

June 1, 1954

R. H. THORNER
CARBURETOR

2,679,835

Filed June 28, 1949

3 Sheets-Sheet 1

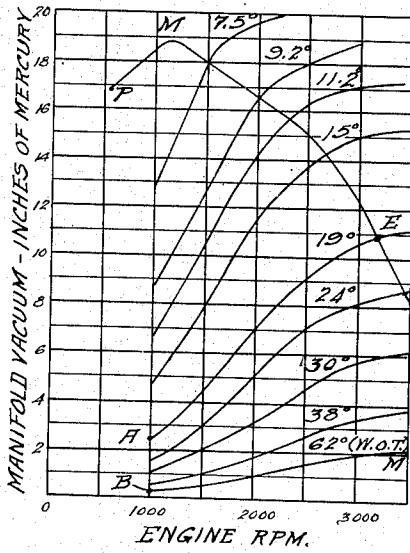


FIG. 2.

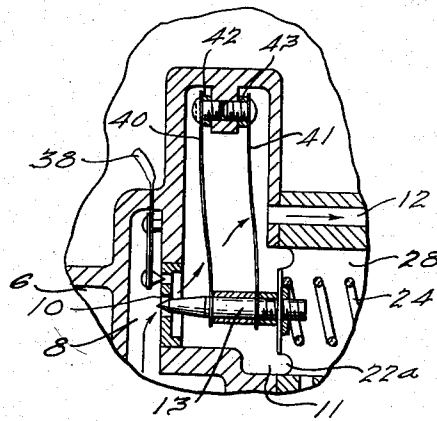


FIG. 4.

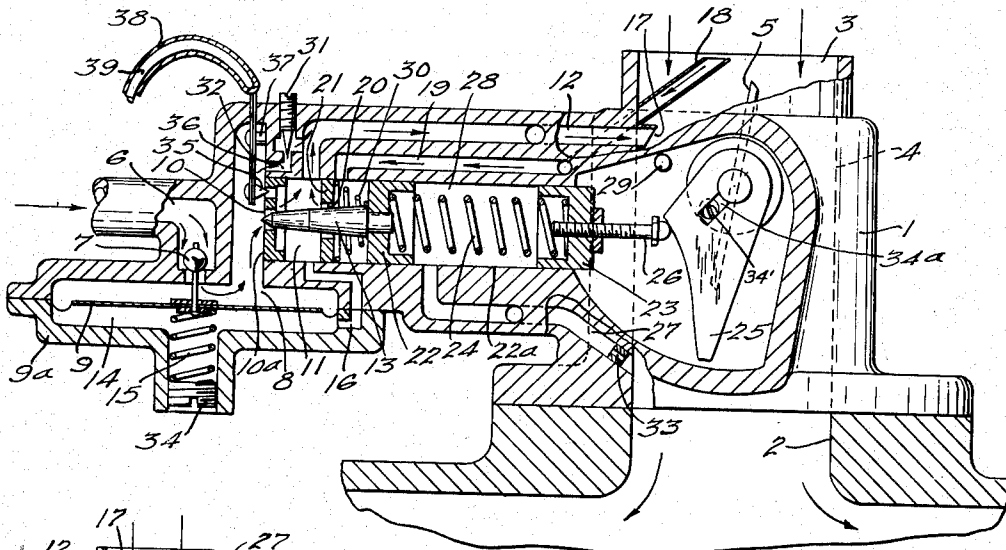


FIG. 1.

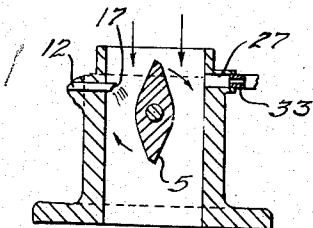


FIG. 3.

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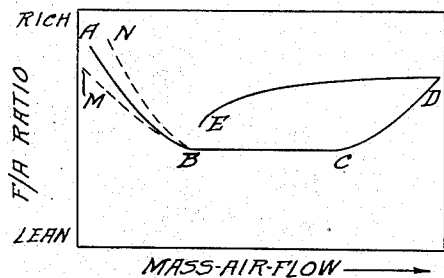


FIG. 5.

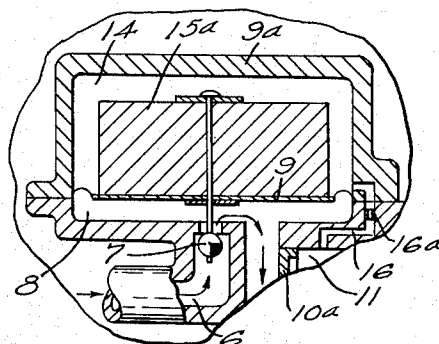


FIG. 8.

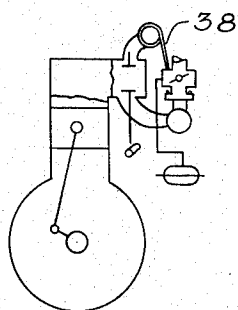


FIG. 12.

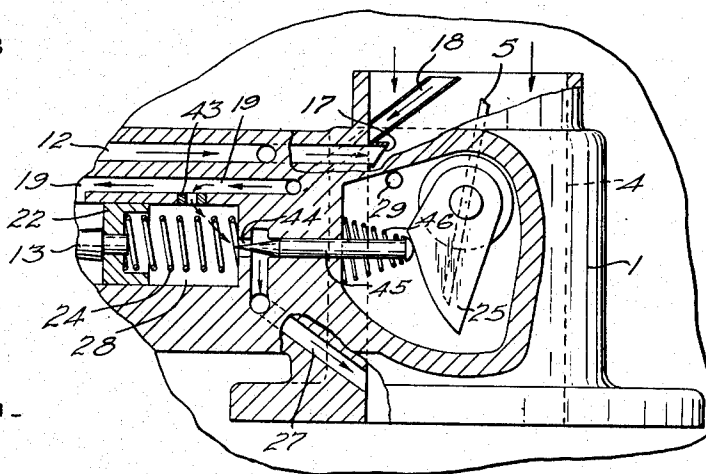


FIG. 6.

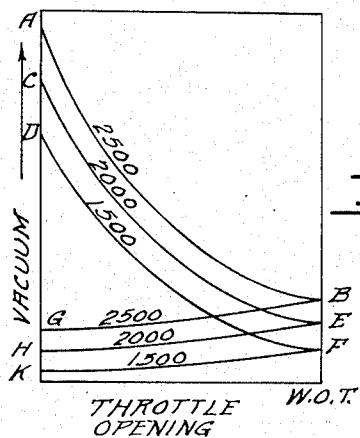


FIG. 7.

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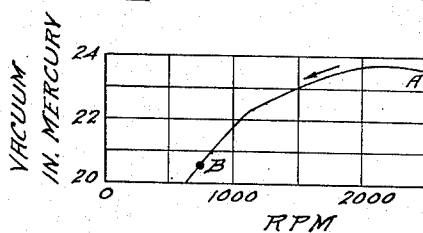
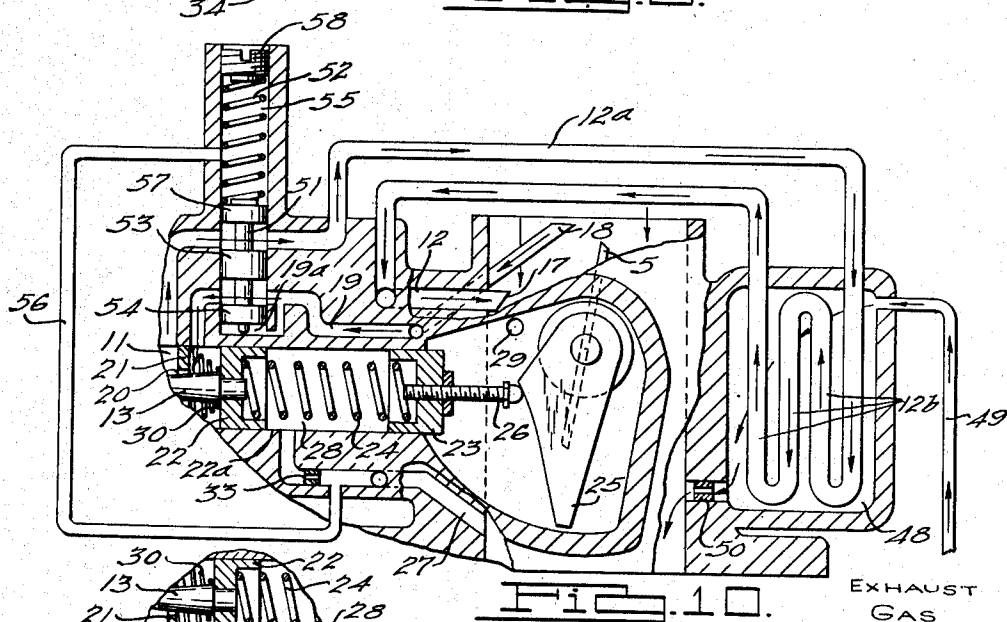
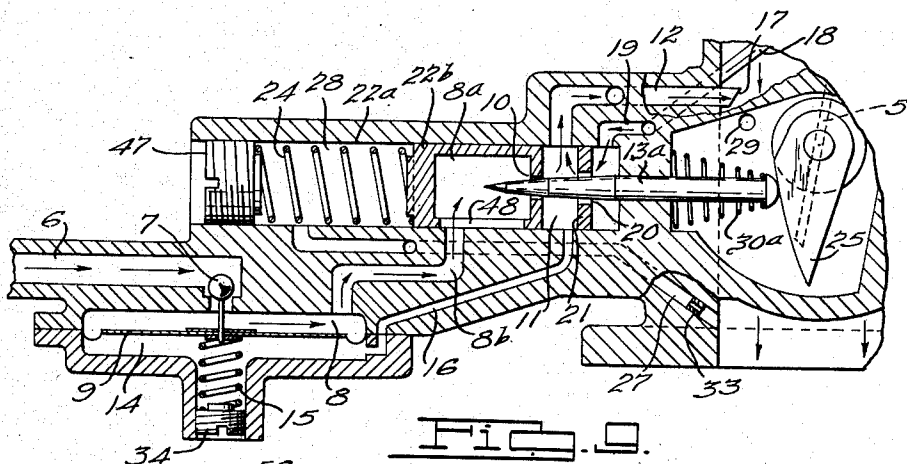


Fig. 11

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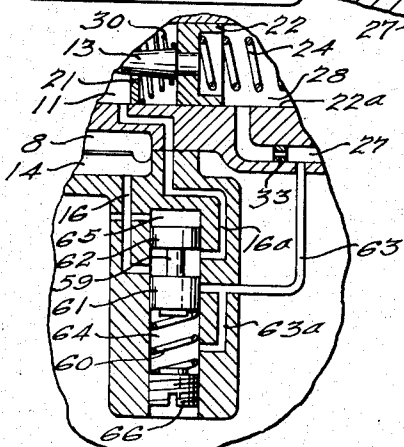


Fig. 12.

