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[54] **APPARATUS FOR REDUCING HYDROCARBON CONTENT OF ENGINE EXHAUST GASES DURING DECELERATION OF AUTOMOBILE**
3 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **123/119,** 123/97, 261/41
[51] **Int. Cl.** **F02m 11/00,** F02d 9/00, F02m 3/04
[50] **Field of Search** .... 123/98(B), 97: 1/119; 261/41.4; 267/(Inquired)

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ABSTRACT: A system for reducing the hydrocarbon content of engine exhaust gases emitted during the deceleration of an automobile through reduction in the air content of the air-fuel mixture to be drawn to the engine via the carburetor by way of the slow mixture supply flow path and through reduction in the intake manifold vacuum which increases rapidly when during deceleration, through the provision of an air chamber in the slow running mixture supply flow path of the carburetor which air chamber communicates with all of the slow mixture supply path air bleeds and to atmosphere and such air chamber is connected to the engine intake downstream of the throttle by a valve opened by deceleration vacuum.

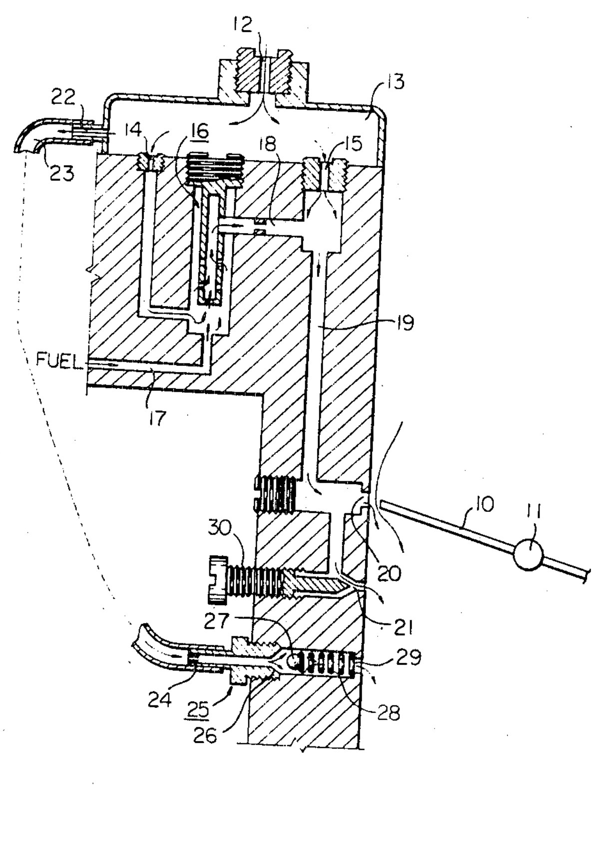


Fig. 1

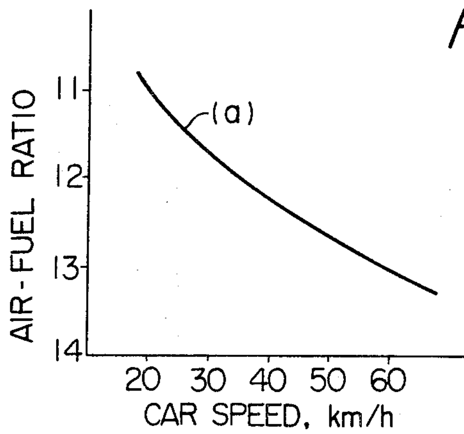


Fig. 2

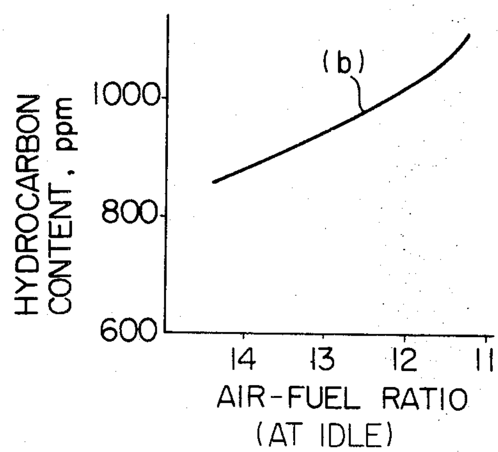


Fig. 3

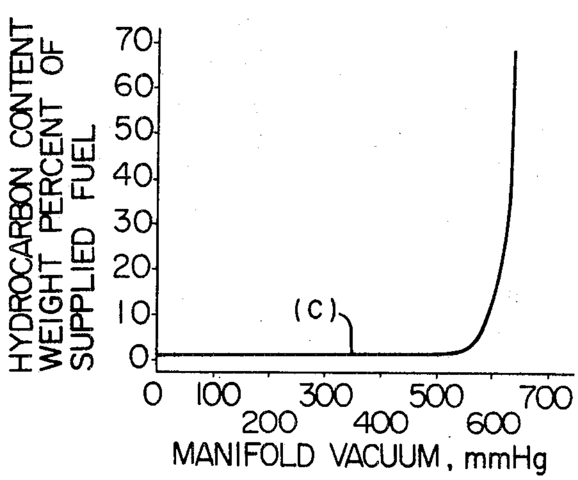


Fig. 4

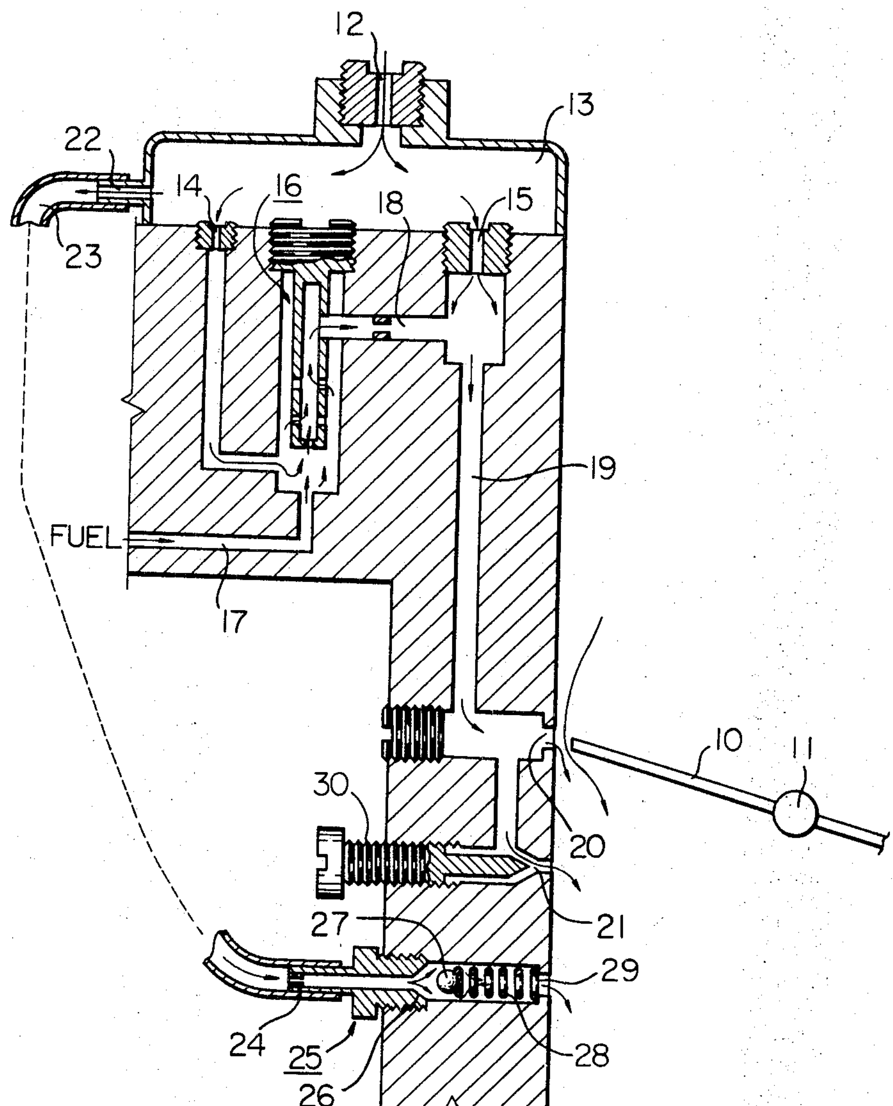
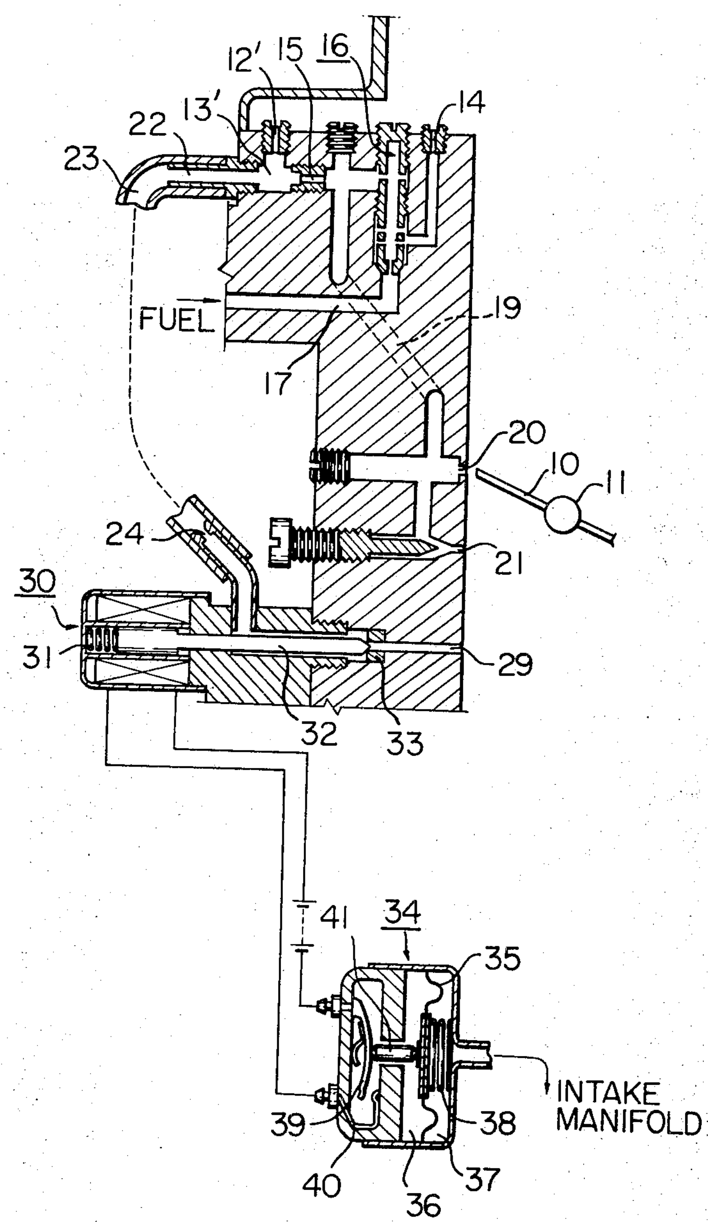


