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2,616,405

ENRICHMENT DEVICE AND METHOD OF CONTROLLING THE SAME

Filed Nov. 20, 1948

4 Sheets-Sheet 1

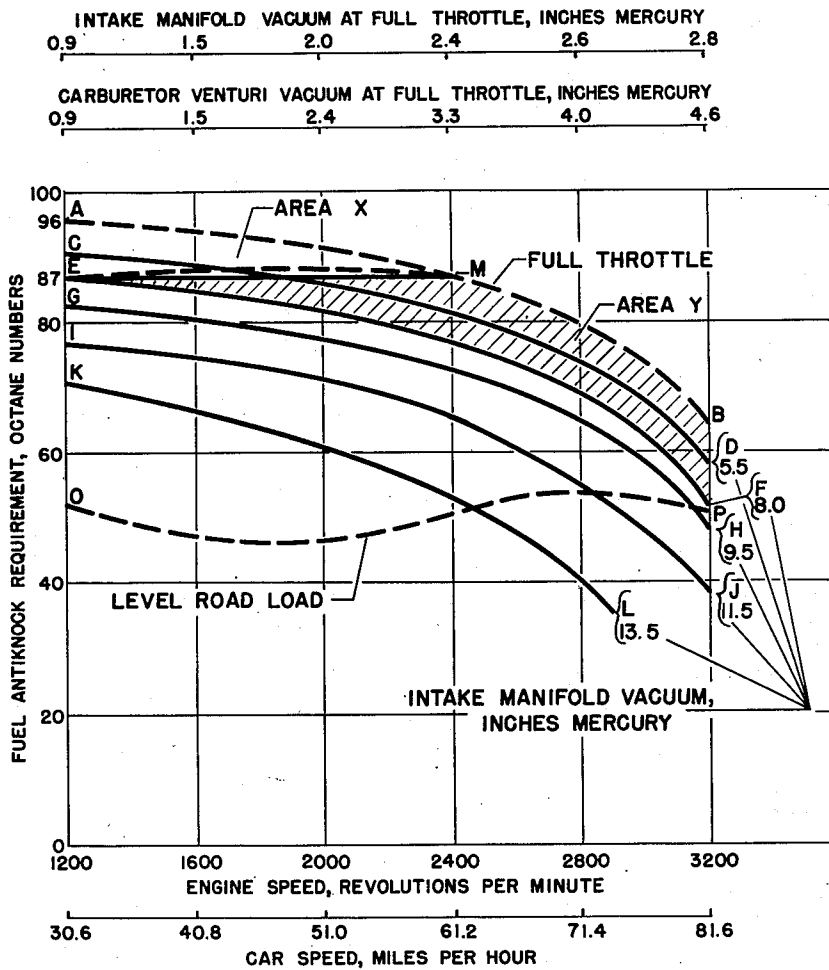


FIGURE 1

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4 Sheets-Sheet 2