UNITED STATES PATENT OFFICE

2,679,835

CARBURETOR

Robert H. Thorner, Detroit, Mich.

Application June 28, 1949, Serial No. 101,827

32 Claims. (Cl. 123—122)

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The present invention relates to carburetors for industrial, automotive, and aircraft internal combustion engines. Present automotive carburetors include an air venturi to measure the air flow, a choke valve to enrich the mixtures when starting, a float regulator to regulate the fuel level, a separate idle system to enrich and regulate the mixtures at lower powers, a separate economizer system to enrich the mixtures at higher powers, and a separate accelerating pump to maintain the mixtures during acceleration. An object of the present invention is to provide a carburetor for an internal combustion engine in which the foregoing elements inherently are not required wherein the cost, size, and complexity of my carburetor are substantially less than that of present carburetors.

Another object of my invention is to provide a carburetor that facilitates a substantial improvement in the vaporization of the fuel wherein smoother engine operation is obtained with greatly improved fuel economy.

Also, an object of my invention is to provide a carburetor combination incorporating novel and improved means for measuring air flow.

A further object of the present invention is to provide a carburetor for internal combustion engines of the gasoline type, said carburetor including main metering system regulating the flow of liquid fuel in accordance with the horse power developed by the engine or with the mass-air-flow in the intake conduit of the engine, whereby a proper mixture is supplied to the engine by said metering system under all practical speed and load conditions of engine operation.

A still further object of the present invention is to provide an improved carburetor of the type specified in the preceding paragraph, said carburetor having means whereby the predetermined fuel-to-air ratio of the fuel mixture supplied to the engine by the metering system may be selectively adjusted to compensate for production variations in the engine and carburetor parts, as well as to take care of special operation conditions.

A still further object of the present invention is to provide a carburetor for gasoline engine, which carburetor is adapted to supply to the engine fuel mixture of a predetermined fuel-to-air ratio throughout the entire range of engine speeds and which does not create at low engine speeds conditions requiring a provision of an idling system constituting, in effect, a separate complicated device added to the metering system.

A still further object of the present invention

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is to provide a carburetor for gasoline engine, adapted to supply to the engine fuel mixture of a predetermined fuel-to-air ratio throughout the entire range of engine speeds, the construction of the carburetor being such that the provision of "acceleration system" therein can be accomplished in an exceedingly simple manner and without addition of such multiplicity of parts as is required for this purpose in conventional carburetors.

Another object of my invention is to provide a carburetor combination that provides better control of the mixtures because the pressure differential across the metering orifice is accurately regulated regardless of the quantitative value of the individual pressures at the entrance or discharge side of the main metering orifice.

A further object of the present invention is to provide an improved carburetor for gasoline engines, in which carburetor the Venturi tube, which constitutes an important element of conventional carburetors, is eliminated, thereby decreasing the height of the carburetor and of the engine, the latter consideration being of critical importance in many engine installations.

A still further object of the present invention is to provide an improved carburetor for gasoline engines, said carburetor having improved means effecting desired degree of evaporation of gasoline prior to its entry into the engine manifold, including virtually complete evaporation, thereby preventing the liquid gasoline particles from being thrown outwardly by the operation of the centrifugal force when flowing through the curved portions of the engine manifold, and carrying excessive amounts of liquid gasoline into some of the cylinders of the engine while leaving insufficient amount of gasoline in the mixture flowing to other cylinders. Such uneven distribution of gasoline in the fuel mixture is particularly serious when the engine is relatively cold, and it totally disorganizes the intended ratio of fuel-to-air in the mixture, producing rough and uneconomical operation of the engine in spite of the presumably correct amounts of fuel and air in the mixture as measured by the carburetor.

A further object of my invention is to provide a carburetor in which the mixtures are leaned during engine deceleration when the throttle is closed suddenly; in this form of my invention, a novel "de-gasser" valve is incorporated to shut off the fuel flow completely when the throttle is closed at engine speeds above the idle R. P. M. during the deceleration period.

Still another object of my invention is to pro-

vide a carburetor combination that includes a novel primer valve that facilitates smooth engine operation immediately after the engine is started, even in cold weather.

These and other objects, which will appear more clearly as the specification proceeds, are accomplished, according to the present invention, by the arrangement and combination of elements set forth in the following detailed description, defined in the appended claims and illustratively exemplified in the accompanying drawings, in which:

Figure 1 is a semi-schematic view, partly in section and partly in elevation, showing one form of my carburetor operatively related to the intake manifold, and which uses the manifold suction as the air measuring force,

Fig. 2 is a chart showing the actual variation of manifold vacuum versus engine speed at various fixed throttle positions,

Fig. 3 is a schematic diagram of a slightly different form of components of my invention wherein the throttle and the fuel discharge passage have different forms,

Fig. 4 is a semi-schematic diagram of another form of components of my invention,

Fig. 5 is a chart showing the shape of the desired mixture ratio curves for automotive operation,

Fig. 6 is a diagrammatic representation of still another form of my invention wherein the air measuring element has a different form,

Fig. 7 is a chart showing the manifold vacuum and the air measuring vacuum in the form of my invention illustrated in Fig. 6 related to throttle position,

Fig. 8 is a schematic illustration of a different form of the pressure regulator in my carburetor,

Fig. 9 shows a diagrammatic view of another form of the air measuring element in my carburetor,

Fig. 10 is a diagrammatic representation of still another form of my carburetor wherein a heat-exchanger and a "de-gasser" valve are incorporated in the discharge passages,

Fig. 11 is a chart showing the typical variation of manifold vacuum versus R. P. M. with the throttle in the idle position,

Fig. 12 is a schematic illustration of another form of "de-gasser" valve that may be employed in combination with my carburetor,

Fig. 13 is a view of my carburetor mounted on an internal combustion engine.

It is to be understood that the invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being practiced or carried out in various ways. Also it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

Automotive and aircraft carburetors usually require at least four systems to satisfy the requirements of a gasoline engine under all operating conditions. These systems are:

1. *Main metering system.*—This system measures the basic fuel flow and discharges the fuel to the engine in a well atomized form. This system normally includes the venturi for measuring the air, the main metering jet, the float-type regulator for regulating the pressure at the jet, and the discharge nozzle.

2. *Idle system.*—This system provides means to

regulate manually the mixtures in the idle power range to compensate for manufacturing variations of the carburetor-engine combination, and it provides the correct mixtures in the idle range where the venturi forces are low.

3. *The acceleration system.*—This system supplies extra fuel during acceleration to prevent lean mixtures during this period.

4. *The power enrichment system.*—This system which is also known as the "economizer," provides additional fuel during high power operation to obtain the best power mixtures, and also to prevent detonation in aircraft installations.

5. *Mixture control system.*—This system is always used with aircraft engines, and occasionally with automotive engines. It provides manual means to vary the mixtures evenly throughout the operating range with a single adjustment. In aircraft carburetors, the mixture control system frequently is partially or wholly automatic to prevent the mixtures from enriching at higher altitudes.

The requirements of carburetors and the systems briefly described above are discussed more extensively in my book, "Aircraft Carburetion," published in 1946 by John Wiley & Sons, New York, and particularly on pages 42-135.

In accordance with the invention I provide a carburetor for internal combustion engines, particularly gasoline engines, in which carburetor the use of Venturi conduit as an air metering and fuel drawing means is entirely eliminated, thereby eliminating among other disadvantages of the venturi the discrepancy between the fuel-drawing performance thereof and the requirements of the engine at the low and at high speeds of the engine. I provide a "metering system" in which the flow of fuel is controlled not by the Venturi vacuum but, in effect, by the manifold vacuum compensated for its changes caused by load variations. I attain such a control by providing a fuel metering orifice having means maintaining a constant pressure differential (difference) between the high pressure side and the low pressure side of said metering orifice, thereby insuring the same discharge of fuel through the same orifice opening or effective area under all conditions of operation. Thereupon I provide means to vary the effective area of the fuel metering orifice in response to the engine speed to increase the fuel flow as the speed increases at fixed throttle; such means may be in the form of a needle valve operated by an articulated piston or by a diaphragm responsive to vacuum in the engine manifold. Furthermore, to complete the practical construction I provide means adapted to increase the flow of fuel as the load (torque) of the engine increases at constant speed, in spite of the fact that under such conditions the vacuum in the intake manifold decreases. Such means may be in the form of a cam operated by the throttle and adapted to move the articulated piston and the needle to increase the area of the fuel metering orifice in a proper relation to the throttle opening. By virtue of such a construction, I attain the flow of the fuel substantially in proportion to the air-mass flow in the intake conduit of the engine or power (H. P.) developed by the engine.

I provide "idling system" i. e. means for enriching the fuel mixture at low speeds by providing in the carburetor an orifice of constant area, with constant pressure differential across such orifice. Such an orifice discharges additional and constant amount of fuel through the

entire range of speed and load conditions of engine operation. At idling and low power operation of the engine, when air mass flow is small, this additional fuel produces sufficient enriching effect on the fuel mixture. However, this effect becomes negligible at higher speeds and wider throttle openings when air-mass flow is much greater. The area of such orifice may be made adjustable to provide for desired idling operation.

