operative;

FIG. 5 is a diagram illustrating the exhaust valve timing schedule realized by the system of the invention;

FIG. 6 is a graphical representation of a relationship between the valve lift and the crankshaft revolution angle as observed in an engine incorporating the valve timing system of the invention;

FIG. 7 is a perspective view showing essential parts of a modified form of the valve timing system embodying the invention;

FIG. 8 is a diagram illustrating the intake valve timing schedule realized by the system of FIG. 7;

FIG. 9 is similar to FIG. 6 but is connected with the system shown in FIG. 7; and

FIG. 10 contains plots indicating the relationship between the engine speed, the intake manifold vacuum and the vehicle speed falling within the operating range of the valve timing system of the invention.

Referring first to FIG. 1, the valve timing system according to the invention is combined in use with an engine cylinder including a rocker cover 10. In the engine rocker cover 10 is provided an exhaust valve 12 which is operatively connected to a rocker arm 14 through a retainer 16. The exhaust valve 12 is axially movable to open and close an exhaust opening (not shown) to discharge the exhaust gases, and is normally kept seated by the action of a compression spring 18. The rocker arm is pivotally supported by a pivot 20 as clearly seen in FIG. 2.

A camshaft 22 is mounted on the cylinder 10 through a camshaft gear or sprocket 24 to which the camshaft 22 is splined. The sprocket 24 is driven from the crankshaft (not shown) so that the camshaft 22 is rotatable with the crankshaft. The camshaft 22 being splined to the sprocket 24, the same is axially movable within the rocker cover 10. Designated by numeral 26 is a locator by which the sprocket 24 is properly aligned. The camshaft 22 is rotatable and axially movably supported by a camshaft support bearing 28 which is fixed relative to the cylinder 10. A lubricating fluid passage 28a may be formed in the support bearing 28 so as to smooth the rotation and axial movement of the camshaft 22.

A first cam lobe 30 and a second cam lobe 32 are formed on the camshaft 22 and are positioned relative to the rocker arm 14 of the exhaust valve 12. Between the leading end of the camshaft 22 and the end wall of the rocker cover 10 is mounted a cylinder member 34 which is secured to the rocker cover. The cylinder member 34 is positioned relative to the leading end of the camshaft 22 and has formed on its inner wall surface a stop 36 for limiting the axial movement of the camshaft 22. A piston 38 is securely mounted on the camshaft 22 at a portion near the leading end of the camshaft by a bolt 40. The piston 38 is fitted to the cylinder member 34 so as to define a chamber 42 therebetween. A compression spring 44 is interposed between the support bearing 28 and the piston 38 through a thrust bearing 45 which is mounted on the piston 38, as illustrated.

The chamber 42 communicates on one side with a hydraulic fluid supply passage 46 and on the other side with a hydraulic fluid discharge passage 48. The hydraulic fluid supply passage 46, in turn, communicates through an orifice 50 with a hydraulic fluid gallery 52 and the hydraulic fluid discharge passage 48 on the other hand communicates with a drain chamber 54. The gallery 52 communicates with a source (not shown) of pressurized hydraulic fluid.

The first cam lobe 30, which is intended to be operative during high speed and/or heavy load driving of the motor vehicle, is smaller in size than the second cam lobe 32, which is operative during low speed and/or light load driving. The first cam lobe 30 is positioned on the camshaft 22 in such a manner that it is normally held in an abutting engagement with the rocker arm 14 when the piston 38 and accordingly the camshaft 22 are forced toward the stop 36 on the cylinder member 34 by the action of the spring 44 in the absence of a hydraulic pressure in the chamber 42. The second cam lobe 32, on the other hand, is positioned so that it is normally held out of alignment with the rocker arm 14 when the first cam lobe 30 abuts thereto and is moved into abutting engagement with the rocker arm 14 when a hydraulic pressure obtains in the chamber 42 so as to move the piston and accordingly the camshaft 22 is moved away from the stop 36 against the action of the spring 44.

The hydraulic pressure to be introduced into and discharged out of the chamber 44 is controlled by a plunger or valve means 56 which is located relative to the hydraulic fluid discharge passage 48. The valve means 56, in turn, is controlled by a solenoid valve which is generally represented by numeral 58. Designated by numeral 60 is a drain passage which is intended to allow a fluid pressure to pass therethrough when the valve means 56 is closing.

