

Feb. 9, 1960

C. E. SUMMERS

2,924,210

INTERNAL COMBUSTION ENGINES

Original Filed Sept. 27, 1956

4 Sheets-Sheet 1

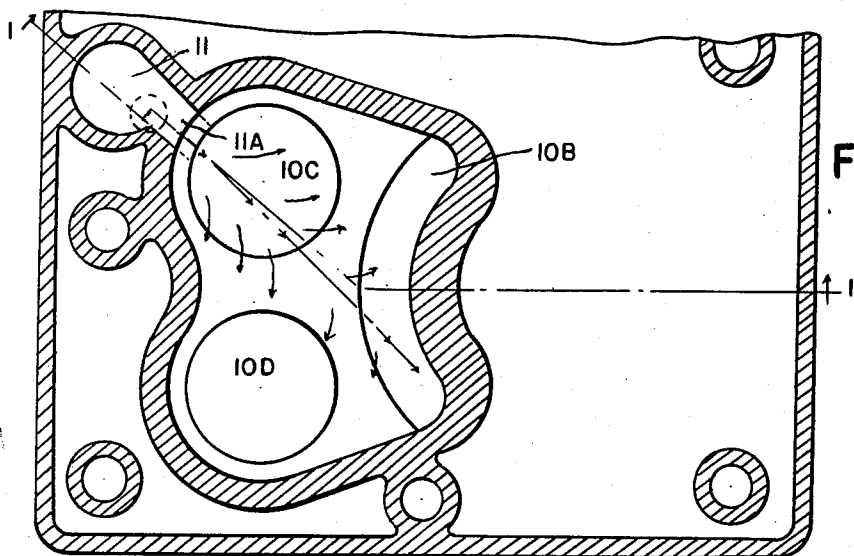


FIG. 2.

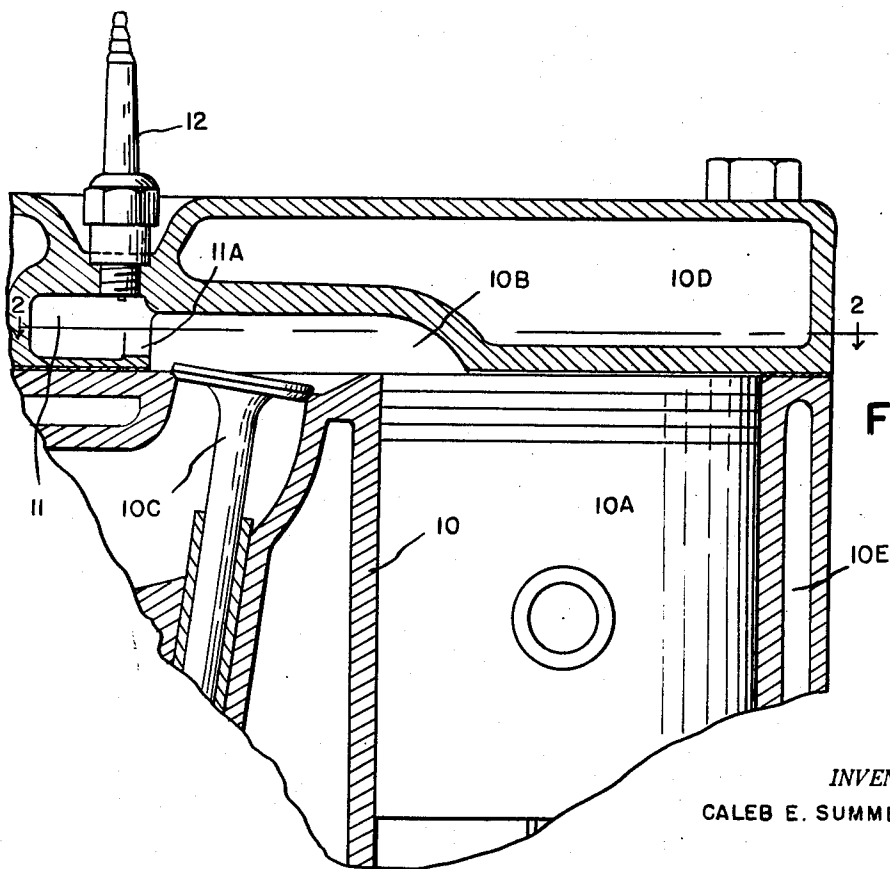


FIG. 1.

INVENTOR.
CALEB E. SUMMERS

Feb. 9, 1960

C. E. SUMMERS

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FIG. 6.

