United States Patent

[11] 3,590,792

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[33] **Japan**
[31] **43/20781, 43/20782 and 43/20783**

[54] **APPARATUS FOR REDUCING HYDROCARBON CONTENT OF ENGINE EXHAUST GASES DURING DECELERATION OF AUTOMOBILE**
6 Claims, 8 Drawing Figs.

[52] **U.S. Cl.** **123/97,** 123/124
[51] **Int. Cl.** **F02d 9/00,** F02m 23/04
[50] **Field of Search** ..... 123/97 B; 1/119, 124; 261/41.4

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Primary Examiner—Wendell E. Burns
Attorneys—Robert E. Burns and Emmanuel J. Lobato

ABSTRACT: System for reducing the engine exhaust gas hydrocarbon content during deceleration of an automobile comprising means which is adapted to reduce the proportion of air in the air-fuel mixture to be drawn to the intake manifold of the engine when the carburetor butterfly valve is substantially fully closed with the resultant increase in the intake manifold vacuum and means for introducing atmospheric air into the intake manifold concurrently with the reduction in the proportion of air in the air-fuel mixture thereby to reduce the intake manifold vacuum.

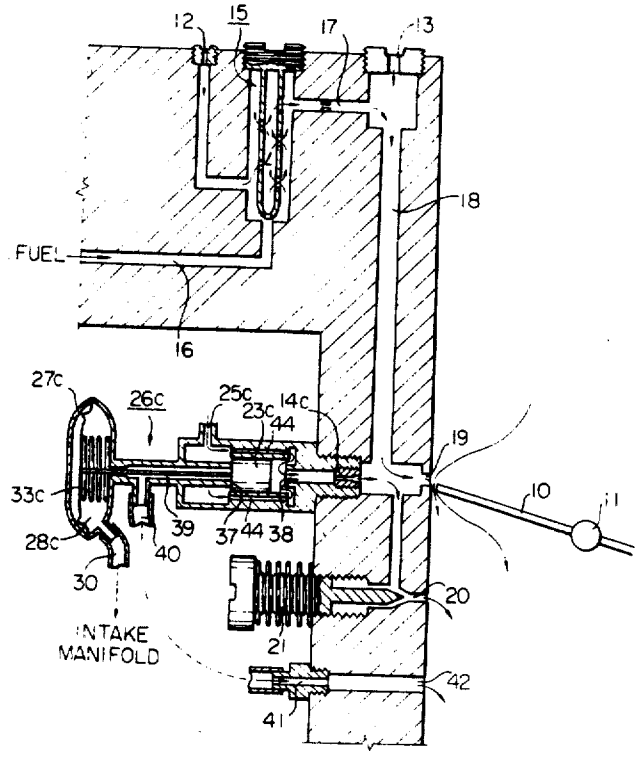


Fig. 1

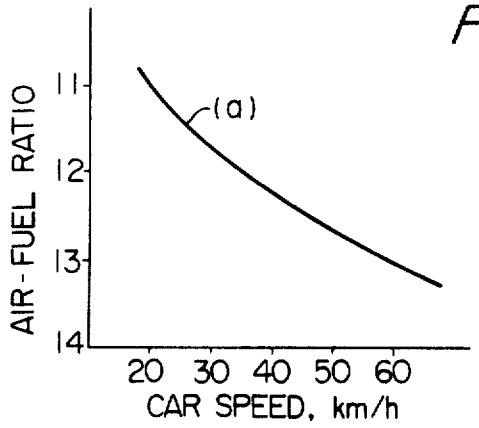


Fig. 2

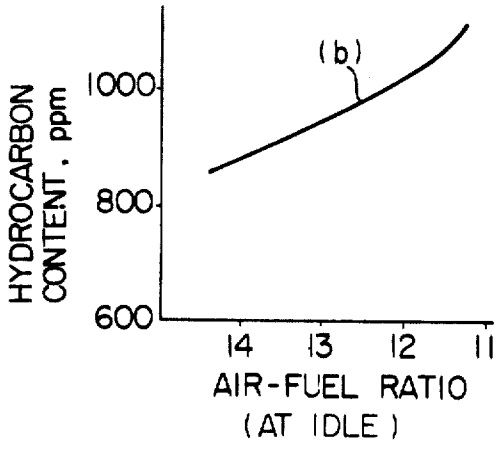


Fig. 3

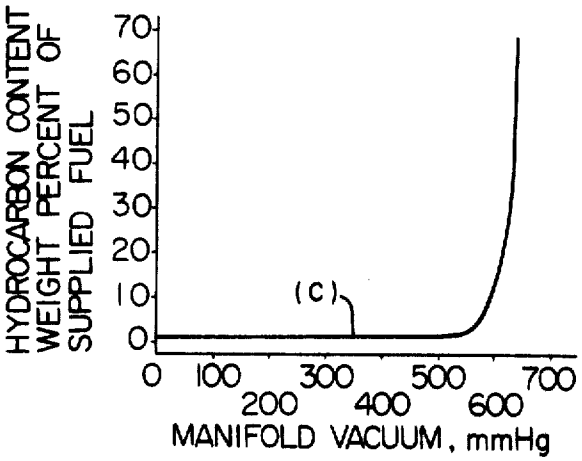
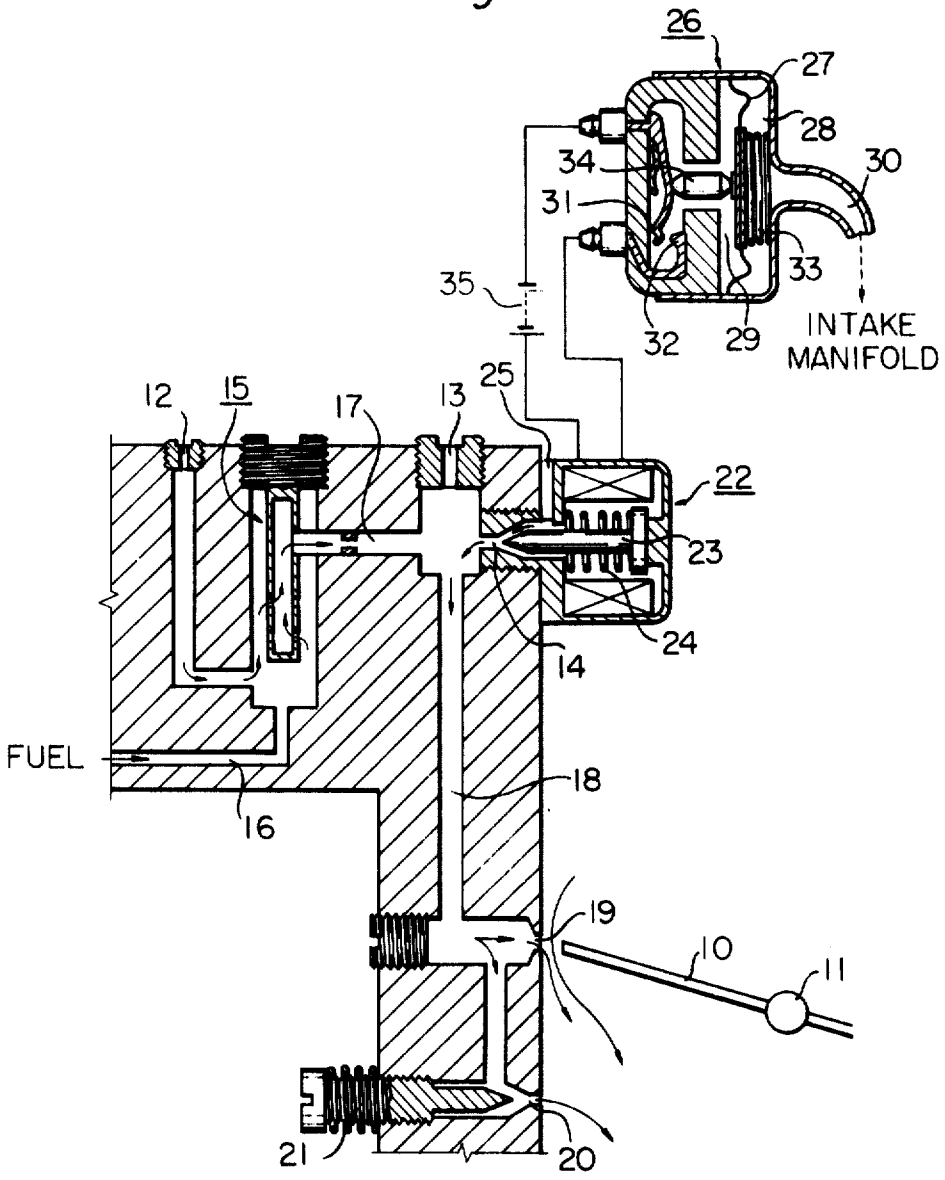


Fig. 4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INTAKE MANIFOLD
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FUEL
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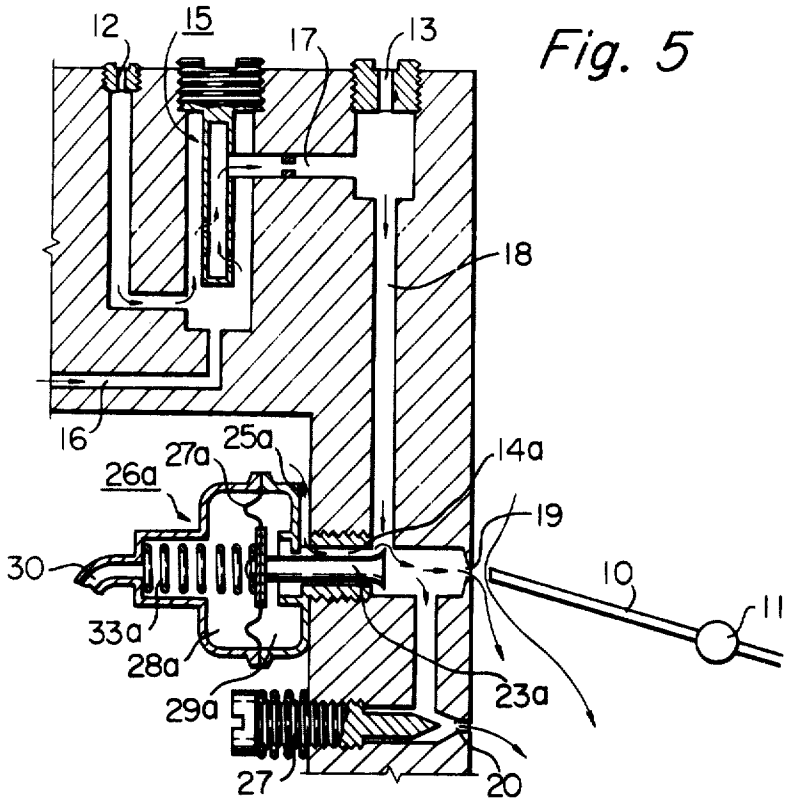
Fig. 5