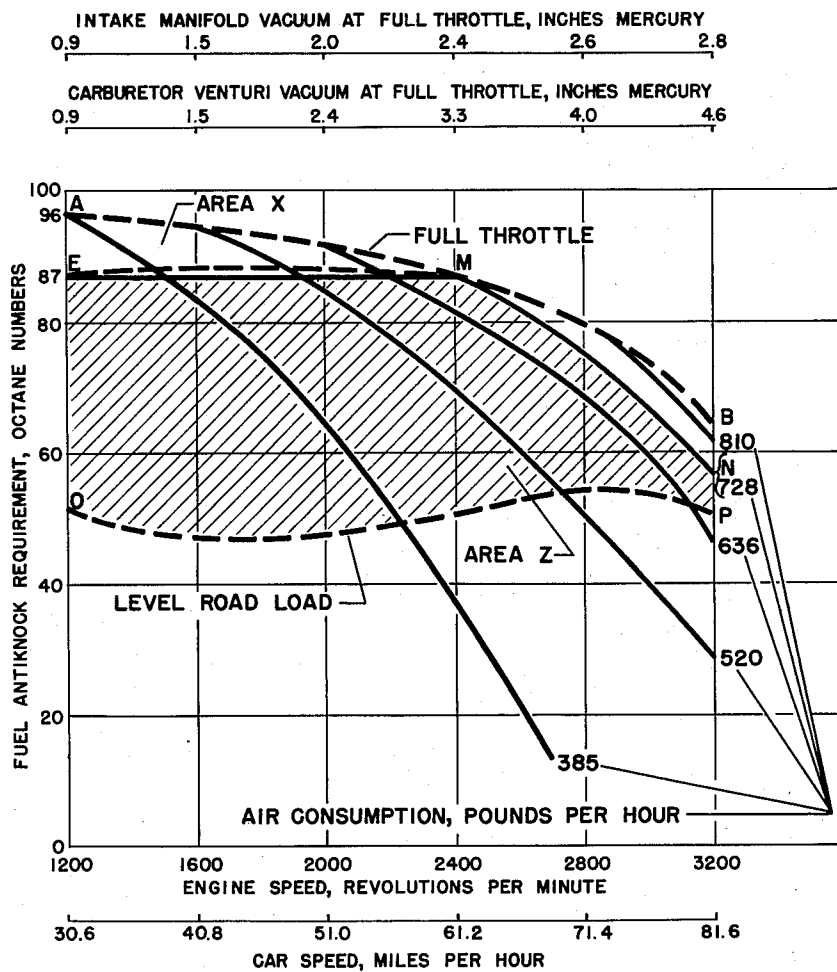


FIGURE 2

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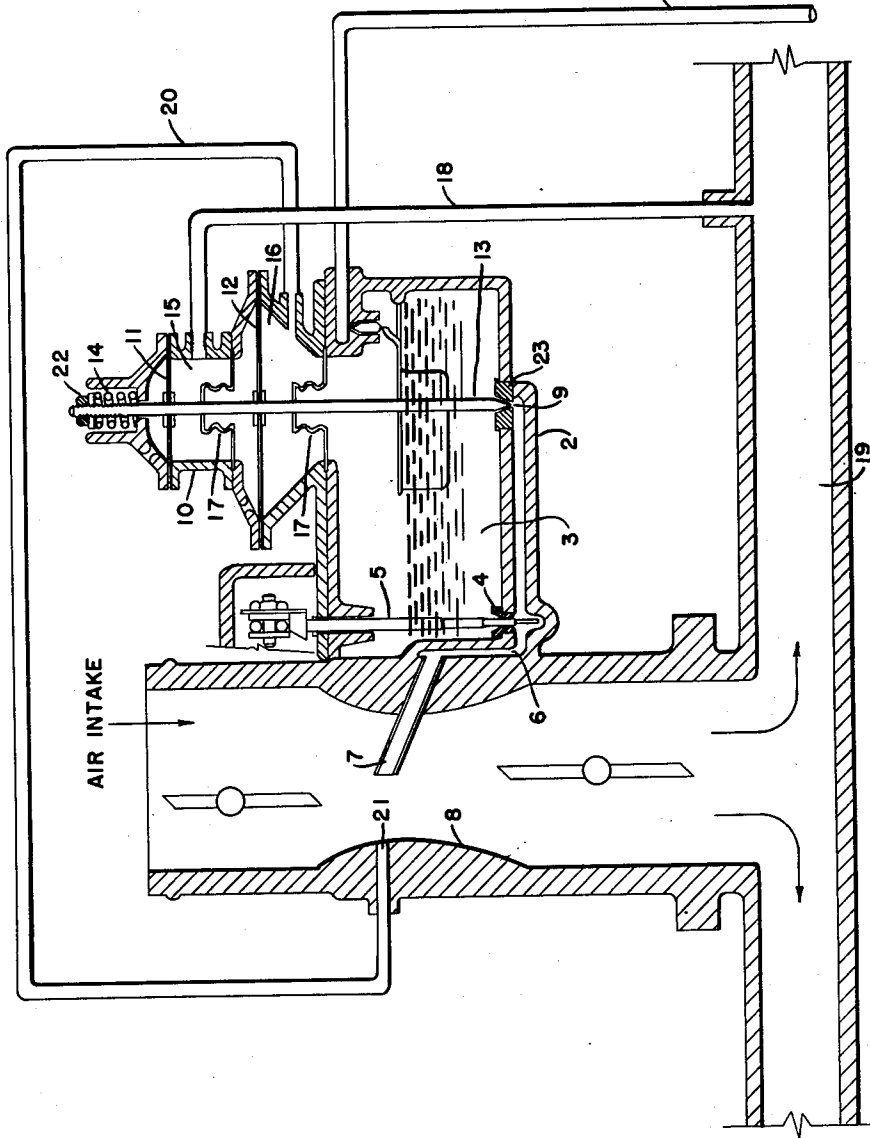
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FIGURE 3