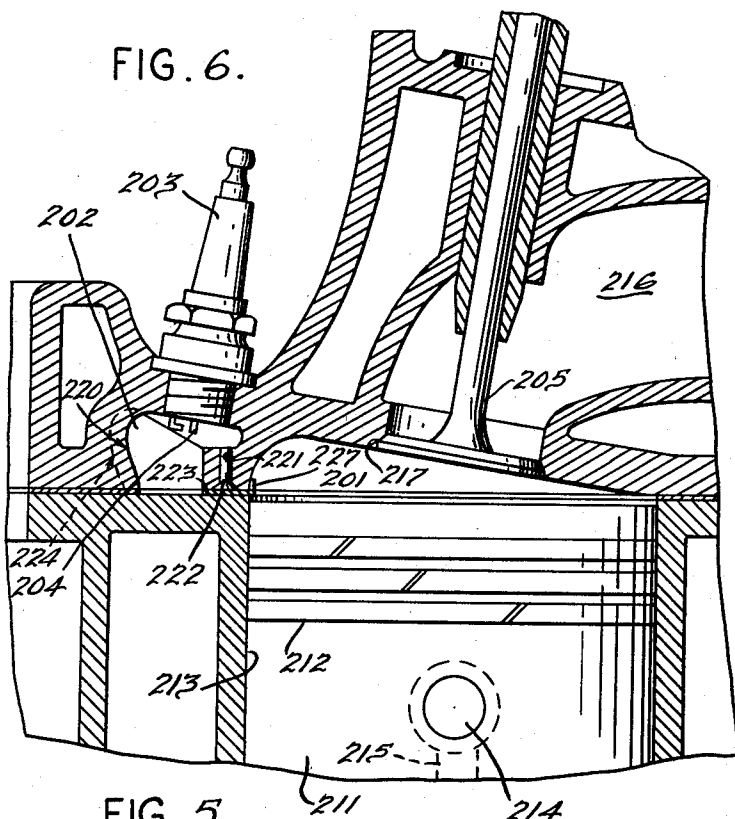


FIG. 7.

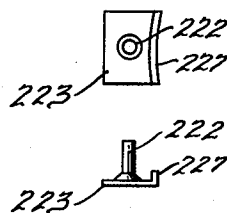


FIG. 8.

FIG. 5.

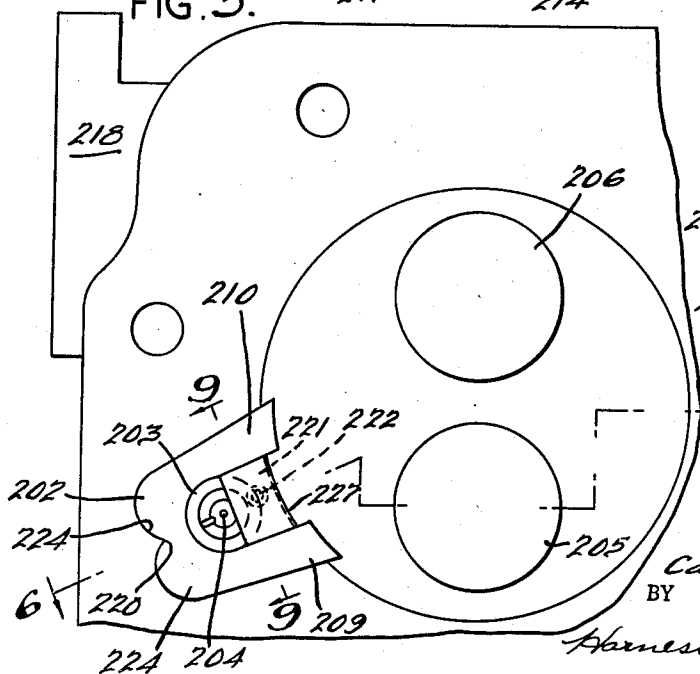
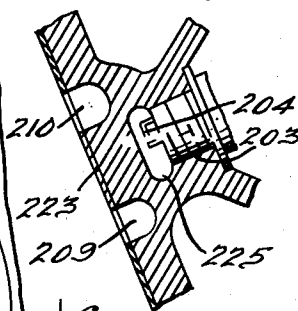


FIG. 9.



INVENTOR.

Caleb E. Summers.

BY

Horness, Dickey & Pierce
ATTORNEYS.