12
15
17
13
18
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25a
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26a
14a
19
30
10
11
33a
28a
23a
29a
27
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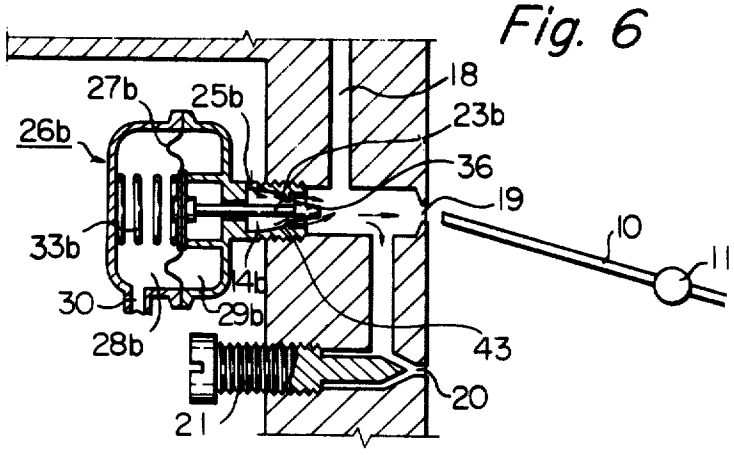
Fig. 6


18
27b
25b
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10
11
33b
14b
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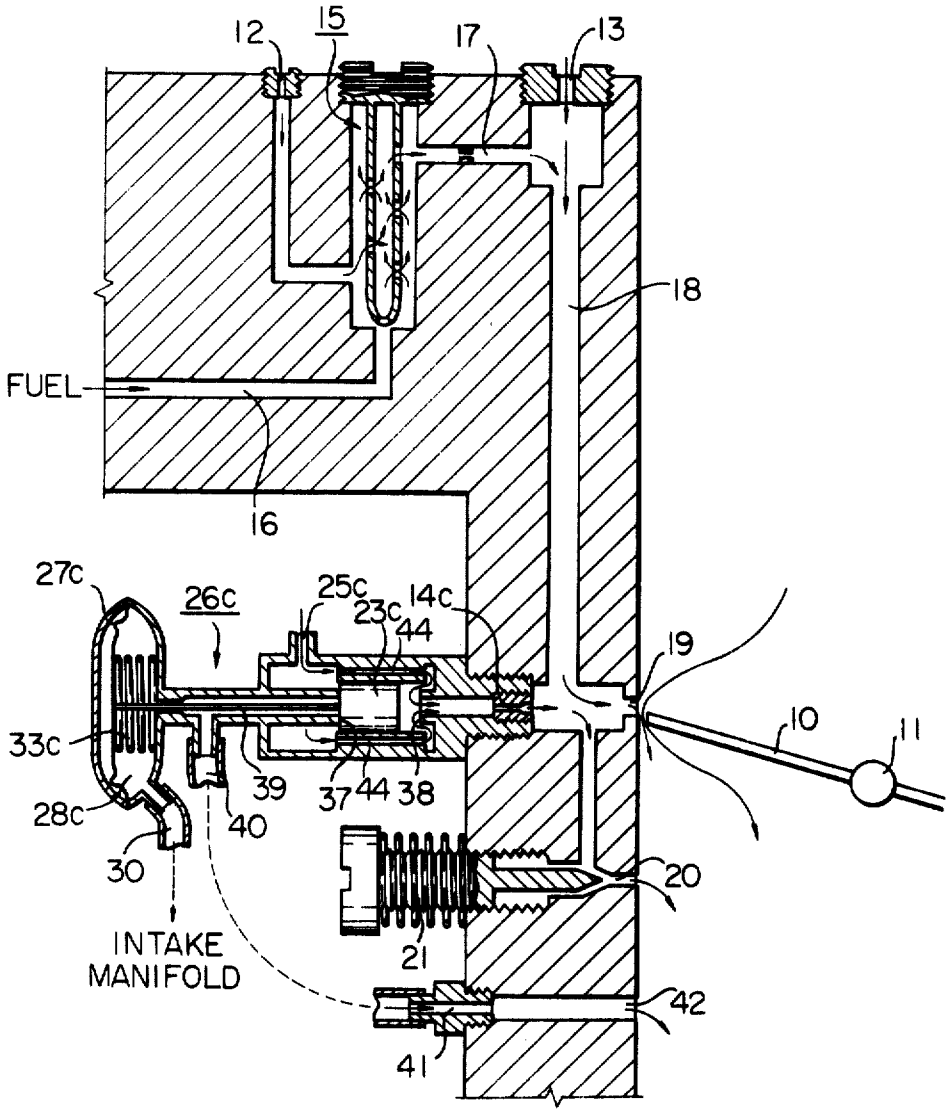
29b
43
28b
20
21