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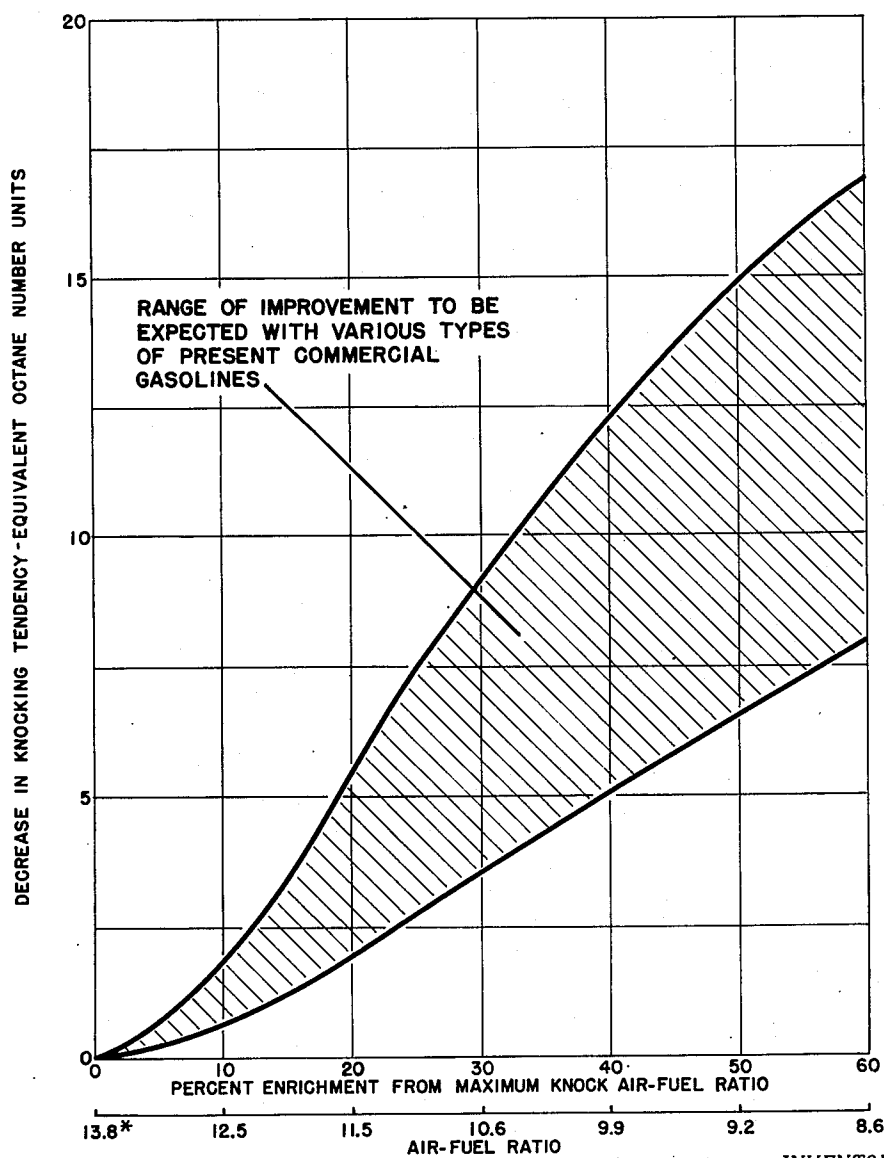
ENRICHMENT DEVICE AND METHOD OF CONTROLLING THE SAME