Feb. 9, 1960

C. E. SUMMERS

2,924,210

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4 Sheets-Sheet 4

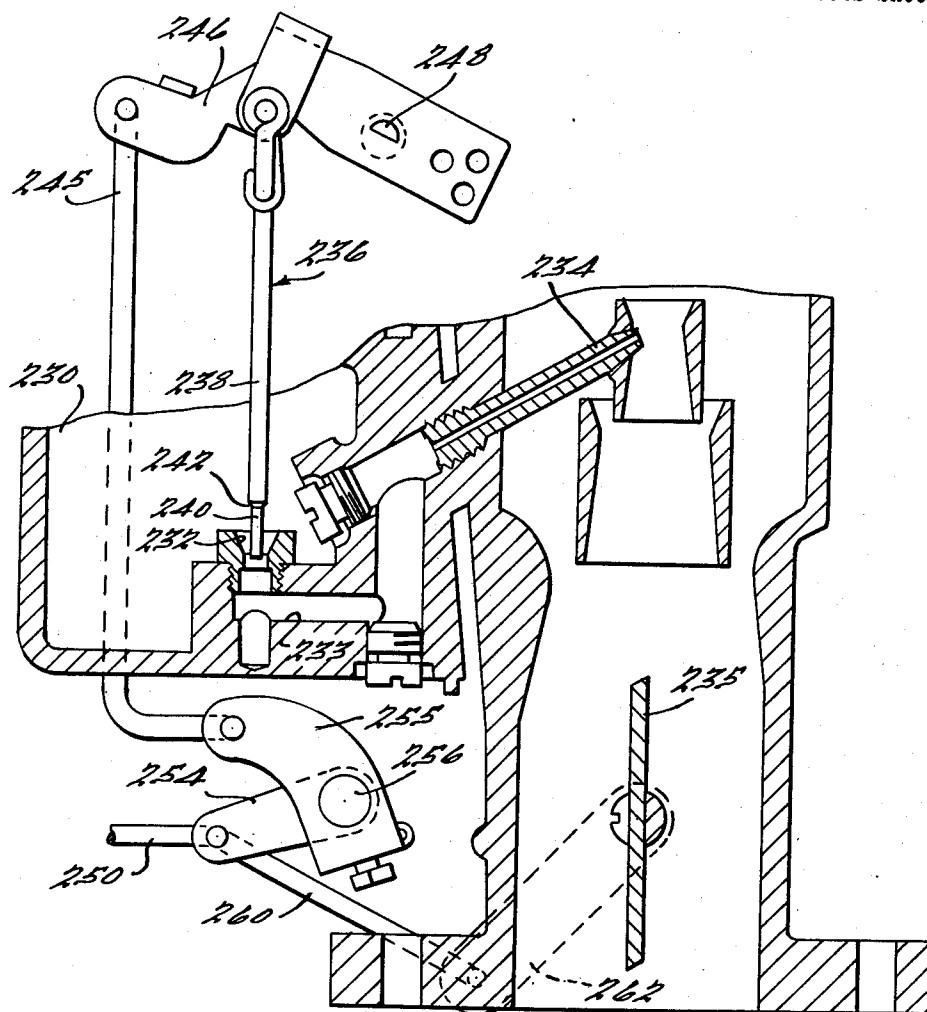


FIG. 10.

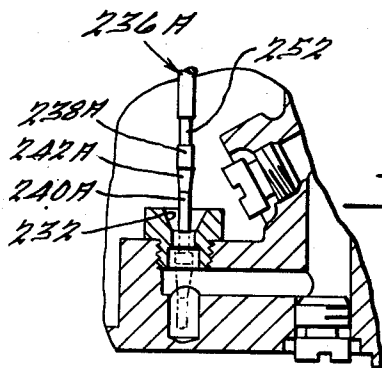


FIG. 11.

INVENTOR.

Caleb E. Summers.

BY

Harness, Dickey & Puris.
ATTORNEYS.

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2,924,210

INTERNAL COMBUSTION ENGINES

Caleb E. Summers, Orchard Lake, Mich.

Continuation of abandoned application Serial No. 612,450, September 27, 1956. This application August 8, 1958, Serial No. 754,092

34 Claims. (Cl. 123—191)

The present invention relates to internal combustion engines of the Otto cycle type and specifically to methods and/or means for controlling the combustion of fuel in such engines.

The present application is a continuation of my previously filed copending application Serial No. 612,450 filed September 27, 1956, now abandoned, as to all subject matter common to the two. Said application Serial No. 612,450 was a continuation-in-part of each of two applications filed theretofore but copending therewith and identified as applications Serial Nos. 152,940, filed March 30, 1950, now abandoned, and Serial No. 317,085, filed October 27, 1952, now abandoned.

Among the objects of the invention is to control such combustion so as to permit higher compression ratios, without detonation, combustion roughness or the use of special fuels, with a resulting gain in power and economy.

A further object is to provide means for obtaining such combustion control.

Among further objects of the invention are:

To provide means for handling the fuel-air mixture or charge during compression so substantially homogeneous mixtures drawn from the carburetor and which are much leaner than a balanced mixture, can be fired positively and efficiently by a spark.

To provide means for handling the charge during combustion, so that importantly higher compression ratios can be used without detonation or combustion roughness.

Practical results of the leaner part load mixture and the higher compression ratio are to increase materially the power and economy of operation of the engine, to reduce carbon deposits in the combustion chamber and fuel dilution of the crankcase oil.

Another result is easier cold weather starting and an immediate full power drive away.

All these and other advantages will readily occur to those skilled in the art upon reference to the following description and the accompanying drawings in which:

Figure 1 is a sectional view as if on line 1—1 of Fig. 2 of the upper portion of one cylinder of a multicylinder L-head engine illustrating the invention;

Fig. 2 is a section on line 2—2 of Fig. 1;

Fig. 3 is a view similar to Fig. 1 but showing a valve-in-head engine, the section being taken on line 3—3 of Fig. 4;

Fig. 4 is a view of the underside of the head shown in Fig. 3;

Fig. 5 is a plan view of the underside of a portion of the cylinder head of an engine incorporating the invention in modified form;

Fig. 6 is a sectional view of the upper portion of the engine of Fig. 5, corresponding to a section on the line 6—6 of Fig. 5 and looking in the direction of the arrows;

Figs. 7 and 8 are respectively a top plan view and a side elevation of a detail of this embodiment;

Fig. 9 is a section on the line 9—9 of Fig. 5;

Fig. 10 is a fragmentary sectional and partly diagrammatic view of a carburetor adapted for use with the

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engine shown in Figs. 5-9 and in the practice of my invention, and

Fig. 11 is a sectional elevational view of the metering jet and metering pin portions of a carburetor provided with a modified type of metering pin.

In the drawings there is shown only a single cylinder, and its head, of an internal combustion engine which may be a multicylinder engine of conventional construction throughout except for certain of the parts illustrated.

Referring to Figs. 1 and 2, a single cylinder of a conventional L-head block is shown at 10 with its piston 10A, combustion chamber 10B, inlet and exhaust valves 10C and 10D respectively and water jacketing 10E.