The solenoid valve 58 consists essentially of a moving core 62 which is integral with the plunger or valve means 56, a spring 64 urging the moving core 62 to be protruded so as to cause the plunger or valve means 56 to be held in a position to close the discharge passage 48, and a solenoid coil 66 which, when energized, causes the moving core 62 to move into its retracted position so that the plunger or valve means 56 is moved to open the passage 48.

The solenoid coil 66 is energized in response to predetermined operating conditions of the motor vehicle so that the valve means 56 is in a position to open the passage 48 only when the vehicle is driven under predetermined conditions as during highway driving. Various operating variables of the motor vehicle may be utilized to represent such operating conditions dictating the movement of the valve means inasmuch as the intent of this invention is maintained. FIG. 3 illustrates an example of an electrical arrangement which may be used as preferable for the control of the solenoid valve 58.

Turning therefore to FIG. 3, the solenoid coil 66 is connected through a line 66a to a first switch 68 which is responsive to variation in the vacuum in the intake manifold (not shown) of the engine. The switch 68 is operated by a diaphragm device 70 having a diaphragm member 72 to which the switch 68 is rigidly connected. A compression spring 74 is seated on the reverse side of the diaphragm member 72, which consequently is biased to a position in which the switch 68 is kept open. The diaphragm member 72 is subjected to a vacuum in the intake manifold of the engine and the compression spring 70 is selected in a manner to overcome the force of the intake manifold vacuum lower than a predetermined level, say, about -100 mm. of Hg for instance. When the vacuum rises beyond such predetermined level as in the deceleration of the motor vehicle, then the spring 74 overcomes the force of the intake manifold vacuum so that the diaphragm member 72 is moved to a position in which the switch 68 is closed.

In lieu of the arrangement shown in FIG. 3, the switch 68 may be controlled from a vacuum controlled advance device of the ignition distributor if preferred.

The switch 68 is connected operatively to a second switch 76 through a line 78. The switch 76 may be a relay switch which is normally open and which is closed when energized with a voltage lower than a predetermined level. More specifically, the switch 76 is operatively connected to an ignition distributor 78 through a line 80 so as to detect the primary pulses produced therein. A voltage is generated which is proportional to the number of the primary pulses, which voltage is then compared with a suitable reference voltage corresponding to a predetermined engine speed which may be 3,200 r.p.m. for instance whereupon the switch 76 is closed. By preference, the switch 76 may be controlled otherwise insofar as the same is closed only when the engine is driven at a speed lower than the predetermined level. For instance, the switch 76 may be controlled from a fluid pressure governor or governors of a power transmission or by a tachometric device where available. Or, the switch 76 may operate on the revolution speed detected by an electromagnetic pickup means which is arranged to be responsive to the rotation of a gearing mounted on the crankshaft.

The first and second switches 68 and 76, respectively, are connected in series with a source 82 of electric power; the power source 82 may be a series of batteries, if preferred.

When, in operation, the motor vehicle is driven on a highway or expressway with the engine speed higher than a predetermined level (3,200 r.p.m. for instance) and the intake manifold vacuum lower than a predetermined value (-100 mm. of Hg, for instance), then the switches 68 and 76 are kept open, keeping the solenoid coil 66 of the solenoid valve 58 unexcited. The plunger or valve means 56 is consequently kept protruded by the action of the spring 64 to close the hydraulic fluid discharge passage 48. This results in an increase in the fluid pressure in the chamber 42 so that the piston 38 and accordingly the camshaft 22 are moved away from the stop 36 against the action of the spring 44 until the cam lobe 32 is brought in alignment with the rocker arm 14. The opening and

closing movements of the exhaust valve 12 is thus governed by the rotation of the greater cam lobe 32 when the motor vehicle is driven at a high speed.

When the motor vehicle decelerates or cruises at a low speed as in city-road driving, the engine speed decreases and the intake manifold vacuum increases so that the switches 68 and 76 are closed simultaneously or differentially. With the two switches 68 and 76 concurrently kept closed, the solenoid coil 66 of the solenoid valve 58 is excited to cause the plunger or valve means 56 to move into its retracted position against the action of the spring 64, opening the hydraulic fluid discharge passage 48. The fluid pressure entrapped within the chamber 42 is now allowed into the drain chamber 54 through the discharge passage 42. The piston 38 and accordingly the camshaft 22 are thus moved toward the stop 36 by the action of the spring 44 until the first cam lobe 30 is brought into alignment with the rocker arm 14. The opening and closing movements of the exhaust valve 12 are now dictated by the rotation of the first cam lobe 30.