Fig. 7


12
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FUEL
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27c
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25c
23c
14c
44
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33c
39
37
44
38
28c
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INTAKE
MANIFOLD
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42
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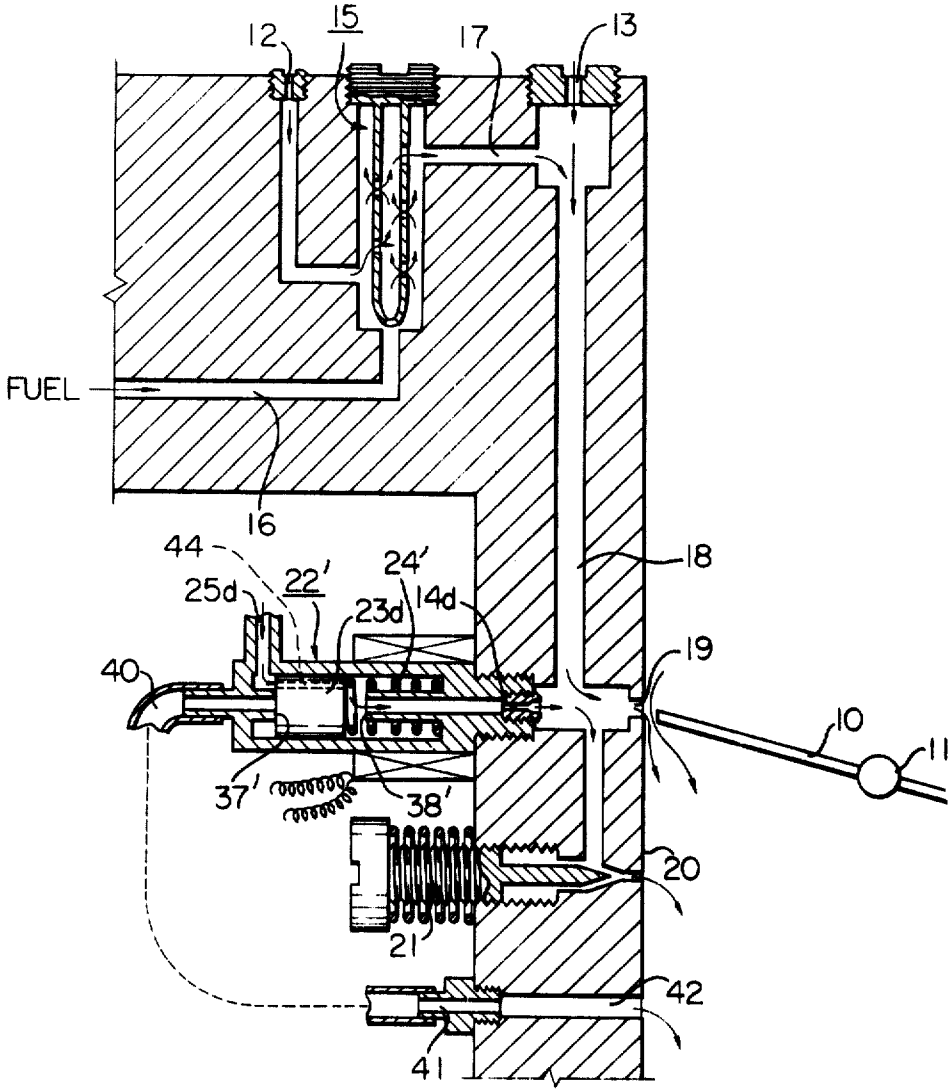
Fig. 8


12
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FUEL
16
44
22'
24'
25d
23d
14d
18
19
40
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37'
38'
20
21
42
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APPARATUS FOR REDUCING HYDROCARBON CONTENT OF ENGINE EXHAUST GASES DURING DECELERATION OF AUTOMOBILE

The present invention relates to a system for reducing the hydrocarbon content of exhaust gases of an automotive gasoline-powered internal combustion engine, and more particularly to a system for controlling 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 during deceleration of the automobile.

The presence of hydrocarbons in engine exhaust gases is of keen interest to the 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 effort to improve the performance characteristics of the carburetor in such a manner as to control the air-fuel ratio of the air-fuel mixture during operations of the automobile. Difficulties have, however, been encountered by the prior art methods and systems in maintaining the air-fuel ratio of the engine air-fuel mixture 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 range of hydrocarbon content of engine exhaust gases varies 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 peaks up during 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 to provide for a satisfactory combustion of the mixture, and partly to the unsatisfactory combustion and misfiring of the air-fuel mixture in the combustion chamber that are invited by the increase in the intake manifold vacuum during deceleration. In order to accomplish satisfactory combustion of the air-fuel mixture during deceleration, therefore, it is important that the carburetor is capable of supplying the engine with a mixture having an air-fuel ratio best suited for each mode to eliminate the presence of partially burned or unburned hydrocarbons in the engine exhaust gases, and further to increase the amount of the mixture to be supplied to the engine thereby to prevent an excess increase of the intake manifold vacuum during deceleration. The fact is however that, during deceleration of the automobile, the air-fuel ratio of the mixture produced by the carburetor remains substantially unchanged from that which is determined for the idling 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 deceleration either to have the air-fuel ratio of the air-fuel mixture for the idling operation fixedly determined at a value which is adequate for effecting the satisfactory combustion of the mixture, under all the driving conditions or to install in the carburetor such a device that is capable of controlling the air-fuel ratio within a predetermined range during deceleration.

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

It is another prime object of the invention to provide a system adapted to maintain the air-fuel ratio of an engine fuel mixture at an optimum level exclusively during deceleration of the automobile.

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

It is another prime object of the invention to provide a system which is capable of continuously controlling the air-fuel ratio of the air-fuel mixture to an optimum level in close relation to the decrease in the automobile speed during deceleration.

It is another prime object of the invention to prevent air pollution caused by the presence of an unburned air-fuel mixture or hydrocarbons in engine exhaust gases and at the same time to significantly save the engine fuel consumption of an automobile driven by a gasoline-powered internal combustion 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 example of a desired 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 total engine exhaust gas hydrocarbon content under the idling, accelerating and normal cruising operations, viz, under the operations excepting 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 a system embodying the invention, wherein the amount of air to be mixed with the fuel is controlled during deceleration of the automobile by the cooperation of a solenoid valve assembly and a diaphragm switch;

FIG. 5 is similar to FIG. 4, but shows a modification of the first embodiment of the invention, in which the amount of the air-fuel mixture is controlled directly by an air shutoff valve connected with a diaphragm which responds to fluctuations in the intake manifold vacuum;

FIG. 6 is similar to FIG. 5, but shows another modification in which the amount of the air-fuel mixture is controlled continuously by a valve having an enlarged tip;

FIG. 7 is also a partial vertical sectional view of a carburetor having further modified air-fuel ratio control system according to the invention, wherein air to be mixed with the fuel is metered and drawn into the main mixture supply flow path of the carburetor downstream of the butterfly valve so as to reduce the intake manifold vacuum to a reasonable extent; and

FIG. 8 is similar to FIG. 7, but shows a further modification in which air is metered and drawn to the carburetor by the cooperation of a solenoid valve assembly and a diaphragm switch (not shown).