The construction of my carburetor is such that provision of an "acceleration system" i. e. means to provide the proper fuel mixture by the engine during fast opening of the throttle, is effected in an exceedingly simple manner. Opening of the throttle in my carburetor creates a much greater flow of fuel than would be required for the normal or economical operation of the engine, giving in effect the richer mixture at the carburetor required during acceleration. I provide means to create a time lag in the response of the needle valve to decrease in manifold vacuum, thereby insuring that as the throttle valve is opened rapidly, the required mixture continues for a required short period of time. Such means may be in the form of a restriction in the conduit subjecting the articulated piston controlling the needle valve to the action of manifold vacuum. The reverse operation of said means produces decrease in fuel mixture richness as the throttle is suddenly closed, which is also a desirable feature.

Means are provided operating, in effect, as the "power enrichment system" of conventional carburetors. In my improved carburetor, such means are of exceedingly simple construction and may be produced merely by changing the cone angle of a needle valve, whereby the same linear movements of the valve at larger openings (i. e. high power operation) of the metering orifice are more effective to increase its effective area than at smaller openings (i. e. lower power operation), thus insuring that when the engine is called upon to deliver its maximum power, the carburetor supplies to it richer fuel mixture as required by the engine.

The construction of my carburetor is such that very substantial aeration and/or heating of the fuel stream may be effected in a very simple manner, insuring virtually complete evaporation of the liquid fuel and eliminating the disadvantage resulting from its improper evaporation, explained above.

Means are also provided to decrease or to interrupt completely the supply of fuel when the vehicle drives the engine, such as in coasting, to eliminate objectionable smell and waste of fuel.

In my carburetor, the functions of the aforementioned systems are performed more efficiently with fewer parts. In Fig. 1, my carburetor is illustrated as a downdraft type in which the carburetor housing 1 is shown in relation to the intake manifold 2 of what may be considered as a conventional type of internal combustion engine, the manifold 2 being employed to direct the gas mixture from the carburetor housing 1 to the various cylinders of the engine, all in a manner well known to those skilled in the art. In Fig. 1, air enters the carburetor at the entrance 3 and flows downward through the uniform-bore carburetor passageway 4 and past the throttle 5 into the intake manifold 2. The gasoline preferably, although not necessarily, is discharged to the air on the upstream side of throttle wherein the throttle is manually oper-

ated to regulate the amount of gas mixture that enters the engine, thereby regulating the power output of the engine. Referring to Fig. 1, in the main metering system fuel is supplied by any conventional fuel pump (not shown) at a pressure of from $2\frac{1}{2}$ to 4 p. s. i. for automotive installations. The pressurized fuel enters the carburetor at the fuel inlet 6 and flows past the regulator valve 7 into the diaphragm chamber 8. The function of the diaphragm 9 and the regulator valve 7 will be discussed presently. The fuel then flows past the variable main metering orifice 10 into the pre-mixing chamber 11; the fuel is then discharged to the intake air through the discharge conduit 12 at the discharge outlet 17.

Before discussing the metering of fuel in the main metering system of my carburetor, first consider briefly the basic principle of metering of fuel in all carburetors as described in my said book, "Aircraft Carburetion," and then how it is utilized for example in a typical float carburetor. Any fuel system of an engine from the fuel tank to the carburetor discharge nozzle is nothing more than a simple hydraulic circuit wherein one unit in the circuit (fuel pump) maintains a continuous supply of fuel through the circuit; and at another point in the flow circuit, specifically at the main metering orifice, the pressure differential across the orifice and/or the size of the orifice is accurately regulated to change the flow of fuel through the circuit proportionally with the flow of air. In a typical float carburetor, the pressure at the entrance of a fixed-size metering orifice is regulated at a constant value by means of a "level" or "head" type pressure regulator comprising the well known float and needle valve; the pressure at the discharge side of the orifice is exposed to the throat of an air venturi wherein this pressure reduces with increase in air flow so that the pressure differential across the orifice, and hence the fuel flow, increases proportionally with air flow.

In the main metering system of my carburetor, means are provided to maintain a substantially constant pressure differential across the main metering orifice at all times, whereas the size of the orifice increases as the mass-air-flow increases whereby the fuel flow increases in a substantially proportional relationship with mass-air-flow. In Fig. 1, assume for the present that the metering needle 13 moves in accordance with changes in mass-air-flow; the manner in which this is accomplished will be explained presently. In my carburetor, a diaphragm pressure regulator is used in place of a float regulator to maintain the desired pressure differential across the main metering orifice 10. The orifice 10 is part of the orifice disc 10^a which is pressed into the bore of the cylinder 22^a. The regulator in my carburetor includes a valve 7 which is actuated by a diaphragm 9 that forms two pressure chambers 8 and 14 in combination with the housing and cover 9^a. A spring 15, or other force producing means, urges the diaphragm in an upward direction, as viewed in Fig. 1, in opposition to the differential of the pressure in chamber 8 and the pressure in chamber 14. The main metering orifice 10 is exposed on its inlet side to the diaphragm chamber 8 so that the pressure at the entrance to the orifice 10 is also applied to the side of the diaphragm 9 included in chamber 8. Also the pressure in chamber 11 at the discharge side of the main metering orifice 10 is

statically transmitted to chamber 14 through the conduit 16.

Thus it is apparent that the pressure differential "across" the main metering orifice is precisely the same as the pressure differential "across" the diaphragm 9 that opposes the force of the spring 15. This spring has a very low rate so that the comparatively short travel of the diaphragm changes the force of the spring 15 a negligible amount; thus the spring 15 applies a substantially constant force on the diaphragm at all times. The valve 7 is arranged in cooperation with its seat wherein a downward movement of the diaphragm causes the valve opening to reduce and an upward movement of the diaphragm causes the valve opening to increase.

The diaphragm automatically and instantly adjusts the valve 7 to maintain a constant differential across the diaphragm 9 and the main metering orifice 10. If for example the effective diaphragm area is 5 square inches and the spring force is 5 pounds, a pressure differential of 1 p. s. i. or approximately 2 inches of mercury is required to balance the spring force at all times. If the pressure in chamber 11 reduces for any reason, the pressure in chamber 14 also reduces so that the diaphragm moves downward until the valve 7 reduces the pressure in chamber 8 the same amount as the reduction of pressure in chamber 11 wherein the pressure differential remains at 2 inches of mercury. Conversely, if the pressure in chambers 11 and 14 increases, the diaphragm, being unbalanced, opens the valve 7 sufficiently to increase the pressure in chamber 8 the same amount as the increase of pressure in chamber 11 wherein the pressure differential again is 2 inches of mercury and the regulator is balanced. Likewise, if the pressure in chamber 8 increases for any reason, the diaphragm, being unbalanced, reduces the opening of the valve 7 until the original pressure differential of 2 inches of mercury is restored. Conversely, if the pressure in chamber 8 is reduced, the diaphragm, being unbalanced, opens the valve 7 enough to restore the original pressure differential.

Thus it is now apparent that in the preferred form, the regulator in my carburetor maintains a substantially constant pressure differential "across" the main metering orifice at all times regardless of any variations in the quantitative value of the pressures at the inlet or discharge sides of the orifice. If desired, chamber 14 may be vented to the outside atmosphere or to the carburetor air inlet which is a substantially constant pressure. Then the regulator will regulate a constant pressure at the entrance of the orifice regardless and independent of the pressure in chamber 11 at the discharge side of the orifice.

The differential pressure regulator illustrated in Fig. 1 facilitates the use of novel means of discharging the fuel to the air. The discharge conduit 12 discharges the fuel at the discharge outlet 17 which is located at any desired position in the air passage of the carburetor. In the preferred form shown in Fig. 1, the discharge nozzle is located where it is exposed to a slight velocity vacuum that varies between about 2 to 5 inches of water. This position will be slightly upstream of the throttle at the closed position so that at low and high powers it is subjected to velocity vacuum. This vacuum is transferred to chamber 11 at the outlet of the orifice 10, but it will have no effect on the metering of fuel because of the action of the differential pressure regulator in

maintaining a constant pressure differential "across" the orifice as previously explained. The sole purpose of this discharge vacuum is to effect a circulation of air from the carburetor inlet through the impact-tube 18, through the conduit 19, and through the air bleed orifice 20 where it mixes with the fuel in chamber 11. The very rich mixture then is drawn out the discharge conduit 12 where it is discharged at the outlet 17. The air bleed orifice may be a fixed orifice in the conduit 12, or it may be a variable orifice as illustrated in Fig. 1. In Fig. 1, a portion of the metering needle 13 in cooperation with an aperture in the disc 21 forms the variable air bleed orifice wherein the air-bleed at higher powers is greater than at lower powers. This novel construction permits a pre-mixing of the fuel with a divided portion of the intake air-flow so that a rich mixture is discharged to the main air flow instead of "solid" fuel; this result effects a more complete vaporization of the fuel so that the engine economy is improved considerably. In present carburetors the fuel is discharged in a more or less "solid" state and does not have enough time to vaporize thoroughly in the short interval before it is carried into the combustion chamber. The principle illustrated in Fig. 1 may be carried further by making the conduits 18, 19, 12, and chamber 11 very large so that a sizable percentage of the total engine air-flow may be re-circulated, as shown, to give the fuel and air sufficient time to vaporize before it is carried to the engine. Furthermore, the discharge conduit may be made very long whereby it circles the carburetor housing 1 several times before the fuel is returned to the discharge outlet 17 where it discharges to the main air flow. This long discharge passage should be located to absorb as much engine heat as possible to facilitate further improved pre-vaporization. Also instead of using a single discharge outlet 17 as shown in Fig. 1, the rich mixture may be discharged in a more homogeneous manner if a plurality of smaller discharge outlets, all of which communicate with the conduit 12, are spaced along a plane at right angles to the carburetor bore.

If preferred, however, the impact tube 18, the conduit 19, and the disc 21 may be omitted wherein "solid" fuel will be discharged to the engine. However in this form of my invention, the discharge outlet 17 should be located at the carburetor entrance where the pressure is substantially atmospheric at all times.