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4 Sheets-Sheet 4

FIGURE 4

DECREASE IN KNOCKING TENDENCY OF COMMERCIAL GASOLINES
DUE TO MIXTURE ENRICHMENT



* MAXIMUM KNOCK AIR-FUEL RATIO OF THE
AVERAGE COMMERCIAL GASOLINE

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UNITED STATES PATENT OFFICE

2,616,405

ENRICHMENT DEVICE AND METHOD OF
CONTROLLING THE SAME

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4 Claims. (Cl. 123—127)

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My invention relates to methods and apparatus for regulating the enrichment of the fuel-air mixture over that normally fed to an internal combustion engine so that knocking is reduced over the range of engine operation while at the same time the consumption of fuel is minimized.

This is accomplished by controlling such enrichment of the mixture jointly in accordance with variation in the intake manifold vacuum of the engine, and its rate of air-consumption.

My invention can be best understood, by referring to the drawings in which;

Figure 1 is a plot of fuel antiknock requirement of a typical high compression engine with automatic transmission over the speed range from 1200 to 3200 revolutions per minute, corresponding to vehicle speeds of approximately 30.6 to 81.6 miles per hour on a level road, at full throttle and for various conditions of constant intake-manifold vacuum.

Figure 2 is a plot similar to Figure 1 except that curves of constant air-consumption have been superimposed and the curves of constant intake manifold have been omitted for the sake of clarity.

Figure 3 is a schematic drawing partially in cross-section, illustrating parts of a conventional carburetor plus a device for controlling an enriching supply of the gasoline from the fuel tank of the vehicle.

Figure 4 is a plot showing the range of decrease in knocking tendency in the octane rating of commercial gasoline resulting from the use of mixture ratios richer in fuel than that for maximum knock.

In the normal operation of passenger car, truck and bus engines, knocking occurs during only a small fraction of the total operating time, and hence during the consumption of only a small fraction of the total gasoline used. The fuel antiknock requirement of such engines usually increases as the manifold vacuum decreases until it reaches a maximum at full throttle conditions. In addition the octane requirement of the engine decreases as engine speed increases, for full throttle operation and for conditions of constant intake manifold vacuum, as can be best understood by referring to Figure 1, in which curve A, M, B, represents the octane number requirement at full throttle over a range of engine speeds for a particular engine. Curves CD, EF, GH, IJ and KL represent the fuel octane number requirement over the speed range at constant manifold vacuums of 5.5, 8.0, 9.5, 11.5 and 13.5 inches of mercury, respectively. The

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term vacuum as used herein is defined as the differential in pressure between atmospheric and that at the point of measurement. The broken line OP shows the octane number requirement for level road operation over a range of constant engine and corresponding constant vehicle speeds. The data represented in Figure 1 were obtained on a car having an automatic transmission which operates in a lower gear at road speeds below about 30 miles per hour with resulting increase in engine speed. Therefore the chart does not extend below a road speed of 30.6 miles per hour or an engine speed of 1200 revolutions per minute. For cars having a conventional change-gear transmission, the proportional scales of engine and car speed in high gear would be extended to the left, as would curves AMB, CD, EF, GH, IJ and KL.

It is observed that this engine would require a 96 octane number fuel to give completely knock-free operation over the included speed range and yet this peak requirement occurs only at full throttle and at an engine speed of 1200 revolutions per minute. Thus there would be considerable excess of fuel antiknock quality when using this fuel at other operating conditions. If the engine were supplied with an 87 octane number fuel, the engine would knock at all combinations of speed and manifold pressure above those represented by the 87 octane number line, which is the solid straight line connecting points E and M. Under all other conditions this engine would give knock-free operation on this fuel.