Fig. 5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APPARATUS FOR REDUCING HYDROCARBON CONTENT OF ENGINE EXHAUST GASES DURING DECELERATION OF AUTOMOBILE

The present invention relates to system for reducing the hydrocarbon content of exhaust gases of an automotive gasoline-powered engine, and more particularly to a system for controlling both the air-fuel ratio of an air-fuel mixture to be drawn into the engine by way of the slow running mixture supply flow path of a carburetor and the level of intake manifold vacuum while in the deceleration of the automobile.

The presence of hydrocarbons in engine exhaust gases is of keen interest to automotive industry for two major reasons—air pollution and fuel economy. To solve problems concomitant with these two factors, numerous attempts have heretofore been made, involving an effect to improve the performance characteristics of the carburetor in such a manner as to control the air-fuel ratio of the air-fuel mixture while in the operations of the automobile. Difficulties have, however, been encountered by the prior art methods and apparatus in maintaining the air-fuel ratio of the engine fuel at a proper level invariably under the widely varying driving conditions and without impairing the driveability of the automobile.

Automobile operation is usually divided into four different driving conditions; idle, acceleration, normal cruising, and deceleration. The ranges of hydrocarbon contents of engine exhaust gases vary markedly according to the mode of automobile operation, and experiments thus far conducted on various engine exhaust gases emitted under different modes of automobile operation have revealed that the hydrocarbon content of exhaust gases displays the highest value during the deceleration. This is due partly to the inability of the carburetor to supply the engine with an air-fuel mixture having an air-fuel ratio which is appropriate for providing for the satisfactory combustion of the mixture in the combustion chamber of the engine and partly to the occurance of an unsatisfactory combustion and misfire of the air-fuel mixture that are invited by the remarkable increase in the intake manifold vacuum during the deceleration. In order to accomplish satisfactory combustion of the air-fuel mixture during the deceleration, therefore, it is important to enable the carburetor to supply the engine with a mixture having an air-fuel ratio best suited to eliminate the presence of partially burned or unburned air-fuel mixture in the engine exhaust gases, and further to increase the amount of the mixture to be supplied to the engine thereby to prevent excess increase of the intake manifold vacuum during the deceleration. The fact is however that, when in the deceleration of the automobile, the air-fuel ratio of the mixture in the carburetor remains substantially unchanged from that which is determined in the idle operation in spite of the engine speed and intake manifold vacuum changing as the automobile speed changes. Thus, it is necessary for reducing the hydrocarbon content of engine exhaust gases during the deceleration either to have the air-fuel ratio of the air-fuel mixture for the idle operation decreased to a value which is adequate for effecting the satisfactory combustion of the mixture, or to install such a device that is capable of controlling the air-fuel ratio under a predetermined level.

It is therefore a primary object of the invention to provide a system which is capable of reducing the hydrocarbon content of engine exhaust gases emitted during the deceleration of an automotive engine independently of the remaining modes of operation.

It is another primary object of the invention to provide a system adapted to maintain both the air-fuel ratio of an engine fuel mixture and the intake manifold vacuum under predetermined limits exclusively during the deceleration of the automobile.

It is another primary object of the invention to provide a system for maintaining the air-fuel ratio of the engine fuel mixture at a proper level during the deceleration and at the same time for lowering the intake manifold vacuum that increases remarkably as soon as the automobile slows down, whereby a total of the hydrocarbon content of engine exhaust gases emitted throughout all the modes of automobile operation is ultimately reduced to a minimum.

It is another primary object of the invention to provide a system adapted to enrich the air-fuel mixture by decreasing the amount of air to be contained in air-fuel mixture through the provision of a special slow air bleed chamber in the slow running mixture supply flow path of a carburetor.

It is another primary object of the invention to prevent the air pollution caused by the presence of an unburned air-fuel mixture or hydrocarbons contained in engine exhaust gases and at the same time to expect to significantly save the engine consumption of an automobile driven by a gasoline-powered engine.

Further and other objects of the present invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings in which like characters of reference designate corresponding parts in all figures and in which:

FIG. **1** is a graph showing a desired example of the relationship between the air-fuel ratio of an air-fuel mixture and the automobile speed during the decelerating operation;

FIG. **2** is a graph showing the relationship between the air-fuel ratio determined under the idling conditions of the engine and the engine exhaust gas hydrocarbon content under the idle, accelerating and normal cruising operations, *viz.*, under the operations excepting the deceleration;

FIG. **3** is a graph showing the effect of the intake manifold vacuum on the exhaust gas hydrocarbon content;

FIG. **4** is a partial vertical sectional view of a carburetor incorporating an apparatus embodying the present invention; and

FIG. **5** is similar to FIG. **4**, but shows a modification of the apparatus shown in said figures.

In a carburetor of the conventional type having the characteristics of operating at the air-fuel ratio determined specifically for idle operation although the engine speed and intake manifold vacuum change as the automobile speed changes during the deceleration, with the result that engine fuel mixture fails to attain an optimum air-fuel ratio assuring satisfactory combustion of the mixture while in the deceleration.