Now consider the air measuring element of the main metering system of my carburetor wherein the metering needle 13 moves in accordance with mass-air-flow. In Fig. 1 the air measuring element comprises the needle valve 13 in cooperation with the orifice 10, the pistons 22 and 23 which are urged in opposite directions in the cylinder 22^a by the spring 24, the throttle-actuated cam 25 which effects a movement of the piston 23 by means of the cam follower 26 when the throttle 5 is actuated, and the vacuum conduit 27 which statically transfers the manifold vacuum into the chamber 23 formed by the pistons 22 and 23 in the cylinder 22^a. The left side of the piston 22, as viewed in Fig. 1, is exposed to the intake air pressure through the conduit 19, and the right side of the piston 23 is exposed to the air pressure on the upstream side of the throttle by means of the opening 29. The area of the piston 22 is substantially equal to the area of the piston 23 so that the vacuum in chamber 28

merely causes a compression of the spring 24 and does not cause a force to bear on the cam. A soft spring 30 causes the assembly of the two pistons, the spring 24, and the cam follower 26 to follow the contour of the cam 25 at all times.

The application of this measuring element in a carburetor depends on the following facts:

1. Mass-air-flow is substantially proportional to horsepower.

2. Horsepower is proportional to the product of torque and R. P. M., or load and R. P. M.

3. Therefore, mass-air-flow is substantially proportional to the product of load and R. P. M.

In the main metering system of any carburetor, the fuel flow should vary substantially in a direct proportion with air flow. Therefore from fact No. 3 above, it is obvious that if the R. P. M. were maintained constant, a 10% increase in load, for example, should give a 10% increase in fuel flow. Also, if the load were maintained constant, a 10% increase in R. P. M. should also give a 10% increase in fuel flow. This reasoning illustrates that the R. P. M. and load should have an equal effect on fuel flow. Hence the air measuring element illustrated in Fig. 1 must be responsive to both speed and load in order to meet the above requirements.

In order to understand how this result is accomplished, it is necessary to know that the intake manifold vacuum is comprised of two components as follows:

1. The manifold vacuum varies as the engine speed is varied at any "fixed-throttle" position, the vacuum increasing as the engine R. P. M. increases. This component is the speed-responsive factor in my carburetor and may be referred to as "speed vacuum."

2. The manifold vacuum varies as the throttle position is changed at "constant R. P. M.," the vacuum increasing as the throttle opening decreases. This component is one of the two load functions in my carburetor and may be referred to as "throttle vacuum."

The "speed vacuum" and "throttle vacuum" components in the manifold vacuum may be understood better by referring to Figs. 2 and 7. Fig. 2 is a chart showing the variation of manifold vacuum versus engine R. P. M. at various fixed-throttle positions; thus each curve illustrates the "speed vacuum" variation previously described. For example, the curve A—E shows that at a fixed-throttle position of 19 degrees when the engine speed increases from 1000 to 3000 R. P. M., the vacuum increased from 2.5 to 10.5 inches of mercury. The torque or "load" is almost, although not exactly, constant at a fixed-throttle position at varying engine speeds. Hence, for the purposes of this disclosure, the throttle movement will also be considered as a load function.

Observe in Fig. 2, that the curve B—M which attains a value of over 2 inches of mercury at 3500 R. P. M. is the wide-open-throttle vacuum curve. In a conventional carburetor this curve normally would be produced by the restricting effect of the air venturi. However in my carburetor, since a venturi is omitted, the curve B—M is produced by means of a throttle stop at the "wide-open-throttle" position so that the throttle 5 actually is closed sufficiently to produce the desired curve.

In Fig. 7 the curve A—B shows that as the throttle is opened at a constant engine speed of 2500 R. P. M., for example, the manifold vacuum decreases rapidly; the curves C—E and D—F represent constant speed vacuum variations at 2000

and 1500 R. P. M., respectively, and are further examples of the "throttle vacuum" component of the manifold vacuum as described previously.

Now consider the operation of the air measuring element illustrated in Fig. 1. At a "fixed-throttle" position of 19 degrees, for example, when the engine speed, and hence the air flow, increases, the "speed vacuum" in chamber 28 increases along the curve A—E, Fig. 2. This increase in vacuum with engine R. P. M. causes the piston 22 to move to the right as viewed in Fig. 1, whereby the metering needle 13 is pulled out of the orifice 10 so that the orifice size and hence the fuel flow is increased. The contour of the metering needle 13 is made so that when the air flow increases at fixed-throttle due to an increase in R. P. M., the fuel flow increases substantially proportionally. Conversely, a decrease in R. P. M. causes the "speed vacuum" in chamber 28 to decrease whereby the opening of the orifice 10 is reduced by the movement of the metering needle 13 so that the mixture is maintained constant.

At a "constant engine speed," if the throttle opening is reduced, the "throttle vacuum" in chamber 28 increases which tends to move the piston 22 to the right, as viewed in Fig. 1, which would increase the fuel flow. However, since the air-flow decreases, it is necessary for the fuel flow to decrease as the throttle opening, or load, is reduced at constant R. P. M. This result is accomplished by means of the throttle-actuated cam 25 which is contoured to move the piston 23 to the left when the throttle opening is reduced, as viewed in Fig. 1; this leftward movement of the piston more than compensates for the compression of the spring 24 by the "throttle vacuum" wherein the metering needle 13 is moved to the left sufficiently that the orifice size and hence the fuel flow is reduced as required. The contour of the cam is made so that the percent change in fuel flow due to a change in R. P. M. is substantially the same as the change in fuel flow due to a corresponding percent change in load. Conversely, when the throttle opening or load is increased at a constant R. P. M., the "throttle vacuum" reduces which would tend to reduce the size of the orifice 10 thereby reducing the fuel flow as the air flow increases; however, the increase in throttle opening revolves the cam so that the piston 23 is moved to the right more than the expansion of the spring 24 whereby the metering needle is moved to the right and the orifice size and hence the fuel flow is increased.

From the foregoing discussion, at any combination of speed and load between constant speed and constant load, the metering needle travel will vary substantially as the product of speed and load. Since the metering needle 13 in Fig. 1 moves in accordance with the product of R. P. M. and load or, more specifically, in accordance with changes in mass-air-flow, and because the metering pressure differential is always maintained constant as previously described, the fuel flow varies in accordance with mass-air-flow so that the main metering system supplies a substantially uniform mixture under all speed and load conditions, as required.

Now consider how means are provided in my carburetor to adjust for the correct idle mixtures manually. The idle mixture is richer than at medium powers. In Fig. 1 an adjustable needle valve 31 regulates a small amount of fuel that parallels the fuel flow through the main metering orifice 10. The pressure differential "across" the

idle orifice is the same as the differential "across" the main metering orifice. Since this pressure differential is constant and the idle orifice is fixed, a constant amount of fuel passes through the idle orifice at all times to provide a richer mixture at idle speeds. Thus, as the air flow increases and the opening of the metering orifice increases correspondingly, the constant amount of fuel flowing through the idle orifice becomes a smaller percentage of the total fuel flowing whereby the mixture is leaned as the power is increased to medium powers wherein the effect of the idle orifice is negligible.

Consider how means are provided in my carburetor for preventing lean mixtures during the acceleration period. In this carburetor the air measuring element previously described also serves as the accelerating pump in combination with the delay orifice 33. When the throttle is manually opened from any fixed throttle position, the piston 23 is simultaneously moved to the right, as viewed in Fig. 1, and the vacuum in the intake manifold simultaneously reduces. However, because of the restricting effect of the delay orifice 33, the vacuum in the chamber 28 reduces very slowly whereas the metering needle is moved much further to the right when the throttle is opened than if the delay orifice were omitted. Hence when the throttle opening is increased, the size of the main metering orifice increases considerably more than if the full manifold vacuum were instantly transferred into chamber 28 whereby additional fuel is instantly discharged during the acceleration period, as required. The size of the orifice 33 determines the period of acceleration fuel discharge; for example, if the orifice 33 is very small, the period of additional acceleration fuel is long, and if the orifice 33 is large, the period of additional acceleration fuel is short. The amount of acceleration fuel may be partially or wholly determined by extending the length of the metering needle 13 so that when the main contour of the needle is moved to the right out of the orifice 10 during acceleration, the contour of the extension, which will be smaller in diameter than the main contour, determines the amount of extra fuel discharged during the acceleration period. This accelerating pump has the advantage that when the engine is decelerated by a reduction in throttle opening, the metering needle moves excessively to the left, as viewed in Fig. 1, because of the effect of the orifice 33; this action leans the mixture during the deceleration period which conserves fuel.

The power enrichment system which provides richer mixtures at high powers in my carburetor is merely a steeper angle on the end of the metering needle 13 as shown. Because the metering needle varies substantially in accordance with mass-air-flow or power, this steeper angle on the end of the needle provides the desired richer mixtures at high powers, and is controllable by the angle of the needle.

For all aircraft installations and in some automotive applications, a manual and/or automatic mixture control is incorporated. The manual adjustment may be accomplished in the present invention by resetting the adjusting screw 34 which varies the force of the spring 15. If the spring is compressed, a higher pressure differential exists across the metering orifices which enriches the mixtures throughout the entire range. Conversely, if the spring 15 is expanded, the metering pressure differential is reduced which leans

the mixtures throughout the range. For automatic control, a conventional aneroid or evacuated bellows, well known to those skilled in the art (not shown), may be employed to compress or expand the spring 15. A second means of varying the mixtures throughout the metering range is to adjust the cam follower screw 26 in relation to the piston 23 which resets the position of the metering needle 13 thereby adjusting the mixtures. In production this adjustment compensates for production variations in the metering needle 13, the pistons 22 and 23, and in the length of the spring 24. Another possible adjustment which can vary the mixtures throughout the range is the eccentric pin 34' which is revolved manually whereby it moves in the slot 34^a to revolve the cam 25. A counter-clockwise rotation of the cam enriches the mixtures and a clockwise rotation of the cam leans the mixtures.

In production the carburetor is calibrated along a loading variation commonly known as a "road-load" curve for automotive operation, and a "propeller-load" curve for aircraft operation. A "road-load" curve for an automotive vehicle would represent the power-R. P. M. characteristics while driving on a level road at all throttle openings from idle to wide-open-throttle. In Fig. 2, the curve P—M—E represents the variation of manifold vacuum and R. P. M. under "road-load" operation in high gear for a Chevrolet passenger car engine, for example. The cam 25, Fig. 1, is calibrated so that the mixtures are correct under all "road-load" conditions. At any fixed throttle position, the variation in vacuum with a change in R. P. M. from the road-load condition causes the metering needle 13 to move; hence the needle contour determines the correct mixtures at fixed throttle operation off the "road-load" calibration. The needle contour is made so that it corresponds to an average of the contours required for the various fixed throttle curves such as the curve A—E. Hence the mixtures will be correct at any load conditions.