FIG. 4 illustrates an example of the range in which the two cooperating switches 68 and 76 are to be closed concurrently, wherein the first switch 68 is assumed to close when the intake manifold vacuum is higher than -100 mm. of Hg and the second switch 76 is assumed to close when the engine speed is lower than 3,200 r.p.m., by way of example.

The first cam lobe 30, which is intended to regulate the valve timing during high speed and/or heavy load driving of the motor vehicle, is so configured that the exhaust valve 12 is opened preferably at about 50° anterior to the bottom dead center (B.D.C.) of the piston movement of the engine cylinder and is closed slightly, preferably at about 10°, posterior to the top dead center (T.D.C.), as seen in FIGS. 5 and 6. The second cam lobe 32, which is used for regulating the movements of the exhaust valve 12 during low speed and/or light load driving of the motor vehicle, is configured in such a manner that, as seen in FIGS. 5 and 6, the exhaust valve 12 is opened at preferably 50° anterior to the B.D.C. and is closed substantially at the T.D.C. It will be appreciated from FIG. 6 that the valve lift is smaller when the second cam lobe 32 is operative than when the first cam lobe 30 is operative.

Only the exhaust valve is controlled selectively depending upon the driving conditions of the motor vehicle in the embodiment of the valve timing system illustrated in FIGS. 1 to 3 but the intake valve as well as the exhaust valve may be controlled on the same principle if desired, an example being shown in FIG. 7.

Referring to FIG. 7, the intake valve is designated by numeral 86 and is associated with a rocker arm 88, retainer 90 and a compression spring 92, similarly to the exhaust valve 12. In the modified valve timing system shown in FIG. 7, the camshaft 22 has, in addition to the set of lobes 30 and 32, another set of a first lobe 94 and a second lobe 96. These cam lobes 94 and 96 are moved and selectively aligned with the rocker arm 88 for the intake valve 86 as the lobes 30 and 32, respectively, are moved and aligned with the rocker arm 14 for the exhaust valve 12 and, as such, discussion of the operations of the cam lobes 94 and 96 is herein omitted.

The first cam lobe 94, which is made operative when the motor vehicle is driven at a speed higher than a predetermined level and/or under heavy load conditions, is configured in a manner that the intake valve 86 is opened slightly, preferably at about 10° anterior to the T.D.C. and is closed preferably at 50° posterior to the B.D.C. The second cam lobe 96 which operates during low speed and/or light load driving of the motor vehicle, is so configured that the intake valve 86 is opened substantially at the T.D.C. and is closed slightly anterior to the point at which the intake valve is closed when the cam lobe 94 is operative. This will be clearly seen in FIG. 8. FIG. 9 illustrates that the valve lift is sizably greater when the cam lobe 94 is operative than when the cam lobe 96 is operative.

FIG. 10 is presented to show how the engine speeds and the intake manifold vacuums, both of which are utilized as

preferred variables to represent the driving conditions of the motor vehicle in the system of the invention, vary markedly with the driving speeds of the motor vehicle, from which it will be understood that the operating range of the valve timing system can be determined suitably so as to achieve the desired purpose of controlling the valve timing in accordance with the driving conditions of the motor vehicle.

It will now be apparent from the foregoing description that the exhaust valve or both of the exhaust and intake valves can be timed for satisfactory combustion of the air-fuel mixture in the engine cylinder without causing a significant power loss through the varying driving conditions of the motor vehicle.

It is, moreover, important for promoting the satisfactory combustion of the hydrocarbons and carbon monoxides in the air-fuel mixture that a sufficient quantity of oxygen be contained in the fuel gases supplied to the engine cylinder. An engine operable with a relatively lean air-fuel mixture is thus proposed and used for this purpose and, where the engine of this type is used, it is necessary to distribute the air-fuel mixture properly to each of the engine cylinders, to propagate the mixture evenly throughout the combustion chamber, and to build up a turbulent flow of the air-fuel mixture in the combustion chamber. This will be accomplished by throttling the intake opening of the engine cylinder by the intake valve thereby to "squeeze" the mixture to be passed therethrough. The modified embodiment of the valve timing system as shown in FIG. 7 is advantageous for this purpose, because the valve lift is significantly limited during low speed and/or light load driving when an increased amount of unburned exhaust gases are usually discharged.