Present day automobile engines generally operate with full throttle maximum power air-fuel ratios of from 12.8 to 13.5:1. These are overall air-fuel ratios and the air-fuel ratio of the mixture being supplied to the individual cylinders may vary considerably from these values. The maximum knocking tendency of commercial gasoline generally occurs between 13.5 to 14.5:1 air-fuel ratio. Hence when knocking occurs, the leanest cylinders usually are the ones responsible, other factors being equal.

As the mixture is made progressively richer than the maximum knock air-fuel ratio, the knocking tendency of the mixture decreases quite rapidly. This effect of rich air-fuel ratios on decreasing the knocking tendencies of fuels has been widely used for controlling knocking in aircraft engines during maximum power output conditions.

Figure 4 shows the approximate range of the decrease in knocking tendency of present commercial motor gasolines resulting from the use

of mixture ratios richer in fuel than that for maximum knock. Because hydrocarbons vary considerably in their response to enrichment, there is a fairly wide band in which the commercial gasolines fall. For instance, with 40% enrichment from the maximum knock air-fuel ratio, from 5 to 12 octane number improvement may be expected, depending on the hydrocarbon composition of the fuel.

The octane number level of the tank fuel affects the actual amount of reduction in knocking tendency, due to enrichment. From the standpoint of engine operation approximately twice as much potential power is available from one octane number increase in the 90 to 100 range than in the 70 to 80 octane number range. Because of this difference in size of octane numbers, the lower the octane number of the tank fuel the more octane number improvement can be expected, other factors being equal, for a given amount of mixture enrichment. However, the few octane numbers obtainable at the higher level are just as valuable as the larger improvement in octane units at the lower level.

In present day engines, mixture enrichment of between 10 to 40% usually may be made at low speeds without adverse effects from the standpoint of engine performance. At higher engine speeds substantial enrichment does result in a loss in engine power. My device, however, limits the enrichment to a low speed range of operation where it is required for control of knocking and therefore avoids loss of power due to enrichment at the higher speeds.

Thus mixture enrichment alone, can be used to meet at least a part of the peak fuel antiknock requirement of the engine which occurs at or near open throttle and at the low engine speeds. Such enrichment enables the use of a tank gasoline having a lower octane number than the peak requirement of the engine. However, with the usual commercial gasoline, enrichment for octane requirement of the engine is not needed at the higher speeds or at engine conditions represented by area Y of Figure 1 or area Z of Figure 2. Any enrichment under conditions of operation represented by these areas is wasted.

It is, therefore, an object of this invention to provide a method of mixture enrichment with varying engine conditions in which enrichment is reduced or stopped as the speed of the engine is increased, thus minimizing the amount of fuel used and yet satisfying at least a portion of the antiknock requirements of the engine. In other words my object is to avoid mixture enrichment under conditions represented by area Y of Figure 1 and area Z of Figure 2 and to employ enrichment only under conditions represented by area X of these figures. A further object of my invention is to meet at least partially the antiknock requirement of the engine at low speed while substantially avoiding loss of power associated with enrichment at the higher speeds.

I accomplish these objects in the following manner: My device for controlling enrichment in accordance with varying engine conditions is actuated jointly by the manifold vacuum and by the vacuum in a venturi, which may be the conventional carburetor venturi, located ahead of the throttle. The vacuum in the venturi is directly related to the rate of air-consumption. As the flow of air becomes greater with increase in engine speed or throttle opening, the vacuum in the venturi increases, tending first to reduce and then to stop the flow of enriching fuel.

Control of the enriching device by manifold vacuum alone will not accomplish the objects of my invention. For instance if the engine whose octane requirement data are shown in Figure 1 is supplied with an 87 octane number tank gasoline the fuel will just meet the requirement of the engine at 8 inches of mercury manifold vacuum at an engine speed of 1200 revolutions per minute (point E). Enrichment then will occur at all manifold vacuum less than 8.0 inches of mercury. Thus if the enrichment is controlled by manifold vacuum alone such a device will supply the additional fuel over the entire speed range under all conditions represented by the area above the line EF, i. e. area X (defined by points A, M, E) and shaded area Y (defined by points E, M, B, F, E), whereas knock suppressing, and hence enrichment, are required only under conditions represented by area X.