Another feature of my carburetor is the novel means for providing a richer mixture for cold starting and the "warm-up" period. In Fig. 1 a primer valve and orifice 35 regulates an additional fuel flow through the orifice which is parallel to the main metering orifice 10, as shown, wherein the metering pressure differential existing "across" the main metering orifice also exists "across" primer valve and orifice 35. The primer valve may be manually or automatically controlled, although the latter form is illustrated in Fig. 1. The primer valve is secured to and positioned by a strip of thermostatic bi-metal 36 which is rigidly supported at the riveted post 37. A heat-conductor 38 is joined to the bi-metal strip at one end, whereas the other end of the heat-conductor is exposed to the interior of the exhaust manifold (not shown) so that a portion of the heat of the exhaust is conducted to the bi-metal strip. The heat-conductor 38 and the bi-metal strip 36 are preferably covered or bonded with a heat insulating material to prevent heat loss wherein the bi-metal will be more responsive. In the preferred form, as shown in Fig. 1, the heat-conductor 38 comprises a hollow and sealed metal tube which contains a heat conducting filler 39, such as sodium, wherein heat is rapidly transmitted to the bi-metal. Also, if preferred, the bi-metal strip may be installed outside the diaphragm chamber to operate a slidable needle valve having one end outside the diaphragm chamber.

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As illustrated in Fig. 1, when the engine is cold, the bi-metal is bent to open the valve 35 slightly. Then when the engine is first started, the pressure developed by the fuel pump (not shown) causes fuel to flow through the main metering orifice and also through the primer valve 35. After the engine starts and the regulator functions normally, the primer valve 35 remains open slightly to enrich the mixtures. When the engine exhaust temperature rises, the bi-metal strip gradually closes the primer valve 35 until the engine functions normally when the primer valve is shut. The angle of the primer valve needle 35 determines the amount of additional fuel supplied during the "warm-up" period. The primer valve 35 may be operable by manual means if preferred wherein the bi-metal strip 36 and the heat-conductor 38 are omitted.

Fig. 3 illustrates another form of components of my carburetor. In Fig. 3 the throttle 5 has a streamlined cross-section which is thick enough that the wide-open throttle vacuum curve B—M, Fig. 2, is produced by the resistance of the throttle when wide open. This design will produce more linear vacuum curves than a flat throttle which is initially open slightly at wide-open-throttle as previously explained. Furthermore, the throttle 5 illustrated in Fig. 3 produces a partial Venturi effect so that a vacuum is available at wide-open-throttle to effect the circulation of air through the conduits 18, 19, and 12, Fig. 1, as previously explained. In Fig. 3, if the discharge outlet 17 is located slightly on the upstream side of the throttle, it will be subjected to a slight velocity vacuum at all throttle positions; at low throttle openings, the air has a high velocity as it passes through the throttle which will produce a vacuum at the discharge outlet 17. The discharge outlet may be located slightly on the downstream side of the throttle if preferred, or anywhere else in the intake passage to obtain a motivating vacuum. Any design of throttle valve may be employed in my carburetor such as a poppet-type valve or a slide valve, for example. Also in Fig. 3, the vacuum passage 27 may be located slightly on the upstream side of the closed position of the throttle 5 as shown, so that the vacuum at idle speeds may be reduced if desired.

Fig. 4 illustrates another form of components of my carburetor whereby a diaphragm 22^c is used in place of the piston 22, Fig. 1. Also, if preferred, leaf springs 40 and 41 may be employed to support the metering needle 13; the leaf springs are rigidly secured at the supports 42 and 43 by any suitable means such as by a screw as illustrated. The other extremities of the leaf springs are secured to the metering needle 13 whereby motion is possible only in an axial direction, and this motion is substantially frictionless. This frictionless supporting means and the use of a substantially frictionless pressure responsive member such as a diaphragm is particularly advantageous in a carburetor having a variable metering orifice, since gum deposits on the moving parts of the variable orifice would not produce effects detrimental to the operation thereof. A sliding metering valve and the use of a piston for the actuating pressure responsive member may be adversely affected by gum deposits from the fuel or other foreign matter.

Fig. 5 is a chart showing the typical desired mixture ratios at various powers for automotive

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operation. The chart shows the variation of mixture ratio with mass-air-flow. In Fig. 5, the idle mixtures, which lean out as the power is increased, are represented by the curve A—B. The idle adjustment 31, Fig. 1, facilitates the selection of a richer curve, N—B, or a leaner curve, M—B, for example. The medium speed range operation is represented in Fig. 5 by the main metering system mixtures, B—C, which correspond to the best-economy mixture ratios. In the power range, the mixtures are progressively enriched along the curve C—D to the best-power mixture at D, which is accomplished in my carburetor by the shape of the metering needle 13. The wide-open-throttle mixtures are represented by the curve D—E and correspond closely to the best-power mixtures.

Fig. 6 illustrates another form of the air measuring element of my carburetor. In Fig. 1, the manifold vacuum in chamber 28 is uncorrected so that the full vacuum is transferred into chamber 28, but the spring 24 is corrected by throttle movement to compensate for the "throttle vacuum" variations. In Fig. 6 the spring force is unaffected by throttle movement, whereas the vacuum in chamber 28 is a corrected manifold vacuum which is modified by throttle operated means. In Fig. 6, an air bleed circuit communicates with chamber 28 in which a small amount of air from the atmospheric passage 19 flows through the fixed orifice 43, through the chamber 28, through the orifice 44 which is variable by means of the throttle-actuated needle valve 45, and out through the manifold vacuum passage 27 to the intake manifold. The needle valve 45 is actuated by the throttle-operated cam 25 in opposition to the spring 46. Because of the air bleed system, when the valve 45 is fully withdrawn, the full manifold vacuum is transferred into chamber 28. And when the valve is closed, the atmospheric pressure exists in chamber 28. Any intermediate position of the valve will establish any pressure in chamber 28 between atmospheric and the full manifold vacuum.

At "constant R. P. M.," the contour of the cam 25 is made so that when the throttle opening is reduced and the manifold vacuum increases, the opening of the orifice 44 is reduced sufficiently to effect a gradual reduction in the vacuum in chamber 28. This reduction in vacuum as the load is reduced at constant R. P. M. allows the metering needle 13, Fig. 1, to reduce the size of the orifice 10 whereby to reduce the fuel flow and maintain the correct mixtures.

The effect of the foregoing action is illustrated in Fig. 7 which is a chart showing the manifold vacuum and the vacuum in chamber 28, Fig. 6, in relation to the throttle opening at constant R. P. M. In Fig. 7 at 2500 R. P. M., for example, the curve B—A represents the increase in manifold vacuum as the throttle opening is reduced, whereas, the curve B—G represents the corresponding vacuum variation in chamber 28 at the same R. P. M. At lower engine speeds, such as 2000 or 1500 R. P. M., the manifold vacuum curves and the curves in chamber 28 are correspondingly lower, as shown by the manifold vacuum curves E—C and F—D, and the corresponding curves E—H and F—K in chamber 28, respectively.

In Fig. 6 at any "fixed-throttle" position, when the R. P. M. is increased the manifold vacuum increases along a curve such as A—E, Fig. 2, for example, so that the vacuum in chamber 28, al-

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though quantitatively less than the manifold vacuum, also increases with R. P. M. This increase of vacuum in chamber 28 causes the metering needle 13 to increase the size of the orifice 10, Fig. 1, whereby the fuel flow is increased as required. Hence it is apparent that this form of measuring element may be made equally responsive to speed and load so that the movement of the valve 13 varies with mass-air-flow as previously described. The contour of the cam 25 is calibrated so that the mixtures are correct along a "road-load" curve whereas the needle contour determines the metering along a fixed-throttle curve, as previously explained. If preferred, the orifice 43 may be varied by throttle movement whereas the orifice 44 will be fixed; then the cam contour must be reversed so that the orifice 43 opens as the throttle closes. This air measuring element is the same as the "brain-unit" disclosed in my co-pending patent application, Serial No. 14,282, filed March 11, 1948.

Fig. 8 illustrates a portion of Fig. 1 wherein a different form of regulator is incorporated in my carburetor. In Fig. 8, a metal weight 15^a is used in place of the spring 15, Fig. 1, to provide the force that determines the amount of pressure differential existing "across" the diaphragm 9 and the main metering orifice 10. In Fig. 1, although the rate of the spring 15 may be very low, there will always be a slight change in the force of the spring due to the short travel of the diaphragm 9; this slightly varying spring force will effect a corresponding but slight change in the pressure differential "across" the main metering orifice. If it is desirable to have an absolutely constant metering pressure differential, the weight 15^a may be employed as illustrated in Fig. 8; since the force on the diaphragm 9 due to the weight 15^a is absolutely constant independent of diaphragm travel, the pressure differential "across" the diaphragm and metering orifice is always constant. The orifice 16^a in the conduit 16 may be employed to dampen any tendency for the weight 15^a to oscillate.

Fig. 9 shows another form of my invention wherein a portion of Fig. 1 is illustrated with a different form of air measuring element. In Fig. 9, the orifice 10 is part of the piston 22^b that includes the hollow interior chamber 8^a. The piston is slidable in the cylinder 22^a and is urged to the right, as viewed in Fig. 9, by the force of the spring 24 which is manually adjustable by means of the adjustment screw 47. The piston 22^b includes a longitudinal slot 48 that facilitates unrestricted communication of conduit 8^b with chamber 8^a in all axial positions of the piston 22^b. A metering needle 13^a is urged against the throttle-actuated cam 25 by means of the spring 30^a whereby the size of the main metering orifice 10 is varied as desired along a "road-load" calibration by means of the contour of the cam 25. The static manifold vacuum is transmitted to chamber 28 through the conduit 27.