The head of the cylinder is illustrated as being provided with a small chamber 11 communicating with the combustion chamber 10B through a passage 11A, a spark plug 12 being set in said small chamber.

It should be noted that the passage 11A opens into chamber 11 unsymmetrically and that the plug 12 is located at the chamber end close to the passage. It should also be noted that the geometric shape of chamber 11 should not be such as would be generated by the rotation of a curve about its axis, but that the side wall should be of spiral form with a small gradual increase in radius. The passage 11A is tangential to the chamber and the spiral so arranged that the larger radius portion is at one side of the passage with the spark gap at the end of the spiral.

It will also be seen from Fig. 1 that the floor of chamber 11 is elevated a short distance so that the bottom of passage 11A is above the level of the heads of valves 10C and 10D when the valves are closed.

In Figs. 3 and 4 a single cylinder of a multicylinder valve-in-head engine is shown at 110, piston at 110A, combustion chamber 110B, inlet and exhaust valves at 110C and 110D respectively and water jacketing at 110E.

In these figures, the cylinder head is also shown as provided with a small chamber 111 communicating with the main combustion chamber 110B through a small passage 111A and into which is set a spark plug, the plug and the opening therefor being indicated at 112. Since, in the valve-in-head engine, the valves are above the combustion chamber 110B, the floor of chamber 111 including the passage 111A, may be the top surface of the block including cylinder 110.

In the operation of the engine, as the piston moves down with the inlet valve open, a charge of fuel-air mixture is drawn in from the manifold and carburetor in the conventional manner. When the inlet valve closes and the piston moves up on the compression stroke, compressing the mixture, part of the latter will flow into chamber 11 through the passage 11A. Since the passage 11A opens unsymmetrically into chamber 11, the inflow causes a rapid rotation of the gases in the chamber and thereby, through centrifugal action, causes any liquid particles or fog of the fuel to be thrown toward the periphery of the rotating mass. And, as the mixture continues to be forced in through passage 11A, this band of richer mixture is driven up to the spark gap of spark plug 12.

Further, since the geometric shape of chamber 11 is not such as could be generated by the rotation of a curve about its axis, as the fluid in chamber 11 rotates under the drive of the blast coming in through passage 11A, the chamber walls tend to knead the charge into an intimate mixture while quickly damping out the rotation when the exciting force subsides.

By locating the spark close to the inner end of passage 11A, the ignited gases issue immediately into the combustion chamber 10B, and since the axis of the passage is lined up with the most distant wall of the combustion chamber, the stream of ignited gases is projected cen-

trally through the compressed mixture but will not impinge forcibly on any metal surface.

The relative size of chamber 11 is so chosen that the fire blast issuing from passage 11A is all absorbed by the gases in the combustion chamber 10B, the tongue of flame neither falling short of reaching across the combustion chamber nor yet heavily impinging on the metal wall.

The cross-sectional area of passage 11A is so chosen with respect to the average of the flame front in chamber 11 that the velocity of the flame issuing from passage 11A into the combustion chamber 10B is approximately three times the velocity of a flame front in a quiet mixture. Thus, by the time the flame front has advanced in chamber 11 only a short distance from the spark gap, the igniting blast issuing from passage 11A has crossed the combustion chamber 10B carrying ignition on both of its turbulent edges.

In the conventional engine with spark ignition in the combustion chamber, combustion starts weakly from the spark and advances slowly on its initially very limited flame front, but, as the flame front increases in area and the temperature and pressure rise, the rate of combustion is expedited in the order of the third power of elapsed time after sparking. This condition invites roughness and detonation.

On the other hand, in the present invention with the combustion being initiated in chamber 11, before normal propagation could reach the main combustion chamber, the pressure developed in chamber 11 will shoot an igniting flame entirely across the main combustion chamber on its longest dimension. Thus a flame front double the diameter of the combustion chamber is established immediately and flame proceeds in two directions with diminishing rates of pressure rise.

Referring now to the embodiment of Figs. 5-9 inclusive, a main combustion chamber is shown at 201, intake and exhaust valves at 205 and 206 respectively. Conventional rocker arms and pushrods entrained with tappets and cams (not shown) actuate the valves 205 and 206. A piston 211 with compression rings 212 reciprocate in the cylinder 213. A piston pin 214 and a connecting rod 215 attach the said piston 211 to a crankshaft (not shown). The intake passage 216 terminating at its inner end in the valve seat 217 and the flow there-through controlled by the valve 205, is connected at its outer end to a source of air-fuel mixture (not shown). The exhaust port controlled by the exhaust valve 206 is in pipe connection at its outer end with an exhaust manifold (not shown). All the structure referred to in this paragraph is conventional.

In addition to the conventional structure described, the cylinder head is also provided with an initial combustion chamber 202 at one side of the main combustion chamber and communicating therewith through the passages 209 and 210, the chamber and passages being preferably produced by suitable cores when the head is cast, the passages and chamber being open to the under face of the head member.

As shown in Fig. 5, both the side walls of the chamber 202, at the rear end of the chamber, are curved as at 224, and meet centrally to provide a relatively sharp edge 220, and as shown in Fig. 6, these walls in their curved portion 224 are also curved in a vertical plane so that the two streams of gases coming in through the passages 209 and 210 are turned inwardly toward each other and also turned upwardly.