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

The hydrocarbon content of engine exhaust gases produced during 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 an example of a desired relationship between the automobile speed and the air-fuel ratio. One simple and economical expedient of approximately realizing a section of the curve (*a*) in a usual carburetor may be to restrict the air-fuel ratio within a certain range, say anywhere between 12:1 and 13:1 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 adjusting screw; the air-fuel ratio determined for idling remains substantially unchanged during 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, 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 deceleration, preferably by the use of a carburetor which is operable with a lean air-fuel mixture during deceleration. 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 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 air-fuel mixture at an optimum level in the course of deceleration in view of the performance characteristics of the carburetor without use of a suitable control device, though the air-fuel ratio during the idling operation can be regulated as desired. In controlling the air-fuel ratio of for the idling operation, moreover, problems are experienced from the difficulty of eliminating the individual errors ranging generally from 9:1 to 15:1 in the air-fuel ratio weight by weight, which is usually regulated by rule of thumb.

The present invention therefore contemplates, before everything else, to improve the slow running fuel supply flow path of a carburetor with a view to maintaining the air-fuel ratio at a relatively high level, preferably within the range of 14:1 to 15:1 during the idling operation and at a relatively low level, preferably within the range of 12:1 to 13:1 during the deceleration, thereby significantly reducing the total amount of the engine exhaust gas hydrocarbon under the widely varying driving conditions of the automobile.

As is apparent from the curve (*b*) of FIG. 2, moreover, it will be advantageous for minimizing the aggregated hydrocarbon content of engine exhaust gases emitted during the idling, accelerating and normal cruising operations (namely under all the modes of automobile operations excepting 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 according to the invention in a carburetor having said flow characteristics will be conducive to the reduction of total amount of hydrocarbons in 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 with the engine idling and the butterfly valve substantially fully closed. The butterfly valve **10** may be of the type which is usually used in the conventional carburetor and is rotatable with the shaft **11**. Represented by **12** and **13** are a first and second slow running air bleeds, respectively, which are vented from the atmosphere and which are so sized in diameter as to admit a suitable amount of air to the slow running mixture flow path of the carburetor. According to the invention, air is also supplied to the slow running mixture supply flow path from a third slow running air bleed **14** while in the idling operation. THe first and the second air bleeds **12** and **13**, respectively, are intervened by a slow running jet **15** at which the fuel fed from the liquid fuel supply passage **16** is metered and mixed with air delivered from the first air bleed **12**. The mixture of air and fuel is spurted from the slow running jet **15** into a slow running economizer **17** and further mixed with air introduced from the second and third air bleeds **13** and **14**, respectively, as shown. The resultant mixture of air and fuel, which has now attained an air-fuel ratio optimum for the idling operation, is fed by way of the air-fuel mixture flow passage **18** to the slow running port **19** and the idling port **20**, from both of which it is allowed into the main mixture flow path of the carburetor downstream of the butterfly valve **10**. The amount of fuel to be supplied by the carburetor and accordingly to the engine combustion chamber (not shown) can be adjusted by the manipulation of the idling port adjusting screw **21**, as desired.

Designated generally at **22** is a solenoid valve assembly of known type having a needle valve **23** and a coil spring **24** which normally holds the needle valve in an open position. The solenoid valve assembly **22** is linked by wires to a diaphragm switch assembly **26** which is divided by a diaphragm member **27** into suction and atmospheric chambers **28** and **29**, respectively. The chamber or the suction chamber **28** communicates with the intake manifold (not shown) of the engine by way of a conduit **30**, while the atmospheric chamber **29** has mounted therein a moving contact **31** and a stationary contact **32**. A coil spring **33** is mounted in the chamber **28** and normally forces the diaphragm member **27** toward the moving contact **31** so that the moving contact, which is connected by a rod **34** with the diaphragm member **27**, is kept released from the stationary contact **32** as illustrated in the drawing. Both of the contacts **31** and **32** are wired to the solenoid valve assembly **22** and powered by a power source **35**.

During the idle operation of the automobile when the intake manifold vacuum remains at a relatively low level, the diaphragm member **27** is forced toward the atmospheric chamber **29** by the action of the spring **33** as shown in the drawing so that the moving contact **31** remains released from the stationary contact **32**, disconnecting the circuit connecting the diaphragm switch assembly **26** and the solenoid valve assembly **22**. The solenoid valve assembly **22** is so arranged that, while it remains deenergized, the needle valve member **23** rests at its rightmost position on the drawing by the action of the spring **24** and consequently that the third air bleed **14** is left open during the idling operation.

With the slow running mixture supply flow path of a carburetor thus constructed, the air-fuel mixture to be supplied to the engine is afforded with an air-fuel ratio in an optimum range for the idling operation especially through the provision of three different slow running air bleeds each so sized as to suck in a predetermined amount of air.