The hydrocarbon content of engine exhaust gases produced during the deceleration will be reduced to a minimum by controlling the air-fuel ratio of the mixture in such a manner as to meet with the curve *a* of FIG. **1** which illustrates a desired example of the relationship between the automobile speed and the air-fuel ratio. One simple and economical expedient of approximately realizing the curve *a* in a usual carburetor may be to restrict the air-fuel ratio fixedly within a certain range, say, anywhere between 12 and 13 in consideration of the air-fuel ratio at idle of the existing automobiles. This will be achieved by regulating the air-fuel ratio by the use of the usual idle fuel adjusting screw; the air-fuel ratio determined at idle remains substantially unchanged during the deceleration, too, as previously noted. Such a restriction of the air-fuel ratio within a relatively low range, however, results in an increased amount of the hydrocarbon content during the idle, acceleration and normal cruising operations because, as observed from the curve *b* of FIG. **2** so that it is advantageous to maintain the air-fuel ratio at a higher level throughout the different automobile operations excepting the deceleration, preferably by the use of a carburetor which is operable with a lean air-fuel mixture. Thus, controlling the air-fuel ratio for the deceleration (during which a particularly large amount of hydrocarbons are contained in the engine exhaust gases) independently of the other modes of operation is necessitated to reduce the total amount of hydrocarbon content of engine exhaust gases produced under all the driving modes of automobile operation.

In the slow running mixture supply flow path of the conventional carburetors, however, it is extremely difficult to maintain the air-fuel ratio of the fuel mixture at an optimum level in the course of the deceleration in view of the performance characteristics of the carburetor not using a suitable control device, though the air-fuel ratio during the idle operation can be regulated as desired. In controlling the air-fuel ratio for the idle operation, moreover, problems are experienced from the difficulty of eliminating the individual errors ranging generally from 9 to 15 in the air-fuel ratio which is usually regulated by a rule of thumb.

Another important factor in reducing the hydrocarbon content of engine exhaust gases is the influence of the high intake manifold vacuum which develops abruptly at the initial stage of the deceleration. The intake manifold vacuum increases sharply as soon as the automobile starts to slow down, say, in excess of 650 mm. of Hg while it remains of the order of 500 mm. of Hg during the idle operation. This is entirely due to the fact that the butterfly valve of the carburetor remains substantially closed during the deceleration so as to shut off the flow of the air-fuel mixture in the main mixture supply flow path although the engine operates at a relatively high speed which is proportioned to the running speed of the automobile. The intake manifold vacuum that has increased to such a high level inevitably leads to unsatisfactory combustion and misfire of the air-fuel mixture in the combustion chamber of the engine, thereby remarkably giving rise to the hydrocarbon content of the engine exhaust gases emitted during the deceleration.

Such a trend in the hydrocarbon content is evidently ascertained from the curve *c* of FIG. 3 which indicates a typical example of the relationship between the engine exhaust gas hydrocarbon content and the engine intake manifold vacuum. As shown, the hydrocarbon content is suppressed at a remarkably low level independent of the intake manifold vacuum below approximately 530 mm. of Hg while at higher vacuums it increases very rapidly.

To reduce the hydrocarbon content of engine exhaust gases in a more effective fashion, therefore, it will be advantageous to have the amount of the engine fuel mixture increased with the resultant reduction in the intake manifold vacuum during the deceleration. Ideally, it will be the best approach to the reduction of the hydrocarbon content of the engine exhaust gases during the deceleration to have the amount of the engine fuel mixture increased to such an extent as to lower the intake manifold vacuum to the vicinity of 530 mm. of Hg. On account of the braking effect of the engine, however, reduction of the intake manifold vacuum to such an extent turns out quite detrimental to the driveability of the automobile and hence, is not suited for practical purposes. The intake manifold vacuum should therefore be decreased to a point where the driveability of the automobile is in no way impaired. In this sense, the reasonable level to which the intake manifold vacuum should be reduced is generally considered to be in the neighborhood of 600 mm. of Hg. As illustrated by the curve *c* of FIG. 3, reducing the intake manifold vacuum to approximately 600 mm. of Hg is apparently conducive to the minimization of the hydrocarbon content of the engine exhaust gases.

As is apparent from the curve *b* of FIG. 2, moreover, it will be advantageous for minimizing the aggregated amount of the hydrocarbon content of engine exhaust gases emitted during the idle, accelerating and normal cruising operations (namely under all the modes of automobile operations excepting the deceleration) to use a carburetor of the type which is operable with a relatively lean air-fuel mixture, that is, with a mixture having a relatively high air-fuel ratio. The carburetor of this type will have the flow characteristics dictated by the lean side of the flow band in the established carburetor flow curve. Thus, using the system implemented according to the invention in a carburetor having said flow characteristics will be conducive to the reduction of the hydrocarbon content of engine exhaust gases emitted during the different operations of the automobile.