Mounted in the upper wall of chamber 202 is a spark-plug 203, in such position that the spark gap 204 is in the upper and forward portion of the chamber.

The invention resides principally in the relative size and shape of the initial combustion chamber 202 and its relation to the main combustion chamber 201; the size and position of the passages 209 and 210 providing communication between the initial combustion chamber 202

and the main combustion chamber 201; the location of the spark gap 204 of the spark plug 203 in its relation to the passages 209 and 210 and the curved inner surface 224 of the chamber 202 and the edge 220; means for cooling the separator 221, also means of forming the chamber 202 and the passages 209 and 210 and their closure at one side of the cylinder block 213.

In operation, during the compression stroke, the piston 211 forces mixture into the chamber 202 through the passages 209 and 210. The total cross-sectional area of the passages 209 and 210 as shown in the drawings, is less than half the cross-sectional area of the chamber 202 and is so chosen in proportion to the volume of chamber 202, that the velocity of inflow into chamber 202 during compression, is high. The inrushing mixture strikes the curving surface 224 and is turned 180°. The centrifugal force tends to separate out any fuel particles or fog. The two streams of richer mixture moving on or near the surface 224, meet at the edge 220 and are deflected by the tilt of the surface 224 (see Fig. 6) toward the spark gap 204 and the pocket 225 which is above and separated from the passages 209 and 210 (see Fig. 9). Thus a richer fraction is abstracted from a lean mixture and carried to the area of the spark gap. This gives a strong ignition which readily fires all the mixture in chamber 202. The projection of two flames into the main combustion chamber 201, gives a positive and rapid ignition to the mixture therein whether ultra lean or balanced.

The structure described in the foregoing paragraph which enables the motor to fire perfectly on very lean mixture, also permits a compression one or more ratios higher. As combustion proceeds from the spark gap 204, the area of the flame front becomes larger than the combined cross-sectional areas of the passages 209 and 210. The velocity of discharge of the burning gases is therefore higher than the orderly speed of a flame front in a mixture. The passages 209 and 210 direct the flame toward the most distant wall of the combustion chamber, and the volume of the chamber 202 is so chosen that the issuing flames carry across but do not impinge forcibly on any wall of the chamber 201. Thus by the actual transfer at high velocity of burning gases, the rate of initial combustion is increased four to six times with a diminishing rate of pressure rise as the flame burns through to the combustion chamber walls in places.

This relatively rapid burn of the first two thirds of the charge with the rate diminishing to zero, is the opposite of conventional combustion which starts slowly and builds up to a very rapid finish. Moreover, the extreme turbulence in the burning mixture, caused by impinging two high velocity flames into it, gives a condition that suppresses detonation. The turbulence also gives such a thorough mixture that few fuel molecules escape, being compined with the oxygen of the charge early in the power stroke.

It is desirable that the volume of flame issuing from passages 209 and 210 respectively should be proportional to the volume of compressed mixture into which it is thrown. In case the main combustion chamber 201 is not symmetrical with the center line of the initial combustion chamber 202, the passage serving the larger volume as 210 (Figs. 5 and 9) is preferably larger than its companion passage 209. It is desirable also that the center lines of passages 209 and 210 be slightly divergent toward chamber 201 and that the cross-sectional area of each passage should increase progressively in the flow from chamber 202 to chamber 201.

To aid in cooling the tongue of metal 221 between the passages 209 and 210, a rivet 222 of copper or other metal of high thermal conductivity and high melting point is inserted in a drilled hole in said tongue 221. The rivet would be of a special form—the head flattened to the same thickness as the cylinder head gasket so it will bear tightly against the cylinder block 213. A

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turned edge 227 (Fig. 8) would hold the head in angular position. The rivet preferably is tin plated to prevent oxidation and so improve heat flow through the surface and its head may, as shown, be proportioned to underlie substantially all of the tongue portion 221. The rivet can be staked through the opening for the spark plug and the pocket 225.

As indicated hereinabove, my improved engine and method attain superior operation at less than full load with fuel-air mixtures leaner than normal. In fact, at light loads, perfect firing is attained with 100% excess air over that required for combustion. Of course in order to develop full power, a full balanced mixture should be supplied at full loads. The invention is also productive of important benefits when so operating at full loads with a normal mixture. Due to the projection of the flaming jet or jets into the main charge from the precombustion chamber, the initial rate of flame propagation is much higher than in conventional engines, although the rate of combustion slows toward the end. This is opposite to conventional practice, in which the initial rate of flame propagation is slow, but increases rapidly toward the end. The latter characteristic of conventional engines is regarded as a cause of detonation. My invention operates with less detonation and with a much later spark setting at full loads. This elimination of the need for a greatly advanced spark at high engine loadings also eliminates the negative work and heat loss occasioned in conventional engines by the early spark and partial burning of the charge long before the piston reaches dead center.

As previously indicated, the carburetor and fuel supply means may be conventional in construction. In Fig. 10 I have indicated, somewhat diagrammatically, essential portions of a conventional carburetor adapted to supply the engine of Figs. 5-9. Gasoline is supplied from a carburetor float bowl 230 through metering jet orifice 232, passages 233 and nozzle 234 into the throat of the carburetor, where the gasoline is atomized and mixed with the inflowing air, and carried past the throttle valve 235 and through the manifold passages and inlet passages as 216 (Fig. 6) to the cylinders.