Fuel from the fuel pump enters the carburetor at a pressure of preferably 3 to 4 p. s. i. where it flows past the regulator valve 7, through chamber 8, conduit 8^b, chamber 8^a, through orifice 10 into chamber 11 and out the discharge passage 12 where it is discharged at the outlet 17. If preferred, an air bleed circuit may be employed, as before, wherein air bleeds into the impact tube 18, through conduit 19 and through the air orifice 20 which is comprised of a portion of the metering needle 13^a and the orifice plate 21, as illustrated; the air then joins the fuel in chamber

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11 so that an emulsion or a very rich mixture is discharged at the outlet 17 thereby providing better vaporization, as previously explained. The metering pressure differential "across" the main metering orifice 10 is maintained substantially constant in the manner previously described.

At "constant R. P. M." in Fig. 9, when the throttle opening is reduced, the "throttle-vacuum" in chamber 28 increases whereby the piston 22^b is moved to the left, as viewed in Fig. 9, in opposition to the force of the spring 24; however, the cam 25 simultaneously effects a movement of the metering needle 13^a to the left more than the travel of the piston 22^b so that the opening of the orifice 10 is reduced sufficiently to reduce the fuel flow for the reduced air flow at the reduced load. An increase in throttle opening at constant R. P. M. effects an increase in the opening of the orifice 10 in a manner conversely as described above whereby the fuel flow is increased for the increased air flow at the higher load.

At "fixed-throttle," when the R. P. M. is increased the vacuum in chamber 28 increases so that the piston 22^b moves to the left, as viewed in Fig. 9, whereby the size of the orifice 10 and hence the fuel flow is increased. A decrease in R. P. M. at a fixed throttle position effects a decrease in the opening of the orifice in a manner conversely as described above whereby the fuel flow is decreased for the decreased air flow accompanying the lower R. P. M. As previously described, the contour of the metering needle 13^a is made so that the mixtures are correct along an average fixed-throttle vacuum curve, such as curve A-E, Fig. 2. In Fig. 9, the adjusting screw 47 may be used to vary the force of the spring 24 which varies the mixtures throughout the entire operating range. Also, if preferred, the metering needle 13^a may be actuated by a piston or diaphragm responsive to the manifold vacuum, whereas the piston 22^b would be directly throttle-actuated by the cam 25, which construction is merely the reverse of the form illustrated in Fig. 9.

Fig. 10 shows another form of my invention wherein a portion of the form shown in Fig. 1 is illustrated with a novel heat exchanger and a "de-gasser" valve in the discharge passage. In Fig. 10, as previously described, air enters through the tube 18, the conduit 19, and the orifice 20 where it pre-mixes with the fuel in chamber 11 so that the fuel vaporization is improved. The rich fuel mixture is discharged through the discharge conduit 12^a and through the tubes 12^b in the chamber 48, and out through the discharge passage 12 to the discharge outlet 17. The additional length of this fuel passage alone facilitates improved vaporization because a small portion of the inlet air is pre-mixed with the fuel, and due to the length of the discharge conduit, the rich mixture has time to vaporize; in an ordinary carburetor the air rushes through so fast that the fuel does not have time to vaporize properly. Furthermore, in Fig. 10, the conduit 49 communicates with chamber 48 and with the interior of the engine exhaust manifold (not shown); also, a small orifice 50 connects chamber 48 with the intake manifold so that a small amount of the hot exhaust gas is caused to circulate through conduit 49, through chamber 48, and through the orifice 50 into the intake passage. The hot exhaust gas flowing through chamber 48 heats the rich gas mixture

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passing through the tubes or passages 12^b so that the pre-vaporization of the fuel is vastly improved, and the high temperature of the rich mixture as it discharges from the outlet 17 further improves vaporization of the fuel as it mixes with the air and hence greatly improves the acceleration and economy characteristics of my carburetor. The interior walls of the chamber 48 preferably are lined with an insulating material so the heat is retained within the chamber.

Fig. 11 is a chart showing the variation of manifold vacuum with engine speed for a light passenger automobile engine as the accelerator pedal is released and the engine decelerates to the idle speed. The idle vacuum for this engine is 19.0 to 19.5 inches of mercury. During this deceleration period when the throttle is at the idle position, the engine does not need any fuel. Hence it is desirable to shut off completely the fuel flow to the engine for three reasons. One reason, obviously, is to improve the fuel economy, particularly for automotive operation in the city. The second reason is that the gasoline normally discharged during this period tends to dilute the thin film of oil on the cylinder wall so that this oil burns out more readily under power, thereby increasing oil consumption, cylinder wear, and piston ring wear. A third reason for shutting off the fuel flow is that the fumes of the burning oil that discharge from the exhaust during deceleration emit an undesirable odor, which is particularly offensive in buses.

Illustrated in Fig. 10 is a "de-gasser" valve unit which shuts off the fuel flow during the deceleration period. The unit comprises in one form a piston-valve 51 which is urged in a downwardly direction by the spring 52 and which has the two flanges 53 and 54 that serve in cooperation with the conduits 12^a and 19, respectively, as port-type valves. The chamber 55 that contains the spring 52 communicates with the intake manifold through the conduit 56, as shown. The flange 57 of the piston-valve 51 serves as a vacuum piston for the unit. When the vacuum in chamber 55 is high enough to effect a force on the flange 57 that exceeds the force of the spring 52 the piston-valve 51 moves upwardly, as viewed in Fig. 10, whereby the flanges 53 and 54 close the conduits 12^a and 19, respectively. The chamber 19^a communicates with conduit 19 which is subject to substantially atmospheric pressure so that the piston-valve movement is responsive to engine vacuum. With the piston-valve 51 in the position shown in Fig. 10, the conduits 12^a and 19 are open. Since the maximum idle vacuum is 19.5 inches of mercury, the force of the spring 52 is set by means of the adjusting screw 58 so that the piston valve closes the passages 12^a and 19 whenever the manifold vacuum is above 20.5 inches of mercury. The spring 52 must have a very low rate so that the short travel of the piston-valve 51 will have negligible effect on the force of the spring. When the engine is decelerated from 2000 R. P. M., for example, and the throttle is closed, the manifold vacuum will be 23.7 inches of mercury (see Fig. 11). This high manifold vacuum instantly causes the piston-valve to move upwardly so that the conduits 12^a and 19 are closed as described, whereby the fuel cannot discharge through either of these conduits. As the engine speed decreases, the manifold vacuum decreases along the curve A—B, Fig. 11. When the vacuum reduces to 20.5 inches of mercury at B which corresponds to 750 R. P. M., the piston-

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valve 51, Fig. 10, moves in a downwardly direction to open the conduits 12^a and 19 whereby fuel is discharged to the engine at speeds below 750 R. P. M., and the engine idles in a normal manner. Whenever the throttle is opened for acceleration, the vacuum is always well below 20.5 inches of mercury so that the passages 12^a and 19 are open. If preferred, a diaphragm may be employed in place of the flange 57 to actuate the piston-valve 51.

Fig. 12 shows a portion of Fig. 1 in combination with another form of the "de-gasser" unit. In Fig. 12, a piston-valve 59 is urged in an upwardly direction by a spring 60. The piston-valve has two flanges 61 and 62 that serve in cooperation with the conduits 16, 16^a, and 63 as port-type valves. The chamber 64 that contains the spring 60 communicates with the intake manifold through the conduits 63 and 63^a, as shown. The flange 61 serves as a vacuum piston for the unit.

When the piston-valve is in the position shown in Fig. 12, the conduit 16^a communicates with the conduit 16, and the conduit 63 is closed by the flange 61. Then the pressure in chamber 11 is transferred statically into chamber 14 so that the regulator and the rest of the carburetor function in a normal manner as described in connection with Fig. 1. When the vacuum in chamber 64 is high enough to effect a force on the flange 61 that exceeds the force of the spring 60, the piston-valve 59 moves downwardly, as viewed in Fig. 12, whereby the flange 62 closes the conduit 16^a to interrupt the communication of conduit 16^a with conduit 16, and the flange 61 uncovers the conduit 63 to communicate with conduit 16. The chamber 65, which is formed by the flange 62, communicates with the atmosphere, as illustrated. Again assume that the maximum idle vacuum is 19.5 inches of mercury. The force of the spring 60 is set by means of the adjusting screw 66 so that the valve moves downwardly whenever the manifold vacuum exceeds 20.5 inches of mercury, for example, which corresponds to 750 R. P. M., Fig. 11. The spring 60 must have a very low rate so that the short travel of the piston-valve 59 will have negligible effect on the force of the spring whereby the total valve movement is accomplished in about 0.2 inch of mercury.

When the engine is decelerated from 2000 R. P. M. for example and the throttle is closed, the high manifold vacuum causes the piston-valve to move downwardly. This action closes conduit 16^a and opens conduit 63 to conduit 16 whereby the full manifold vacuum is statically transferred into chamber 14. This high vacuum in chamber 14 instantly shuts the regulator valve 7, Fig. 1, so that all fuel flow ceases immediately. When the vacuum in chamber 64 reduces to 20.5 inches of mercury at 750 R. P. M. as described previously, the piston-valve 59, Fig. 12, moves in an upwardly direction whereby the chamber 14 communicates only with chamber 11 so that the regulator valve functions in a normal manner and fuel instantly flows from the discharge outlet at engine speeds below 750 R. P. M. When the throttle is opened for acceleration, the vacuum in chamber 64 is always less than 20.5 inches of mercury so that the piston-valve is in the upward position and the regulator functions in a normal manner. If preferred, the piston-valve 59 may be actuated by a diaphragm which would enclose chamber 64.

I am aware that the invention may be embodied in other specific forms without departing from

the spirit or essential attributes thereof, and I therefore desire the present embodiments to be considered in all respects as illustrative and not restrictive; reference being had to the appended claims rather than the foregoing description to indicate the scope of the invention.

Having thus described the invention what is claimed and desired to be secured by Letters Patent of the United States is:

1. In a carburetor for an internal combustion engine, a body having an intake passageway for the flow of air therethrough, throttling means in said passageway, at least two variable orifices, means to supply fuel to said orifices, means to control the differential of pressures on opposite sides of the said metering orifices, means to vary the opening of one of the said orifices in accordance with the flow of air through the said intake passageway, means operable in accordance with the heat of the engine to vary the opening of another of said orifices whereby said last-named orifice is open when the engine is cold and gradually closes as the engine temperature increases.