One embodiment of the present invention to achieve such an end is shown in FIG. 4, wherein the carburetor is illustrated to be under the decelerating operation with its butterfly valve substantially fully closed. The butterfly valve **10** may be of the type which is usually used in the conventional carburetor and is mounted rotatably on the shaft **11**.

Air is introduced into the slow running mixture supply flow path from the orifice **12** which is provided atop the slow running air bleed chamber **13** and which is vented from the atmosphere. Air introduced from the orifice **12** is further admitted into the first and second slow running air bleeds **14** and **15**, respectively, in a normal state. It will be understood that the amount of air to be introduced from the orifice **12** may be determined properly by varying the inside diameter thereof. Air passing through the first air bleed **14** is then fed to the slow running jet **16** where it is mixed in a predetermined mixture ratio with the liquid fuel supplied by way of the fuel supply passage **17** from the liquid fuel source (not shown). The mixture of air and fuel is metered and atomized at the slow jet **16** and delivered to the slow running economizer **18** for further mixing with air introduced from the second air bleed **15**. The resultant engine fuel mixture is now fed through the fuel mixture supply passage **19** and is spurted out of the slow port **20** and the idle port **21** into the main running mixture supply path of the carburetor downstream of the butterfly valve **10**. The amount of the fuel mixture to be spurted out of the idle port **21** may be adjusted in a usual manner by the use of the idle adjusting screw **30**.

According to the invention, the slow running air bleed chamber **13** is so arranged as to communicate with the main mixture supply flow path of the carburetor downstream of the idle port **21** by way of an outlet **22**, a conduit **23**, an orifice **24**, a valve assembly **25** and a decelerating port **29**.

As previously noted, the intake manifold vacuum remains of the order of 500 mm. of Hg during the idle operation so that the ball valve member **27** is forced against the valve seat **26** by the action of the coil spring **28**, prohibiting air to flow through the valve assembly **25** into the decelerating port **29**.

As soon as the automobile starts to slow down, on the other hand, the intake manifold vacuum increases rapidly, say, in excess of 650 mm., with the result that the ball valve member **27** is forcedly drawn toward the decelerating port **29** and moves away from the valve seat **26**, allowing air to flow through the valve assembly **25** into the main mixture supply flow path downstream of the butterfly valve **10**.

Thus, the air introduced from the orifice **12** of the chamber **13** is admitted to the main mixture supply flow path as well as to the slow running mixture flow path during the deceleration while it is permitted to flow solely into the slow running fuel flow path while in the idle operation of the automobile. The amount of air passing the valve assembly **25** may be determined by properly selecting the inside diameter of the orifice **24** thereof, preferably in the neighborhood of 600 mm. of Hg so as to meet with the characteristics of the curve *c* of FIG. 3. The orifice **12** is so sized in inside diameter as to maintain the interior of the air bleed chamber **13** at a normal or slightly lower pressure during the idle operation and at a suitable level of vacuum during the deceleration.

With the slow running fuel supply flow path of the carburetor thus constructed, the engine is supplied during the idle operation with such an amount of the fuel mixture as is considered reasonable in the conventional carburetors. While in the deceleration, however, a material amount of air is fed to the main mixture supply flow path by way of the conduit **23** so that the pressure in the chamber **13** becomes negative. The result is that the amount of air to be admitted to the first and second air bleeds **14** and **15**, respectively, is reduced in proportion to the drop of the pressure in the chamber **13**, so that the fuel mixture to spurt out of the slow port **20** and the idle port **21** is enriched. The fuel mixture delivered out of these two ports **20** and **21** is admixed with the air flowing through the clearance between the butterfly valve **10** and the slow port **20** and further with air introduced from the decelerating port **29** so that the amount and the air-fuel ratio of the engine fuel mixture attain values optimum for the deceleration of the automobile.