As shown in Fig. 10 the metering valve pin, generally designated 236, has an upper cylindrical portion 238 which is somewhat smaller in diameter than the metering jet orifice 232, and a lower end portion 240, which is also cylindrical, and which is of smaller diameter than the upper portion 238 and joined thereto by a relatively abrupt shoulder 242. The metering pin is so connected to the operating means for the throttle valve 235 that movement of the throttle operating link 250 to a position to fully open the throttle, moves the metering pin upwardly so that only the small portion 240 obstructs the metering jet orifice, and the effective cross section of the orifice is then great enough to supply a full balanced mixture. As the throttle is moved toward closed position, the metering pin moves downwardly, and for approximately the first ten degrees of movement of the throttle valve toward the closed position, only the small pin portion 240 is in the orifice 232, so that the full mixture is supplied until, as the shoulder 242 reaches the small portion of the orifice, the effective cross section of the orifice is reduced by the entry of the larger diameter portion 238 thereinto. The portion 238 is of a diameter such as to admit fuel in proportion to the air in a quantity only sufficient to provide approximately one half a balanced mixture, and as the cylindrical portion 238 continues to move downwardly, in response to further closing movement of the throttle, the reduced mixture is maintained right down to idle.

Fig. 11 illustrates a modification wherein the metering pin is provided with a cylindrical lower portion 240A, proportioned and positioned to provide a full balanced mixture at full throttle, and corresponding to the part 240 of Fig. 10. The length of part 240A may be such

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as to maintain a full balanced mixture as the pin moves downwardly during an initial increment of closing movement of the throttle from full open (e.g. 10°). Above the cylindrical lower part 240A the pin is provided with a portion 242A of gradually increasing diameter and which tapers outwardly and upwardly and which at its upper end is joined to a cylindrical portion 238A which is of a diameter to maintain a desired lean mixture. This cylindrical part 238A is in the light throttle range, and its diameter may be such as to supply approximately one half of a balanced mixture. When the pin is moved downwardly all the way, however, to the position it occupies at idle, a somewhat reduced portion 252 of the pin is brought into the metering orifice, thereby somewhat enlarging the effective orifice at idle. This reduction of diameter need only be sufficient to insure smooth idling, and may either be a full balanced mixture, or somewhat less than a full balanced mixture, as the preference of the designer and the operating characteristics of the engine may dictate. It will also be realized that the contour of the metering pin may be varied in other ways to give the best performance, and that this may be experimentally determined for each type of engine to which my invention may be applied. With the provision of an inclined portion, such as the portion 242A, as the throttle is moved toward the closed position in this range, the metering pin gradually reduces the effective cross section of the jet orifice 232 more rapidly than, and to a leaner mixture than, do the designs employed in conventional engines. It will be appreciated also that in varying the contour of the pin, such a graduated portion, instead of having a straight taper as does the portion 242A, may be longitudinally curved to vary the rate of change of the effective orifice diameter during throttle movements.

With conventional engines, the metering pin or other gasoline flow-controlling means of the carburetor is designed to tend to maintain substantially a balanced mixture at all throttle settings. In contrast, I modify this means in such manner as to reduce the mixture to a lower fuel-air ratio as the throttle is moved toward closed position, and vice versa. Although with a carburetor of the indicated variety this is done by modifying the metering pin, it will be appreciated that other types of gasoline flow-regulating means may readily be modified in an analogous manner. Tests have indicated that the proportioning of the valving end of the metering pin of a carburetor of the type illustrated may be such that at approximately half loads, the amount of fuel supplied may be approximately one half normal, as indicated. Thus the metering pin (or the other gasoline flow-controlling means of the carburetor) is so designed as to vary the mixture between a full mixture at full load and a relatively very lean mixture at part load.

In the particular carburetor illustrated, the throttle actuating arm 250 is presumed to be actuatable in conventional fashion by an accelerator pedal, and is connected to arm 254 of an angularly adjustable crank assembly comprised of arms 254, 255, rockable as a unit about the axis of their supporting shaft 256. Arm 255 is connected by a link 245 to a lever 246 rockable upon a fulcrum shaft 248, the upper end of the metering pin 236 being articulated to the arm 246 between the fulcrum 248 and the point of connection of link 245, as shown in Fig. 10. Arm 254 is also connected by link 260 to throttle valve actuating arm 262, which is fast with respect to throttle valve 235, so that the throttle is moved toward closed position as the metering pin 236 is moved downwardly, and vice versa, in the manner above described.

It will be appreciated that many carburetors of this general class are provided with manifold pressure-responsive or so-called "vacuum-meter" means, so arranged as to tend to move the metering pin to, or hold it in, an open position if the manifold pressure rises too high (vac-

uum falls away) thus tending to maintain or establish a richer mixture when engine loading makes it desirable at part throttle. Such a provision is of course desirable but is not a part of my invention and would have no bearing upon the operation of my improved engine except, as with conventional engines, to tend to maintain a richer mixture when the engine is heavily loaded at part throttle. The construction of the carburetor, as well as the means for regulating or metering the flow of gasoline is subject to wide variation in other respects, and in fact different constructions are employed for this purpose by different carburetor manufacturers. The means employed to perform this function does not in itself constitute an essential element of the present invention, except to the extent that it provides means for varying the mixture so that when the throttle is operated in the normal manner, and the engine is operating under normal conditions, the supply of liquid gasoline will vary between a lean mixture at light loads and a normal balanced mixture at full load. The specific illustrated forms of the other conventional engine components are of course also shown by way of example.