When, now, the automobile running at a normal cruising speed starts to decelerate with the butterfly valve **10** substantially closed similarly to the case of the idle operation but with the engine operating at a speed decreasing in accordance with the automobile speed decline, the intake manifold vacuum augments abruptly. It therefore follows that the pressure in the suction chamber **28**, which communicates with the intake manifold by way of the conduit **30** as previously described, decreases sharply so that the diaphragm member **27** is forced toward the suction side against the action of the coil spring **33**. When the diaphragm member **27** moves rightwardly of the drawing, the moving contact **31** is made to abut against the stationary contact **32** and the diaphragm switch **26** becomes electrically connected with the solenoid valve assembly **22**, which is consequently initiated into action. The actuation of the solenoid valve assembly **22** urges the needle valve member **23** to move leftwardly of the drawing, bringing the third air bleed **14** into a fully closed position. As the result, air introduced from the inlet **25** to the third air bleed **14** is shut off and the amount of air to be admixed with the fuel is accordingly diminished to cause the air-fuel mixture to the enriched to a predetermined value. The air-fuel ratio of the air-fuel mixture at idling may be adjusted by properly determining the diameter of the third air bleed **14** when in designing the carburetor.

It will be understood that the solenoid valve assembly may by preference be located anywhere between the economizer **17** and the slow port running **19**, for example, at the second air bleed **13** (in which case the third air bleed may be dispensed with) or behind the slow running port **19** (with the third air bleed communicating directly with the port), whereby similar

performance and effect to those obtained in the construction arrangements of FIG. 4 will be attained.

The air shutoff valve 23 for the third air bleed 14 is so arranged in the above described embodiment of the invention as to be opened and closed by the cooperation of the solenoid valve assembly 22 and the diaphragm switch assembly 26. As an alternative, however, the air shutoff valve may be controlled more simply by such a valve member that is combined directly with a diaphragm member which is responsive to the fluctuations in the intake manifold vacuum.

An example of such construction arrangement is shown in FIG. 5, wherein a third slow running air bleed 14*a* is provided behind the slow port 19 and has movably inserted therein a poppet valve member 23*a* having a head directed toward the slow port 19. The poppet valve member 23*a* is connected at the end opposite to its head with a diaphragm member 27*a* which separates a diaphragm assembly 26*a* into suction at atmospheric chambers 28*a* and 29*a*. The suction chamber 28*a* communicates with the intake manifold (not shown) of the engine by way of the conduit 30 and has mounted therein a coil spring 33*a* normally biasing the diaphragm member 27*a* and accordingly the poppet valve member 23*a* toward the slow port 19 so that air introduced from the inlet 25*a* is fed to the slow port 19 by way of the third air bleed 14*a*.

During deceleration of the automobile, the intake vacuum decreases remarkably so that the diaphragm member 27*a* and accordingly the valve member 23*a* are forced away from the slow running port 29, namely, leftwardly of the drawing. The third air bleed 14*a* is thus closed by the head of the poppet valve member 23*a*, prohibiting air to enter the slow running port 19 from the inlet 25*a* . The result is that the amount of air-fuel mixture is decreased and consequently that the engine air-fuel mixture is enriched to attain an air-fuel ratio in a predetermined range.

The air-fuel ratio of the mixture may be adjusted to best suit deceleration of the automobile by properly determining the diameter of the third air bleed 14*a* when in designing the carburetor, while the total amount of air and fuel to debouch out of the idling port 20 may be regulated by adjusting the opening of the idle port in a usual manner through the manipulation of the idle port adjusting screw 21.

It is now apparent that the systems described in the foregoing are specially suited for controlling the amount of air to be admixed with the fuel so as to maintain the air-fuel ratio of the mixture at predetermined valves within predetermined ranges, for example, between 14 and 15 for the idling operation and between 12 and 13 for deceleration. The design concept of the two embodiments resides in that the desired curve (*a*) of FIG. 1 is approximately realized in a fixed range. It is, furthermore, more advantageous for minimizing the hydrocarbon content of engine exhaust gases to control the air-fuel ratio exactly in agreement with the curve (*a*), namely, to have air-fuel ratio reduced continuously as the automobile speed decreases, during deceleration. For this purpose, it is necessary that the amount of the air-fuel mixture introduced through the third air bleed be decreased continuously in proportion to the decrement of the automobile speed in such a manner as to follow exactly the characteristics of the curve (*a*) of FIG. 1.

In order to accomplish this purpose, as shown in FIG. 6, a frustoconical tip 36 is attached to the leading end of the straight valve member 23*b* combined with the diaphragm assembly 26*b*, while a projecting annular portion or constriction 43 is provided on the internal wall of the third air bleed 14*b*.

During the idle operation of the automobile when the intake manifold vacuum remains at a relatively low level, the diaphragm member 27*b* is held in its rightmost position as illustrated in the drawing by the action of the coil spring 33*b* mounted in the suction chamber 28*b* of the diaphragm assembly 26*b* so that the valve member 23*b* fixedly connected with the diaphragm member 27*b* is also held in its rightmost position on the drawing, thereby admitting air into the slow port 19 by way of the air bleed 14*b*.

During deceleration the intake manifold vacuum increases abruptly and the diaphragm member is accordingly forced away from the atmospheric chamber 29*b*, and the valve member 23*b* moves toward the suction chamber 28*b* against the action of the spring 33*b*. As the valve member 23*b* moves toward the chamber 28*b* and away from the idling port 19 through the constriction 43 due to the intake manifold vacuum, the air-fuel mixture introduced from the inlet 25*b* of the air bleed 14*b* is permitted to spurt into the idling port 19 with a maximum volume. Since, now, the amount of the air-fuel mixture flowing past the air bleed 14*b* varies in proportion to the change in the amount of the clearance between the frustoconical tip 36 and the constriction 43 in proportion to the decrease in the automobile speed, the air-fuel ratio of the engine air-fuel mixture may be relatively low during deceleration from high speed cruising to low speed cruising and may be so determined as to exactly agree to the characteristics of the curve (*a*) of FIG. 1 through the proper selection of the shape and dimensions of the valve head 36 of the valve member 23*b*. By preference furthermore, the inside diameter of the third air bleed 14*b* may be reduced gradually from the projecting portion 43 toward the outlet thereof so as to control the air-fuel mixture flow rate more accurately as the valve member 23*b* retracts.