What is claimed is:

1. In an automotive internal combustion engine having engine cylinders each including intake and exhaust valves, a valve timing system comprising a camshaft rotatable with the crankshaft of said engine and axially movable through a camshaft support bearing fixed relative to the engine cylinder, said camshaft having first and second cam lobes which are located relative to the rocker arm of said exhaust valve, said second cam lobe being greater in size than said first lobe, a cylinder member fixed relative to said engine cylinder and located relative to the leading end of said camshaft, said cylinder member being provided with a stop located for abutting engagement with said leading end of said camshaft, a piston securely mounted on said camshaft at a portion near said leading end and fitted to said cylinder member to define a chamber therebetween, a compression spring seated between said support bearing and said piston for forcing said piston and camshaft toward said stop, a hydraulic fluid supply passage communicating at one end with a source of pressurized hydraulic fluid and at the other with said chamber, a hydraulic fluid discharge passage communicating with said chamber, valve means adapted to selectively open and close said hydraulic fluid discharge passage, and control means for controlling said valve means to normally close said hydraulic fluid discharge passage and to open the discharge passage when said engine is driven at a speed lower than a predetermined level and when the vacuum in the intake manifold of said engine is higher than a predetermined level, said second cam lobe being held in an abutting engagement with said rocker arm when said valve means is in a position to close said hydraulic fluid discharge passage to move said piston and camshaft axially away from said stop against said compression spring and said first cam lobe being moved into abutting engagement with said rocker arm when said valve means is moved to a position to open said hydraulic fluid discharge

passage to cause said piston and camshaft to axially move toward said stop by the action of said compression spring.

2. A system according to claim 1, wherein said control means comprises a solenoid valve including a moving core rigidly connected to said valve means, a solenoid coil operatively connected to a source of electric power and a spring means urging said moving core to a position in which said valve means is protruded to close said discharge passage, a first switch interposed between said solenoid coil and said source of electric power and responsive to the revolution speed of said engine, said first switch being closed when said revolution speed is lower than a predetermined level, a second switch connected in series with said first switch and responsive to the vacuum in the intake manifold of said engine, said second switch being closed when the intake manifold vacuum is higher than a predetermined level.

3. A system according to claim 1, wherein said camshaft has another set of first and second cam lobes which are located relative to the rocker arm of said intake valve and of which the latter is greater in size than the former, the second cam lobe associated with said intake valve being held in an abutting engagement with said rocker arm of said intake valve when said valve means is in a position to close said hydraulic fluid discharge passage to move said piston and camshaft axially away from said stop against said compression spring and the first cam lobe associated with said intake valve being moved into abutting engagement with said rocker arm of said intake valve when said valve means is moved to a position to open said hydraulic fluid discharges passage to cause said piston and camshaft to axially move toward said stop by the action of said compression spring.

4. A system according to claim 1, wherein said first cam lobe is configured to open said exhaust valve anterior to the bottom dead center of the piston movement in said engine cylinder and to close the same immediately posterior to the top dead center of the engine cylinder piston and said second cam lobe is configured to open said exhaust valve posterior to the bottom dead center of the engine cylinder piston and to close the same substantially at the top dead center of the piston.

5. A system according to claim 3, wherein said first cam lobe associated with said intake valve is configured to open the intake valve immediately anterior to the top dead center of said engine cylinder piston and to close the same posterior to the bottom dead center of the engine cylinder piston and said second cam lobe associated with said intake valve being configured to open the intake valve substantially at the top dead center of said engine cylinder piston and to close the same posterior to the bottom dead center of the engine cylinder piston substantially later than the timing at which said intake valve is caused to close by said first cam lobe associated with said intake valve.

6. A system according to claim 4, wherein said first cam lobe is configured to open the exhaust valve at about 50° before the bottom dead center and close the same at about 10° past the top dead center and said second cam lobe is configured to open the exhaust valve at about 50° past the bottom dead center.

7. A system according to claim 5, wherein said first cam lobe associated with the intake valve is configured to open the intake valve at about 10° before the top dead center and to close the same at about 50° past the bottom dead center and said second cam lobe associated with the intake valve is configured to close the intake valve at an angle appreciably smaller than 50° past the bottom dead center.

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