In this embodiment of the present invention, as is apparent from the foregoing description, the amount of air to be admixed with the fuel mixture fed from the first and second air bleeds **14** and **15**, respectively, is controlled through the reduction in the level of the pressure in the chamber 13 which diminishes during the deceleration. It is, however, more conducive to the increased simplicity of the mechanical construction of the carburetor to have controlled the amount of air to be admitted into the second air bleed only, through the provision of slow running air bleed chamber at the second air bleed, whereby similar performance and effect to those obtained in the first embodiment of the invention may be achieved.

Such a concept of the carburetor construction is advantageously implemented in the air-fuel ratio control system illustrated in FIG. 5, wherein the components corresponding to those used in the first embodiment are represented by like numerals.

Referring to FIG. 5, a slow running air bleed chamber 13′ and a second air bleed 15 are provided in the slow running mixture supply flow path so that air supplied from the atmosphere through the orifice 12′ is mixed with the fuel mixture to be fed from the slow jet 16 and spurts out of the slow port 20 and the idle port 21 into the main mixture supply flow path during the idle operation and, while, in the deceleration, said air is also drawn to the decelerating port 29 by way of the conduit 23.

Different from the first embodiment and for the sake of increased stability of the air shutoff valve performance, the air drawn from the outlet 22 is controlled by the cooperation of a solenoid valve assembly 30 and a diaphragm switch assembly 34, which are electrically wired to one another. The construction of the diaphragm switch assembly 34 is such that it is divided by a diaphragm member 35 into two different chambers 36 and 37 of which the suction chamber 37 communicates with the intake manifold (not shown) by way of a conduit 42 and of which the atmospheric chamber 36 has mounted therein a set of moving and stationary contacts 39 and 40, respectively, of which the moving contact 39 is connected by a rod 41 with the diaphragm member 35. The diaphragm member 35 is normally forced toward the chamber 36 by the action of the spring 38 and as the consequence the moving contact 39 is kept released from the stationary contact 40.

The solenoid valve assembly 30, on the other hand, has mounted therein a needle valve member 32 which is normally forced against the valve seat or stopper 33 by the action of the coil spring 31 so that air introduced by way of the conduit 23 is prohibited to flow into the decelerating port 29 inasmuch as the solenoid valve assembly 30 remains inoperative.

When, now, the automobile running at a normal cruising speed starts to slow down, namely, at the initial stage of the deceleration of the automobile, the intake manifold vacuum increases immediately to the level of 650 mm. of Hg or more, as already discussed. It therefore follows that the diaphragm member 35 is drawn toward the suction side, namely, rightwardly of the drawing, causing the moving contact 39 to abut against the stationary contact 40. The solenoid valve assembly, which is now electrically connected with the diaphragm switch assembly, becomes actuated to let the valve member 32 withdraw from the valve seat 32 against the action of the coil spring 31. The result is that the air introduced from the chamber 13′ by way of the outlet 22, the conduit 23 and the orifice 24 is allowed to pass the passage leading to the decelerating port 29 and into the main mixture supply flow path of the carburetor. Air in the chamber 13′ being thus imparted to the main running mixture supply path by way of the conduit 23, the air pressure in the chamber 13′ materially decreases and the fuel mixture to be delivered from the slow port 20 and the idle port 21 is enriched accordingly.

The air-fuel ratio of the engine fuel mixture for the idle and decelerating operations may be determined to at optimum values by appropriately selecting the diameters of the orifice 12′, first air bleed 14 and second air bleed 15, when in designing the carburetor. Furthermore, the amount of air to be drawn from the chamber 13′ to the decelerating port 29 can attain a desirable intake manifold vacuum level by properly determining the size of the orifice 24.

It will be now apparent from the foregoing description that the hydrocarbon content of engine exhaust gases is reduced during the deceleration of the automobile by lowering the intake manifold vacuum through introduction of air from the slow running air bleed chamber to the main mixture supply flow path of the carburetor downstream of the butterfly valve and by the enrichment of the main engine fuel mixture through reduction in the amount of air to be admixed to the fuel mixture in the slow running mixture supply flow path.

According to a feature of the present invention, the hydrocarbon content of engine exhaust gases is diminished through the effective utilization of the abrupt increase in the intake manifold vacuum in the slow running mixture supply flow path without major dimensional modification to the carburetor in its entirety. This is particularly important in this invention in that the concentration of the hydrocarbons in engine exhaust gases is sufficiently stabilized by improving the quality of combustion in the combustion chamber especially during the deceleration of the automobile.