Likewise the control of enriching fuel solely by change of vacuum in the venturi as the rate of air-consumption changes does not accomplish the objects of my invention. To illustrate, reference is made to Figure 2 which is similar to Figure 1 except that curves of constant vacuum are omitted for sake of clarity, and curves of constant rates of air consumption are superimposed, indicated by the quantities 385, 520, 636, 728, and 810 which express pounds per hour.

If the enriching valve were controlled by Venturi vacuum alone and it were desired to operate this engine on a tank fuel having 87 octane number, the enriching valve would be adjusted to close at a Venturi vacuum of approximately 3.3 inches of mercury corresponding to an air flow of 728 pounds per hour, i. e. the air consumption at full throttle at 2400 revolutions per minute (point M). At higher speeds, the full throttle octane number requirement is less than 87. By this control alone, injection would occur on a level road under all constant speed engine conditions represented by area X (previously defined) and area Z (defined by E, M, N, P, O), i. e. all the area above the level road line OP. Areas below line OP represent conditions of operation where in the vehicle is either decelerating or descending a grade. With this method of control, flow of enriching fuel would also occur under the latter conditions, represented by the area extending below line OP.

Thus it is seen that neither control alone is sufficient to provide at least a portion of the antiknock requirements of the engine without waste of antiknock quality, fuel or both. However, when the enriching valve is under the joint control of the manifold vacuum and the Venturi vacuum as shown in Figure 3 and subsequently described herein, the areas of the two diaphragms subjected to these two vacuums can be proportioned so as to provide complete cutoff along the broken line connecting points E and M in Figures 1 and 2. Enriching, then, occurs only under engine conditions represented by the area above this line where the additional antiknock quality is required. Also by the joint control, modulation of flow is provided so that the amount of enrichment is approximately proportioned to the variations in knocking which would occur with the primary fuel alone as conditions of engine operation are changed.

The engine whose octane requirement relationships are shown in Figures 1 and 2 can be substantially satisfied antiknockwise by the use of an 87 octane number tank fuel in conjunction with enrichment. However with tank fuels hav-

ing octane number ratings substantially lower than 87, enrichment alone would not be an entirely satisfactory means of completely meeting the antiknock requirements at the lower speeds. However enrichment alone will satisfy at least a portion of the antiknock requirements at the lower speeds. Whether enrichment alone meets the antiknock requirement depends on the peak octane requirement of the engine, and on the octane number and hydrocarbon composition of the tank fuel. Whether or not the antiknock requirements are completely met by enrichment alone, my invention is advantageous because it prevents enrichment where it is not needed. i. e., my invention eliminates enrichment for engine conditions represented by area Y in Figure 1 and area Z in Figure 2. This result cannot be obtained through control of enrichment by either manifold vacuum or means related to air consumption alone.

Referring to Figure 3, a device is illustrated for controlling the enriching supply of fuel jointly by intake manifold vacuum and carburetor Venturi vacuum. While Figure 3 illustrates an embodiment of my invention in which the control device is incorporated with the carburetor, it is to be understood that my control device could be an entirely separate unit. Fuel line 1 is connected to a special carburetor 2 and a conventional pump and fuel supply (not shown). Fuel fed to the carburetor is referred to herein as the tank fuel. In general it is a commercial fuel composed in whole or in part of hydrocarbons and in most cases containing an antiknock agent such as tetraethyl lead. However it may contain other antiknock agents or other fuels such as alcohols.