2. In a carburetor for an internal combustion engine having an exhaust manifold, a body having an intake passageway for the flow of air therethrough, an exhaust manifold, throttling means in said passageway, at least one metering orifice, means to supply fuel to said metering orifice, a diaphragm pressure regulator to control the differential of pressures on opposite sides of the said metering orifice, means to vary the opening of the said metering orifice in accordance with the flow of air through the said intake passageway, a heat exchanger, conduit means for conducting the fuel from the said metering orifice through the said heat exchanger to the said intake passageway, means for conducting a portion of the exhaust gas from the exhaust manifold through the heat exchanger to the said intake passageway whereby the heat of the exhaust gas contacts the said fuel conduit means.

3. In a carburetor, an air conduit, a throttle adapted to control the flow of air through said conduit, a fuel metering orifice adapted to pass the fuel for discharge into said air conduit to form combustible fuel-and-air mixture, means to supply fuel to said orifice, differential pressure regulator means operating to maintain a constant pressure differential across said orifice, a needle valve adapted to regulate the discharge from said orifice by controlling the effective area thereof, and means responsive to pressure on the downstream side of the throttle and operating at fixed throttle positions to actuate said needle valve to increase the fuel discharge from said opening as said pressure decreases and to decrease the fuel discharge from said orifice as said pressure increases, and a connection between said throttle and said needle valve to move said needle valve in a direction to increase the fuel discharge as said throttle is opened.

4. In a carburetor, an air conduit, a throttle controlling flow of air through said conduit, a fuel metering orifice, means to supply fuel to said orifice, pressure regulating means to control the pressure differential across said orifice, a valve to control the effective area of said orifice, pressure responsive means connected to said valve for actuating the same to increase the metering orifice opening as pressure acting on said pressure responsive means decreases and to decrease the metering orifice opening as said pressure increases as the flow of air in said air conduit changes with the throttle being fixed, a con-

necting conduit operatively connecting said pressure responsive means to said air conduit at the downstream side of the throttle, means actuated by the throttle to move said valve to increase the effective area of said metering orifice as the throttle opens, and a restriction in said connecting conduit to delay for a predetermined period of time the action of the pressure on said pressure-responsive means.

5. In a carburetor, an air conduit, a throttle to control the flow of air through said conduit, fuel metering orifice means, means to supply fuel to said orifice means including a pressure regulator to control the fuel pressure differential across said orifice means, means responsive to the pressure in the air conduit on the downstream side of said throttle to increase the effective area of said metering orifice means as said pressure decreases at constant throttle opening, and to decrease said area as said pressure increases, and means actuated by said throttle and operating to increase the effective area of said metering orifice means as said throttle is opened.

6. In a carburetor, an air conduit, a throttle to control the flow of air through said conduit, a fuel flow circuit, variable area restriction means in said circuit including at least one orifice member and valve member cooperating therewith to vary the amount of fuel passing through said circuit, a pressure regulator device to maintain a predetermined pressure differential across said variable area restriction means, means responsive to pressure on the down-stream side of said throttle at fixed positions thereof to actuate one of said two members in a direction such that the amount of fuel passing through said fuel flow circuit increases as the said pressure decreases and the amount of fuel passing through said fuel flow circuit decreases as the said pressure increases at a fixed-throttle position, and means actuated by the throttle to effect a variation of said variable area restriction means in a direction to increase the amount of fuel passing through said fuel flow circuit as the throttle opens.

7. The construction defined in claim 6 and including supplementary fuel discharge orifice in parallel with said variable area restriction means and of constant effective area and subject to constant pressure differential, the area of said orifice being selected to effect fuel discharge therethrough which is sufficient appreciably to enrich fuel mixture only for idling and low mass-air-flow operation of the carburetor.

8. The construction defined in claim 6, said valve member varying throughout its length to make the linear movements of said valve member at high air-mass flows more effective to increase the effective area of said variable area restriction means than at lower air-mass flows, and thus to provide for production of richer mixtures at higher mass-air-flows.

9. The construction as defined in claim 6 and including pressure responsive means connected to said pressure regulator to interrupt the flow of fuel to the air conduit when the throttle is in its idle position and pressure on the downstream side of the throttle falls below the pressure corresponding to that at the idling position of the throttle.

10. The construction defined in claim 6, said valve member being adapted at higher mass-air-flows to increase the effective area of the said variable area restriction means to provide for

production of richer mixtures at higher mass-flows.

11. A carburetor for an internal combustion engine comprising means having an intake passageway for the flow of air therethrough, throttling means in said passageway, at least one metering orifice means, means to supply fuel to said metering orifice means and thence to said intake passage, said metering orifice means comprising two orifice forming members movable in relation to each other whereby to vary the effective area of said orifice means, a pressure regulator to control the differential of pressures on opposite sides of the said metering orifice means, a pressure chamber, means communicating said pressure chamber with the said intake passageway, a displaceable member comprising a wall of said chamber, means operable by said displaceable member responsive to the pressure in said chamber to vary the movement of one of the said movable orifice forming members whereby to increase the effective area of said orifice means as the pressure in said chamber decreases at fixed positions of said throttling means, and a connection between one of said orifice forming members and said throttle operating to increase the effective area of said orifice means as said throttle is opened and to decrease the effective area of said orifice means as said throttle is closed.

12. A carburetor for an internal combustion engine comprising means having an intake passageway for the flow of air therethrough, throttling means in said passageway, at least one metering orifice, means to supply fuel to said metering orifice and thence to said intake passage, a pressure regulator to control the differential of pressures on opposite sides of the said metering orifice, means to vary the opening of said metering orifice in accordance with the flow of air through the said intake passageway, said last-named means comprising a pressure chamber, means communicating said pressure chamber with the said intake passageway, two displaceable members included in opposite walls of said chamber, resilient means urging the two members in opposite directions, means operable by one of the said displaceable members to increase the size of the opening of the said metering orifice at fixed throttle positions as the pressure in said chamber decreases, and a connection between said throttle and the other of said displaceable members operating to increase the effective area of said orifice as said throttle is opened and to decrease the effective area of said orifice as said throttle is closed.

13. A carburetor for an internal combustion engine comprising means having an intake passageway for the flow of air therethrough, throttling means in said passageway, at least one metering orifice, means to supply fuel to said metering orifice and thence to said intake passageway, a pressure regulator to control the differential of pressures on opposite sides of the said metering orifice, means to vary the opening of the said metering orifice in accordance with the flow of air through the said intake passageway, said last-named means comprising a displaceable member responsive to pressure differential to vary the opening of the said metering orifice, a pressure chamber, said displaceable member comprising a wall of said chamber, resilient means to oppose the force of the pressure differential actuating said displaceable member, said displaceable member operating at fixed throttle position to increase the opening of said

metering orifice as the pressure in said chamber decreases, a fluid bleed circuit communicating with said chamber and having an outlet orifice communicating with the intake passage and an inlet orifice communicating with a region of pressure higher than the pressure at the outlet of said circuit, and means connected to said throttle to vary the effective area of one of said bleed circuit orifices whereby said displaceable member decreases the effective area of said metering orifice when said throttle is closed and increases the effective area of said metering orifice when said throttle is opened.

14. The combination defined in claim 6 and further including a fuel-air premixing chamber substantially adjacent the outlet side of said variable area restriction means, conduit means for introducing air into said chamber to form a rich mixture of fuel and air therein, and a discharge conduit for conducting said rich mixture to the said air conduit.

15. In a carburetor for an internal combustion engine having an intake passageway for the flow of air therethrough, throttling means in said passageway, a circuit for the flow of fuel therethrough, a metering orifice in said circuit, a differential pressure regulator to control directly the pressure differential across said metering orifice irrespective of the variation of the quantitative values of the individual pressures at the inlet and outlet sides of said metering orifice, and means to effect an increased flow of fuel through said orifice as the air-flow through said passageway increases, and to decrease the flow of fuel as the air-flow reduces, a fuel-air pre-mixing chamber, and conduit means for introducing air into said chamber to form a rich mixture of fuel and air therein, and a discharge conduit for conducting said rich mixture to the said intake passageway.

16. In a carburetor for an internal combustion engine having an intake passageway for the flow of air therethrough, a circuit for the flow of fuel therethrough, a metering orifice in said circuit, a pressure regulator to control fuel pressure at said metering orifice, and means to effect an increased flow of fuel through said orifice as the air-flow through said passageway increases, and to decrease the flow of fuel as the air-flow reduces, the improvement comprising a device in said carburetor to affect the flow of fuel therethrough including a pressure responsive member, valve means in said circuit to control fuel flow, said valve means including a valve body member and a seating member cooperable therewith, said pressure responsive member actuating one of said valve members, and leaf spring means supporting said last named member for substantially frictionless suspension to prevent surface contact of said last-named member during operational movements thereof except at the fully closed position of said last named member.

17. In a carburetor for an internal combustion engine having an intake passageway for the flow of air therethrough, throttling means in said passageway, the combination comprising, a circuit for the flow of fuel therethrough, a metering orifice in said circuit, a pressure regulator to control fuel pressure at said metering orifice, means to effect an increased flow of fuel through said orifice as the air-flow through said passageway increases, and to decrease the flow of fuel as the air-flow reduces, valve means in said circuit to control fuel flow, said valve means including a valve body member and a seating member

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cooperable therewith, and a pair of spaced substantially parallel and frictionless swingable members each having width imparting rigidity in one direction acting to support one of said valve members for substantially frictionless movements in a direction transverse to said first-named direction and to suspend said last-named valve member within the fluid controlled thereby with only fluid contact at the flow-controlling surfaces thereof during operational movements.

18. The combination defined in claim 11 in which said displaceable member comprises a closed pressure responsive member and further in which said movable orifice forming member is supported for substantially frictionless movement by leaf springs.

19. In a carburetor for an internal combustion engine having an exhaust manifold, a body having an intake passageway for the flow of air therethrough, throttling means in said passageway, at least one metering orifice, means to supply fuel to said metering orifice, a pressure regulator to control directly the differential of pressures on opposite sides of the said metering orifice irrespective of the variation of the quantitative values of the individual pressures at the inlet and outlet sides of said metering orifice, means to vary the opening of said metering orifice in accordance with the flow of air through the said intake passageway, and a conduit for conducting the fuel from said metering orifice into heat-exchange relationship with said exhaust manifold and thence to said intake passageway.