What is claimed is:

1. In an internal combustion engine having a portion defining an enclosed space constituting a cylinder portion and a main combustion chamber portion, means for introducing into said space a charge of generally homogeneous pre-carbureted air constituting the full air-fuel charge for said cylinder, a piston reciprocable in said cylinder portion toward and from the said main combustion chamber portion, means defining an initial combustion chamber having no separate fuel charging means, said initial combustion chamber being separated from said space, and a restricted opening portion providing communication between said initial combustion chamber and said main combustion chamber portion, said initial combustion chamber having a concavely curved wall portion substantially tangent to the path of gases entering said initial combustion chamber from the main combustion chamber portion through said opening portion, localized ignition means in said initial combustion chamber positioned in the path of gases which may be guided by and along said curved wall portion, the restriction and direction of said opening portion being such as to direct an accelerated inflowing stream of the air-fuel charge into the initial combustion chamber and substantially tangentially against and along said curved wall portion in response to movement of the piston toward the main combustion chamber portion, and to direct an accelerated flaming jet into said main combustion chamber portion from said initial combustion chamber when firing is effected in said initial combustion chamber by said ignition means, the curved wall portion being interposed in the path of said inflowing stream between the opening portion and the ignition means to impart angular movement to said inflowing stream, thereby tending to separate heavier fuel components in said inflowing stream centrifugally and to guide and direct them toward said ignition means.

2. In an internal combustion engine as defined in claim 1, cooling means for extracting heat from said curved wall portion.

3. In an internal combustion engine having a portion defining an enclosed space constituting a cylinder and a main combustion chamber, means for introducing into said space a generally homogeneous charge of pre-carbureted air constituting the full air-fuel charge for said cylinder, a piston reciprocable in said space toward and from said main combustion chamber portion thereof, means defining an initial combustion chamber having no separate fuel charging means, means defining a pair of restricted passages interconnecting laterally spaced portions of said initial combustion chamber with said main combustion chamber portion, a partitioning wall located between said passages and separating said initial combustion

chamber from said space, said initial combustion chamber having two concavely curved wall portions, each of which is substantially tangent to an outer wall of one of said passages, said curved wall portions curving toward one another and defining the outer walls of said initial combustion chamber and curving re-entrantly inwardly with respect to said initial combustion chamber and forming at their juncture a generally pointed centrally disposed wall portion directed toward said partitioning wall, a spark plug having electrodes located in said initial combustion chamber substantially on a line between said pointed wall portion and said partitioning wall, the restriction and direction of each of said passages being such as to direct an accelerated inflowing stream of the air-fuel charge into the initial combustion chamber during movement of the piston toward the main combustion chamber and to direct an accelerated flaming jet into said space from said initial combustion chamber when firing is effected in said initial combustion chamber by said spark plug, each of the curved walls being interposed, considered in the path of the inflowing stream, between one of said passages and the electrodes, whereby convergent and re-entrant angular movement of said two inflowing streams is effected by said curved walls, and said streams are re-directed toward said electrodes, the angular momentum of the fuel tending to separate the heavier components of the fuel and to cause them to move in relatively close proximity to said curved walls, said curved walls and said pointed juncture thereof being positioned to direct said heavier components toward said electrodes.

4. An engine construction as defined in claim 3 having a separable water jacketed head, said main combustion chamber portion and said initial combustion chamber being formed in said head, a water jacketed portion in said head appurtenant to said curved wall portions for extracting heat from the latter, a water jacketed block portion defining the cylinder portion of said space, and a heat conductive metallic portion incorporated in said partitioning wall and bearing against said block.

5. An engine as defined in claim 1 wherein said ignition means is located closer to said opening than is at least a portion of said initial combustion chamber, whereby upon firing of the ignition means a portion of the flame front moves outwardly through the opening and into said space and a portion of the flame front moves into portions of the initial combustion chamber spaced from the opening to increase the pressure in the initial combustion chamber.

6. An engine as defined in claim 3 wherein said ignition means is located closer to said passages than is at least a portion of said initial combustion chamber, whereby upon firing of the ignition means a portion of the flame front moves outwardly through the passages and into said space and a portion of the flame front moves into portions of the initial combustion chamber spaced from the passages to increase the pressure in the initial combustion chamber.

7. An engine as defined in claim 1 wherein said opening opens into said main combustion chamber in a direction substantially transverse to the direction of movement of the piston and is so proportioned that a blast of flame is directed into the main combustion chamber through said opening upon ignition of the charge within said initial combustion chamber with a force sufficient to carry said blast substantially entirely across the main combustion chamber without impinging heavily against the opposite side of said main combustion chamber.

8. An engine as defined in claim 3 wherein said passages open into said space in a direction substantially transverse to the direction of movement of the piston and are so proportioned that blasts of flame are directed into the main combustion chamber through said passages upon ignition of the charge within said initial combustion chamber with a force sufficient to carry said blasts substantially entirely across the main combustion chamber with-

out impinging heavily against the opposite side of said main combustion chamber.