The tank fuel flows into float chamber 3 and then through a conventional carburetor jet 4 wherein the flow is controlled by a conventional metering rod 5 whose movement is integrated with throttle opening. The fuel then flows through passageway 6 to fuel tube 7 which is located in the carburetor venturi 8. The equipment described so far is merely one type of design intended to give conventional air-fuel ratios used in motor car operation. These full throttle air-fuel ratios are generally in the neighborhood of from 12.8 to 13.5 to 1. In addition to the conventional carburetion controls, float chamber 3 contains an enriching control valve 9 which provides another avenue for fuel to flow into passageway 6 and into the carburetor venturi 8 thereby enriching the fuel-air mixture supplied to the engine. The amount of enrichment beyond the standard air-fuel ratio depends on the quantity of fuel flowing through valve 9. Valve 9 is controlled by the regulating valve mechanism 10. The regulating valve mechanisms 10 comprises two vacuum-actuated elements such as diaphragms 11 and 12 which are operatively connected to stem 13 of enriching valve 9. Spring 14 holds valve 9 normally in an open position allowing additional fuel to flow into passageway 6 thereby providing a rich air-fuel mixture to the engine. Leakage from chambers 15 and 16 is prevented by bellows type seals 17 attached to the valve stem 13. Chamber 15 connects through line 18 to the intake manifold 19, and chamber 16 through line 20 and passageway 21 to the carburetor venturi 8. Thus means are provided for actuating diaphragms 11 and 12 by vacuums in the intake manifold and the venturi, and for applying this action to the valve stem. An increase in manifold vacuum due either to a decreased throttle opening or an in-

crease in engine speed, or an increase in Venturi vacuum due to increase in rate of air flow through the venturi will tend to close valve 9. At all times the total force acting on the valve stem is the sum of the forces produced by the two diaphragms. The enriching valve and the control diaphragms can be so designed that the rate of reduction of flow of enriching fuel will follow any desired pattern of speed and manifold vacuum for a given engine and thus permit operation on a tank fuel having any reasonable selected octane number. By proper proportioning of diaphragms 11 and 12 and adjustment of the tension on spring 14 by nut 22, the cut-off pattern illustrated in Figures 1 and 2 can be obtained.

The net effective areas of the two diaphragms required to close the valve under either of the combinations of intake manifold and carburetor Venturi vacuums, corresponding to points E and M of Figures 1 and 2, is easily calculated by solving two simultaneous equations. One equation can be set up for the closing force on the valve at point E. This closing force is equal to the sum of the intake manifold vacuum and carburetor Venturi vacuum at point E multiplied by the net effective area of each of their respective diaphragms 11 and 12. A similar equation can be set up for the closing force on the valve at point M. These two closing forces are equal hence the two equations can be solved for the relative areas of the two diaphragms. The actual areas of diaphragms 11 and 12, in the calculated ratio, should be just sufficient for their combined forces to compress the chosen spring 14 and close valve 9 under conditions corresponding to points E and M. Usually it is desirable to have the diaphragms small for convenience. At the other speeds and throttle openings between points E and M, the combined effect of diaphragms 12 and 13 results in the closure of the injection valve substantially in accordance with the broken line EM of Figures 1 and 2.

Once the areas of the two diaphragms are proportioned for a given engine and for a tank fuel of a given octane number, approximate adjustments for use with a different octane number tank fuel within a reasonable range can be made by nut 22. The size of the opening in valve seat 23 is so selected that when valve 9 is wide open, a sufficient amount of additional fuel will flow to prevent knocking at low speed and wide-open throttle. The relative amount of additional fuel required will depend on the octane number requirement of the engine and the octane number and hydrocarbon composition of the tank fuel, and is usually from 10 to 40 per cent of that which flows simultaneously through the regular carburetor metering system. For over-the-road operation the additional amount of fuel required due to enrichment generally is from 1 to 15% of the total fuel consumed.

During the start of acceleration from low speed with an automatic transmission, or in high gear with a conventional change-gear transmission, the engine is usually operated at full throttle by the average driver of the vehicle. If the driver continues acceleration at full throttle, as he frequently does, the vacuum in the carburetor venturi increases with the increase in engine speed, causing diaphragm 12 to move the enriching fuel valve toward the closed position. When a speed and Venturi pressure corresponding to point M of Figures 1 and 2 have been reached, the valve

closes completely. At higher speeds no enrichment occurs.