20. A carburetor for an internal combustion engine having an intake passage and a throttle therein, a metering orifice, means to supply fuel to said metering orifice and thence to said intake passage, a pressure regulator including a diaphragm and an associated regulator valve to control fuel pressure at said metering orifice, means to effect an increased flow of fuel through said orifice as the air-flow in said intake passage increases, a normally closed communication between one side of said diaphragm and said intake passage, and means to open said communication to impose full intake passage vacuum on said diaphragm in a direction to close said associated regulator valve when the throttle is in its idle position and the pressure on the downstream side of the throttle falls below the pressure corresponding to that at the idling position of the throttle.

21. In a carburetor for an internal combustion engine, a body having an intake passageway for the flow of air therethrough, throttling means in said passageway, at least two orifices, means to supply fuel to said orifices, means to control the differential of pressures on opposite sides of one of said orifices, means including a pressure responsive member to vary the opening of said one of said orifices in accordance with the flow of air through said intake passageway, means including a bi-metallic arm operable in accordance with the heat of the engine to vary the opening of the other of said orifices whereby said last named orifice is open when the engine is cold and gradually closes as the engine temperature increases.

22. A carburetor as defined by claim 6 in which said pressure regulator device includes a pressure responsive member and a valve member in said fuel flow circuit, a second valve member, means to establish communication through said second valve member between said pressure responsive member and the pressure at the dis-

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charge side of said metering orifice in a first position of said second valve member, and between said pressure responsive member and the pressure at the downstream side of said throttle in a second position of said second valve member, means urging said second valve member to stand in said first position, and pressure responsive means to move said second valve member to said second position when said throttle is in its idle position and the pressure in the intake manifold falls below the value of manifold pressure corresponding to normal idling condition, whereby said pressure responsive member is caused to move said first valve member to shut off the flow of fuel when said throttle is in its idle position and the pressure on the downstream side of said throttle falls below a predetermined minimum.

23. A carburetor for an internal combustion engine having an intake passage and a throttle therein, a metering orifice, means to supply fuel to said metering orifice and thence to said intake passage, a pressure regulator including a pressure responsive member and an associated regulator valve to control fuel pressure at said metering orifice, means to effect an increased flow of fuel through said orifice as the air-flow in said intake passage increases, a second valve member, means to establish communication through said second valve member between said pressure responsive member and the pressure at the discharge side of said metering orifice in a first position of said second valve member, and between said pressure responsive member and the pressure at the downstream side of said throttle in a second position of said second valve member, means urging said second valve member to stand in said first position, and pressure responsive means to move said second valve member to said second position when said throttle is in its idle position and the pressure in the intake manifold falls below the value of manifold pressure corresponding to normal idling condition, whereby said pressure responsive member is caused to move said regulator valve to shut off the flow of fuel when said throttle is in its idle position and the pressure on the downstream side of said throttle falls below a predetermined minimum corresponding to that at the idling position of said throttle.

24. The combination of elements defined in claim 15 and in which said means to effect an increase flow of fuel through said orifice includes pressure responsive means and valve means actuated thereby to vary the effective aperture of said orifice, conduit means connecting one side of said pressure responsive means to pressure in said intake passageway, and said first-named air conduit means connecting the other side of said pressure responsive means with a region of substantially constant air pressure.

25. The combination of elements defined in claim 15 in which said circuit includes a fuel inlet means, and said differential pressure regulator comprises; valve means in said fuel inlet means to vary the opening of said fuel inlet means, a pressure responsive member connected to said valve means for actuation thereof, one side of said pressure responsive member communicating with the fuel pressure at the inlet side of said metering orifice, and the other side of said pressure responsive member communicating with the fuel pressure at the outlet side of said metering orifice, and biasing means acting on said valve means to oppose the differ-

ence of said pressures acting on opposite sides of said pressure responsive member, whereby to control directly only the pressure differential across the said metering orifice irrespective of the variation of the quantitative values of the individual pressures at the inlet and outlet sides of said metering orifice.

26. In a carburetor for an internal combustion engine having an intake passageway for the flow of air therethrough and throttling means therein, the combination comprising, a circuit for the flow of fuel therethrough, metering orifice means in said circuit, said orifice means including a movable valve member for varying the opening of said orifice means, a differential pressure regulator for controlling directly only the pressure differential across said orifice means irrespective of the variation of the quantitative values of the individual pressure at the inlet and outlet sides of said orifice means, means to effect an increased flow of fuel through said orifice means as the air-flow through said intake passageway increases, and to decrease the flow of fuel as the air-flow reduces, said last-named means including pressure responsive means connected to said movable valve member for actuation thereof, conduit means connecting one side of said pressure responsive means to said intake passageway, an air chamber, the other side of said pressure responsive means forming a wall of said air chamber, a fuel-air pre-mixing chamber, said pre-mixing chamber including said orifice means and containing fuel discharged therefrom, a second wall of said air chamber separating said pre-mixing chamber and said air chamber, said movable valve member projecting through said second wall into said pre-mixing chamber to vary the opening of said metering orifice means, air conduit means connecting said air chamber with a region of substantially constant air pressure, said second wall including an aperture therein for the flow of air therethrough, and a discharge conduit connecting said pre-mixing chamber with said intake passageway at a point to produce pressures in said pre-mixing chamber slightly less than said constant air pressure, whereby air will flow through said air conduit means and through said aperture to form a rich mixture of fuel and air in said pre-mixing chamber for passage through said discharge conduit to said intake passageway.

27. The combination of elements defined in claim 26, and substantially frictionless swingable means having width imparting rigidity in one direction acting to support said movable valve member for substantially frictionless movements in a direction transverse to said first-named direction and to suspend said movable valve member within the fluid controlled thereby with only fluid contact at the flow-controlling surfaces thereof during operational movements, said movable valve member projecting through said aperture in said second wall, and said aperture providing perimetral clearance for said movable valve member to prevent surface contact therewith, whereby the movements of said movable valve member are free from the adverse effects of gum deposits from the fuel.

28. The combination of elements defined in claim 19, in which said means to vary the opening of said metering orifice includes pressure responsive means and valve means actuated thereby, conduit means connecting one side of said pressure responsive means to pressure in said intake passageway, and air conduit means

connecting the other side of said pressure responsive means to a region of substantially constant air pressure.

29. In a carburetor for an internal combustion engine having an exhaust manifold for the flow of exhaust gases therethrough, a body having an intake passageway for the flow of air therethrough, throttling means in said passageway, the combination comprising, a circuit for the flow of fuel therethrough, metering orifice means in said circuit, said orifice means including a movable valve member for varying the opening of said orifice means, a differential pressure regulator for controlling directly only the pressure differential across said orifice means irrespective of the variation of the quantitative values of the individual pressures at the inlet and outlet sides of said orifice means, means to effect movement of said valve member in response to changes in the flow of air through said intake passageway, said last-named means including pressure responsive means connected to said valve member for actuation thereof, conduit means connecting one side of said pressure responsive means to pressure in said intake passageway, an air chamber, the other side of said pressure responsive means forming a wall of said air chamber, said metering orifice means and the fuel discharged therefrom being outside said chamber, said movable valve member projecting through a second wall of said air chamber to vary the opening of said metering orifice means, air conduit means connecting said air chamber with a region of substantially atmospheric air pressure, said second wall including an aperture therein for the flow of air therethrough, a heat exchanger for absorbing a portion of the heat in the exhaust gases, and a conduit for conducting the fuel from the discharge side of said orifice means through said heat exchanger into heat exchange relationship with said heat from the exhaust gases and thence to said intake passageway, said fuel-conducting conduit communicating with said intake passageway at a region of sufficient vacuum to produce slightly sub-atmospheric fuel pressures at the discharge side of said metering orifice means, whereby air will flow through said air conduit means and through said aperture to mix with the fuel at the discharge side of said orifice means, the fuel and entrained air being preheated when passing through said heat exchanger in said fuel-conducting conduit to said intake passageway.

30. The combination of elements defined in claim 29, and substantially frictionless swingable means having width imparting rigidity in one direction acting to support said movable valve member for substantially frictionless movements in a direction transverse to said first-named direction and to suspend said movable valve member within the fluid controlled thereby with only fluid contact at the flow-controlling surfaces thereof during operational movements, said movable valve member projecting through said aperture in said second wall, and said aperture providing perimetral clearance for said movable valve member to prevent surface contact therewith, whereby the movements of said valve member are free from the adverse effects of gum deposits from the fuel.

31. The combination of elements defined in claim 29, and a pair of spaced substantially parallel leaf spring members having width imparting rigidity in one direction acting to support said movable valve member for substantially fric-

tionless movements in a direction transverse to said first-named direction and to suspend said movable valve member within the fluid controlled thereby with only fluid contact at the flow-controlling surfaces thereof during operative movements, said movable valve member projecting through said aperture in said second wall, and said aperture providing perimetral clearance for said movable valve member to prevent surface contact therewith, whereby the movements of said valve member are free of the adverse effects of gum deposits from the fuel.

32. In a carburetor for an internal combustion engine having an intake passageway for the flow of air therethrough, throttling means in said passageway, the combination comprising, a circuit for the flow of fuel therethrough, a metering orifice in said circuit, a pressure regulator to control fuel pressure at said metering orifice, means to effect an increased flow of fuel through said orifice as the air-flow through said passageway increases, and to decrease the flow of fuel as the air-flow reduces, said last-named means including a substantially frictionless pressure responsive member, the movable effective area of said member contacting only the actuating fluid in its operative movements without sliding surface contact, conduit means connecting said pressure responsive member to pressure in said intake passageway to effect movement thereof in response to changes in the flow of air through said intake passageway, valve means in said circuit to control fuel flow, said valve means including a valve body member and a seating member co-operable therewith, said pressure responsive

member connecting with one of said valve members for actuation thereof, and substantially frictionless swingable means having width imparting rigidity in one direction acting to support said last-named valve member for substantially frictionless movements in a direction transverse to said first-named direction and to suspend said last-named valve member within the fluid controlled thereby with only fluid contact at the flow-controlling surfaces thereof during operational movements, whereby the combined movements of said pressure responsive member and said supported valve member are substantially instantaneous and are free of the adverse effect of gum deposits from the fuel.

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