It will be understood from the foregoing description of the preferred embodiments of the present invention that the air-fuel mixture to be drawn to the engine combustion chamber is enriched either continuously or to a predetermined value within a predetermined range so as to permit the mixture to be burnt under satisfactory conditions during deceleration.

Now, as previously noted, the intake manifold vacuum increases sharply during deceleration, say in excess of about 650mm. of Hg. while it remains of the order of 500mm. of Hg. during the idling operation. This is entirely due to the fact that the butterfly valve of the carburetor remains substantially closed during deceleration so as to shut off the flow of the air-fuel mixture in the main mixture supply flow path although the engine operation at a relatively high speed which is proportional 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 misfiring of the air-fuel mixture in the combustion chamber of the engine, thereby giving rise to an increase in the hydrocarbon content of the engine exhaust gases emitted during deceleration.

Such a trend in the hydrocarbon content is evident 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 to a low level independently of the intake manifold vacuum below approximately 530mm. 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 engine air-fuel mixture increased with the resultant reduction in the intake manifold vacuum during deceleration. Ideally, it will be the best approach to the reduction of the hydrocarbon content of the engine exhaust gases during deceleration to have the amount of the engine air-fuel mixture increased to such an extent as to lower the intake manifold vacuum to the vicinity of 530mm. of Hg. On account of the braking effect on 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 not considerably impaired. In this sense, the level to which the intake manifold vacuum should be reduced is generally considered to lie in the neighborhood of 600mm. of Hg. As illustrated by the curve (*c*) of FIG. 3, reducing the intake manifold vacuum to approximately 600mm. of Hg. is apparently conducive to the reduction of the hydrocarbon content of the engine exhaust gases.

Referring to FIG. 7 which illustrates a preferred example implementing such a concept, a combination diaphragm and valve assembly **26***c* is provided behind the third slow running air bleed **14***c* which debouches into the slow running port **19**. The combination diaphragm and valve assembly **26***c* accommodates in a slidable engagement therewith a cylindrical valve member **23***c* which is connected by a rod **39** with a diaphragm member **27***c*. The diaphragm member **27***c* and accordingly the valve member **23***c* are normally held in their leftmost positions, namely, in the direction opposite to the air bleed **14***c* by the action of the coil spring **33***c* which is mounted in the suction chamber **28***c* of the assembly **26***c*. The suction chamber **28***c* communicates, on the one hand, with the intake manifold (not shown) by way of a conduit **30** and, on the other, with a calibrated orifice **41** by way of a conduit **40**, said an orifice further communicating with a third port **42**.

While the automobile is under driving conditions, the liquid fuel supplied from the fuel supply passage **16** is first mixed at the slow jet **15** with air introduced from the first slow running air bleed **12** in a predetermined amount and mixture ratio, fed through the slow running economizer **17**, further mixed with air introduced from the second air bleed **13**, and debouches into the slow running port **19** through the passage **18**.

During the idling operation when the intake manifold vacuum is maintained at a relatively low level, say, in the neighborhood of 500mm. of Hg., the diaphragm **27***c* and the valve member **23***c* connected with the former rest at their leftmost positions, namely, at the limit positions remote from the third air bleed **14***c* by the action of the coil spring **33***c*, the valve member **23***c* being held in a closing engagement with the stopper **37** which serves as a valve seat. With the valve member **23***c* assuming such a position, air introduced from the inlet **25***c* is fed to the air bleed **14***c* by way of the air passage indicated by **44**, adding to the air content of the air-fuel mixture delivered from the passage **18**.

During the deceleration of the automobile, in contrast, the intake manifold vacuum rapidly increases to about 650mm. of Hg. or more and consequently the diaphragm member **27***c* and the valve member **23***c* are forced rightwardly in the drawing, namely toward the stopper **38** of the passage to the third air bleed **14***c*, closing the passage to the air bleed and opening the passage to the conduit **40**. The result is that air introduced from the inlet **25***c*, is, instead of being fed through the air bleed **14***c*, passed to the conduit **40** from which it is supplied to the third port **42** by way of the orifice **41**, reducing the vacuum downstream of the butterfly valve **10** and accordingly the intake manifold vacuum to a reasonable extent, preferably to about 600mm. of Hg.

The amount of air to be supplied to the third port **42** may be suitably adjusted by properly determining the diameter of an orifice **41**.

It will be understood that the combination diaphragm and valve assembly **26***c* utilized in the embodiment of FIG. **9** may be replaced with a suitable form of other control mechanism such as for example the solenoid valve assembly and the diaphragm switch assembly that are used in the first embodiment of the present invention.

As shown in FIG. **8**, the intake manifold vacuum is reduced by means of a solenoid valve assembly **22'** under the cooperation of a diaphragm switch assembly (which is constructed similarly to the diaphragm switch assembly **26** shown in FIG. **4** and, hence, is removed from FIG. **8**) incorporating a moving contact and a stationary contact electrically wired to the solenoid valve assembly in a manner similar to the counterpart used in the first embodiment.

During the idling operation of the automobile, the solenoid valve assembly **22'** is kept deenergized with the aid of the diaphragm switch assembly so that the valve member **23***d* is, by the action of the coil spring **24'**, held in closing engagement with the stopper **37'** of the passage to the conduit **40** which communicates with the orifice **41** and eventually with the third port **42**, whereupon air introduced from the inlet **25***d* is fed through the passage **44'** and the third air bleed **14***d* to the slow port **19**.