With a conventional change-gear transmission, acceleration in first or second gears is often done at part throttle, as may also be done with an automatic transmission. In this event enrichment is cut off under conditions represented by broken line EM. Thus the use of my invention generally results in a large saving of enrichment fuel during acceleration.

All vehicles operate a part of the time under engine conditions represented by area X of Figures 1 and 2 and would therefore receive the benefit of modulated enrichment provided by my device. All vehicles also operate a part of the time, and some, such as trucks and busses, the greater part of the time under conditions represented by area Y of Figure 1 and area Z of Figure 2, under which conditions no enrichment occurs during the use of my device. Thus under any condition of engine operation the use of my invention limits the consumption of additional fuel to a minimum necessary and thereby effects large savings over a device controlled either by manifold vacuum or carburetor Venturi vacuum alone.

Other modifications of my invention are possible within the scope of the following claims:

I claim:

1. A method for improving the performance of an internal combustion engine having an air intake manifold and an air intake venturi separated from each other by a throttle valve, said method comprising supplementing the amount of fuel normally supplied to the said engine essentially only while the operating conditions thereof are such as to cause knocking, by controlling the supply of fuel in accordance with the combined effect of changes in both the Venturi vacuum and the air intake manifold vacuum, increasing the supplemental supply whenever the air consumption rate decreases and whenever the manifold vacuum decreases, and decreasing the supply whenever the air consumption rate increases and whenever the manifold vacuum increases.

2. A device for enriching the fuel-air mixture supplied to an internal combustion engine that has an intake manifold and a carburetor with a venturi and a throttle valve connected to control the delivery of fuel to the engine by controlling the flow through the venturi and into the intake manifold, said device comprising supplemental fuel supply structure, regulating means having two control elements for separate connection to respond respectively to the intake manifold vacuum and to the Venturi vacuum, each of said elements being connected to the supplemental fuel supply structure to separately open the supplemental fuel supply in response to decreases in its actuating vacuum, and to separately close the supplemental fuel supply in response to increases in its actuating vacuum, the control elements being permanently interconnected with each other as well as to the supplemental fuel supply structure for increasing the supplemental supply in response to the additive effects of any decrease

in manifold vacuum and any decrease in air consumption rate, and for decreasing the supplemental supply in response to the additive effects of any increase in manifold vacuum and any increase in air consumption to limit the supplemental fuel supply substantially to those operating conditions in which there would be a tendency for knocking to occur.

3. A device for enriching the fuel-air mixture supplied to an internal combustion engine comprising in combination a carburetor with a primary valve for supplying the normal amount of fuel to the engine, and a dual actuated auxiliary valve for supplying additional amounts of the same fuel to said engine, said auxiliary valve being controlled by two diaphragms, one of which is connected to fully respond to any change in the vacuum in the carburetor venturi and the other of which is connected to fully respond to any change in the vacuum in the air-fuel intake manifold, each of said diaphragms being connected to the auxiliary valve to separately open this valve in response to decreases in the diaphragm-actuating vacuum and close this valve in response to increases in the diaphragm-actuating vacuum, said diaphragms being permanently linked to each other as well as to said auxiliary valve to move the auxiliary valve toward closed condition with any increase in the vacuum to which it responds, and to move said auxiliary valve toward open condition with any decrease in the vacuum to which it responds, the responses of the individual diaphragms being adjusted for limiting the opening of the auxiliary valve to substantially those operating conditions in which there would be a tendency for knocking to occur.

4. A method for improving the performance of an internal combustion engine having an air supply, a fuel supply, and an air-intake manifold and supplied with a mixture of fuel and air for combustion, said method comprising varying the fuel-air ratio when said engine would knock at the normal fuel-air ratio, by adding supplemental fuel in accordance with the joint and additive effect of any change in the amount of air supplied to the engine and any change in the vacuum in the air intake manifold, increasing the fuel-air ratio as said combined effect increases, and decreasing the fuel-air ratio as said combined effect decreases.

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