According to another feature of the invention, not only the amount but also the air-fuel ratio of the engine fuel mixture can be controlled during the deceleration of the automobile independently of the other modes of the automobile operation in such a manner as to keep the engine fuel mixture richer during the deceleration and leaner during the idle, accelerating and normal cruising operations of the automobile.

According to a further feature of the invention, the intake manifold vacuum which increases abruptly at the initial stage of the deceleration of the automobile is rendered low, say, reduced to about 600 mm. of Hg which is considered a level appropriate for minimizing the presence of hydrocarbons in the engine exhaust gases without impairing the driveability of the automobile, as is previously noted with reference to the curve *c* of FIG. 3.

If, furthermore, the apparatus according to the invention is placed on use with a carburetor operating on the lean side of the flow band of the carburetor flow curve, it will lend itself to the reduction of the hydrocarbon content of engine exhaust gases during every mode of the automobile operation.

Since the system according to the invention is operable with a relatively lean air-fuel mixture, it will prove advantageous in the reduction of carbon monoxide content of engine exhaust gases as well as in the saving of engine fuel consumption.

While two embodiments of the invention have been shown and described in detail, it will be apparent to those skilled in the art that such is by way of illustration only and numerous changes may be made thereto without departing the spirit and scope of the present invention which is defined by the appended claims.

We claim:

1. In a carburetor for an automotive gasoline-powered engine and having a main mixture supply flow path leading to the intake manifold of said engine and kept substantially closed by a butterfly valve mounted therein during the idle and decelerating operations of the automobile and a slow running mixture supply flow path which is adapted to supply said engine with an air-fuel mixture having a predetermined air-fuel ratio during said operations and which includes a first and second air bleeds which are vented to the atmosphere, a liquid fuel passage leading from a fuel source and communicating with said first and second air bleeds, a mixture passage for passing the air delivered from said first and second air bleeds and fuel delivered from said fuel passage, a slow port communicating with said mixture passage and opening into said main mixture supply path at a position where said butterfly valve substantially closes the last named path during the idle and decelerating operations and an idle port communicating with said slow port and opening into said main mixture supply flow path downstream of said butterfly valve, a system for reducing the air-fuel ratio of the air-fuel mixture to be drawn to the combustion chamber of said engine through said slow running mixture supply flow path during the decelerating operation of the automobile, said system comprising an air chamber which

is vented from the atmosphere through an air orifice and which communicates with said first and second air bleeds, a valve assembly which communicates with the intake manifold of said engine and which consists of a valve member, a coil spring and a valve seat, and a suction conduit linking said air chamber with said valve assembly by way of a suction orifice, said valve member being normally forced against said valve seat by the action of said coil spring for keeping said suction conduit closed by said valve member during the idle operation, wherein, as an increased vacuum develops at the intake manifold of the engine during the decelerating operation, said valve member becomes released from said valve seat in response to the increase in the vacuum at the intake manifold and against the action of said coil spring, whereby air is introduced from said air chamber into the intake manifold of the engine by way of said suction conduit and said valve assembly and, simultaneously, the amount of air to be entrained in the air-fuel mixture to be delivered into said main mixture supply flow path through said slow and idle ports is lessened.

2. The system as set forth in claim 1, wherein said valve assembly further comprises a solenoid device which becomes energized in response to the increase in the vacuum at the intake manifold of the engine for thereby causing said valve member to be released from said valve seat.

3. The system as set forth in claim 2, wherein said solenoid device is connected by an electrical circuit to a diaphragm switch assembly by way of a power source, said diaphragm switch assembly being divided by a diaphragm member into two different chambers, of which the atmospheric chamber has accommodated therein a set of moving and stationary contacts both connected with said electrical circuit and of which the suction chamber communicates with the intake manifold of the engine and has accommodated therein a coil spring acting to normally keep said moving contact released from said stationary contact, wherein, as an increased vacuum develops at the intake manifold of the engine during the decelerating operation, said diaphragm member is displaced with said increased vacuum exerted thereto and against the action of the last named coil spring in a direction to cause said moving contact to abut against said stationary contact for letting said solenoid device be energized from said power source during the decelerating operation.