During the decelerating operation, on the other hand, the solenoid valve assembly **22'** becomes actuated by the action of the diaphragm switch assembly responsive to the increase in the intake manifold vacuum, and the valve member **23***d* is attracted toward the stopper **38'** of the passage to the third air bleed **14***d* against the spring action and opens the passage leading to the conduit **40**. It follows that air supplied from the inlet **25***d* is, instead of being fed to the air bleed **14***d*, drawn to the third port **42** by way of the orifice **41**. The amount of air to be spurted from the port **42** into the main mixture supply flow path of the carburetor downstream of the butterfly valve **10**.

In the last two modified embodiments of the invention, as is apparent from the foregoing description, the air-fuel mixture delivered from the passage **18** is supplied with additional air introduced from the third air bleed during idle operation, but, as soon as the automobile decelerates and the intake manifold vacuum increases rapidly (to 650mm. of Hg. or more), air delivered from the third air bleed is shut off to enrich the air-fuel mixture and concurrently the mixture thus enriched is supplied with additional air at a flow rate predetermined to attain an air-fuel ratio ranging from 12:1 to 13:1. Addition of air to the air-fuel mixture causes the intake manifold vacuum to be diminished to a predetermined level (600mm. of Hg., for example). Thus, both the air-fuel ratio of the mixture and the intake manifold vacuum can be controlled simultaneously by supplying the mixture with additional air in the main mixture supply flow path downstream of the butterfly valve, thereby satisfying the requirements dictated by the curves (*a*) and *c*) of FIGS. **1** and **3**, respectively.

According to a feature of the present invention, the hydrocarbon content of engine exhaust gases is diminished through the effective utilization of the abrupt decrease in the intake manifold vacuum of the engine without major constructional 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 combustion in the combustion chamber especially during the deceleration of the automobile.

According to another feature of the invention, the air-fuel ratio of the mixture during deceleration can be controlled independently of the other modes of the automobile operation so that it will permit reduction in the hydrocarbon content of engine exhaust gases produced under the idle, acceleration and normal cruising operations by keeping the air-fuel mixture lean solely during the idling operation.

If, furthermore, the system according to the invention forms part of 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 during idling, accelerating and normal cruising operation, 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 a few 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.

What we claim is:

1. In a carburetor for an automotive gasoline-powered internal combustion engine having a main mixture supply flow path to supply an air-fuel mixture to the engine under the control of a butterfly valve which is substantially fully closed during idling and deceleration and a slow running mixture supply flow path including a mixture passage leading from a fuel supply source and from at least two air bleeds for passing a controlled amount of air-fuel mixture therethrough, a slow running port communicating with said mixture passage and opening into said main mixture supply flow path at a position immediately upstream of the butterfly valve which is substantially fully closed, and an idling port communicating with said

slow running port and opening into said main mixture supply flow path downstream of said butterfly valve, a system for reducing the hydrocarbon content of the exhaust gases emitted from the engine during deceleration, said system comprising vacuum responsive means which is responsive to a vacuum higher than the vacuums obtaining in the intake manifold during idling, valve means which is positioned relative to one of said at least two air bleeds and which is normally held in a position to open said one of said at least two air bleeds, and air passing means having a conduit providing air communication between the atmosphere and the intake manifold, which air communication is normally blocked by said valve means, said valve means being actuated by said vacuum responsive means to close one of said at least two air bleeds and to concurrently provide said communication.

2. A system according to claim 1, wherein said vacuum responsive means includes a diaphragm assembly comprising atmospheric and suction chambers which are separated from each other by a diaphragm member, said atmospheric chamber being vented to the atmosphere and said suction chamber communicating with the intake manifold through said conduit, and a compression spring accommodated in said suction chamber and biasing said diaphragm member to overcome vacuums lower than said vacuums obtaining during idling.

3. A system according to claim 2, wherein said valve means is rigidly connected to said diaphragm member and directed toward said one of said at least two air bleeds.

4. A system according to claim 2, wherein said conduit further communicates with the atmosphere through an opening formed in a valve seat on which said valve means is normally seated by the action of said compression spring, said valve means being unseated from said valve seat when said valve means is moved with said diaphragm member to open said one of said at least two air bleeds when a vacuum higher than said vacuums obtaining during idling is exerted to the diaphragm member.

5. A system according to claim 2, wherein said valve means comprises a solenoid assembly including a moving core serving as a valve member, a solenoid coil surrounding said moving core and electrically connected to an electric power source and a compression spring normally forcing said valve member away from the position to close said one of said at least two air bleeds and wherein said diaphragm assembly further comprises switch means including moving and stationary contacts electrically connected to said solenoid coil through said power source, said moving contact being secured to said diaphragm member and normally held disconnected from said stationary contact by the action of the first-named spring when said diaphragm member overpowers said vacuums lower than the intake manifold vacuums obtaining during idling whereby said valve member is normally held in a position to open said one of said at least two air bleeds and wherein said diaphragm assembly further comprises switch means including moving and stationary contacts electrically connected to said solenoid coil through said power source, said moving contact being secured to said diaphragm member and normally held disconnected from said stationary contact by the action of the first-named spring when said diaphragm member overpowers said vacuums lower than the intake manifold vacuums obtaining during idling whereby said valve member is normally held in a position to open said one of said at least two air bleeds and, when said solenoid coil is energized in response to a vacuum higher than the vacuums at idle, is unseated and moved to a position in which said one of said at least two air bleeds is closed and said conduit is permitted to communicate with the atmosphere.

6. A system according to claim 5, wherein said conduit communicates with the atmosphere through an opening formed in a valve seat on which said valve member is normally seated by the action of the first-named compression spring, said valve member being unseated from said valve seat when said solenoid coil is energized to move said valve member to a position in which said one of said at least two air bleeds is closed thereby and said conduit is permitted to communicate with the atmosphere.