9. In an internal combustion engine, a main combustion chamber and an initial combustion chamber, a pair of passages converging toward the latter and affording communication between the two chambers, the combined cross-sectional area of the passages being less than half the cross-sectional area of said initial combustion chamber on any medial plane, said initial combustion chamber having a vertically arranged V-shaped inwardly projecting rear wall, the side walls of said initial combustion chamber being continuations of the outer side walls of said passages and being curved and having the curvature continued to meet at the apex of the V-shaped rear wall, said rear wall being also vertically inclined, and a spark plug fixed in the upper wall of said initial combustion chamber with its spark gap central laterally of the latter and substantially over the inner ends of the passages.

10. An internal combustion engine as defined in claim 1 including a block containing said cylinder-defining portion, and a removable head with a substantially planar bottom face adapted to fit over and substantially close the cylinder-defining portion, both the main combustion chamber portion and the initial combustion chamber being formed in said head and opening in said bottom face thereof, said block having a substantially planar head-supporting wall extending outwardly from the end of said cylinder-defining portion nearest to said main combustion chamber portion, the open portion of said initial combustion chamber overlying and being closed by said head-supporting wall, said restricted opening comprising a groove in said bottom face of the head.

11. Means as defined in claim 10 including a second groove forming a second such restricted opening between the initial combustion chamber and the main combustion chamber portion, said grooves opening into the main combustion chamber portion at spaced positions and also opening into said initial combustion chamber at spaced positions, each of said grooves communicating with an individual curved wall portion within the initial combustion chamber, the two curved wall portions intersecting one another at a position substantially midway between said grooves and defining a linear projection at the position of intersection, such linear projection lying in a plane substantially perpendicular to said planar bottom face of the head and projecting in a direction generally toward said ignition means.

12. Means as defined in claim 10 including a second groove forming a second such restricted opening between the initial combustion chamber and the main combustion chamber portion, said grooves opening into the main combustion chamber portion at spaced positions and also opening into said initial combustion chamber at spaced positions, each of said grooves communicating with an individual curved wall portion within the initial combustion chamber, the two curved wall portions intersecting one another at a position substantially midway between said grooves and defining a linear projection at the position of intersection, such linear projection lying in a plane substantially perpendicular to said planar bottom face of the head and projecting in a direction generally toward said ignition means, the ignition means comprising a spark plug having electrodes opening into said initial combustion chamber at a position spacedly above said open lower portion of the initial combustion chamber, and said projection being inclined upwardly in a direction to project inflowing gases upwardly toward said electrodes.

13. An internal combustion engine as defined in claim 1 wherein the arc of curvature of said concavely curved wall portion is non-circular.

14. An internal combustion engine as defined in claim 1 wherein the arc of curvature of said concavely curved wall portion is non-circular, and is of decreasing radius

in a direction away from said opening and toward said ignition means.

15. An internal combustion engine as defined in claim 3 including a block portion containing said cylinder and a head portion containing both the main combustion chamber and the initial combustion chamber, both of said combustion chambers opening into a generally planar face of said head which is adapted to overlie said block, with the main combustion chamber at least partially overlying an end of said cylinder and the initial combustion chamber overlying a wall of and being substantially closed by said block, said passages being formed by open-sided channels in said face of the head.

16. An internal combustion engine as defined in claim 3 including a block portion containing said cylinder and a head portion containing both the main combustion chamber and the initial combustion chamber, both of said combustion chambers opening into a generally planar face of said head which is adapted to overlie said block, with the main combustion chamber at least partially overlying an end of said cylinder and the initial combustion chamber overlying a wall of and being substantially closed by said block, said passages being formed by open-sided channels in said face of the head, and cooling means communicating with a wall of said initial combustion chamber for extracting heat therefrom.

17. In an internal combustion engine as defined in claim 15, a water jacketing portion formed in said block and having a top wall portion which is overlain by said initial combustion chamber and by said partitioning wall, and metallic heat conducting portions in intimate heat conductive association with said partitioning wall and adapted to bear directly upon said top wall portion of said block to conduct heat from said partitioning wall in the head to said water jacket in the block.

18. In an internal combustion engine as defined in claim 17, gasket means interposed between the block and head, said heat conducting portions extending through an opening in said gasketing and including a portion bearing directly against the block to provide a heat path from the partitioning wall to the block without requiring the conduction of heat through said gasket.

19. In an internal combustion engine as defined in claim 17, gasket means interposed between the block and head, said heat conducting portions extending through an opening in said gasketing and including a portion bearing directly against the block to provide a heat path from the partitioning wall to the block without requiring the conduction of heat through said gasket, said initial combustion chamber having a top wall spaced from said planar face of the head, said spark plug being mounted in said top wall, said electrodes being spaced above said face, the pointed juncture of said concavely curved wall portions defining a generally knife-edged portion inclined upwardly and outwardly with respect to said initial combustion chamber, whereby fuel is directed upwardly as well as inwardly from said knife-edged portion.

20. In an internal combustion engine as defined in claim 18, an opening-defining portion in said gasket aligned with said open bottom of said initial combustion chamber whereby said top wall of the water jacketed portion of the block is directly exposed to the interior of said initial combustion chamber for direct absorption of heat therefrom.

21. In an internal combustion engine as defined in claim 15, a gasket interposed between said block portion and said face of said head and cut away in the region overlain by said partitioning wall and by said open face of the initial combustion chamber, the partitioning wall having a heat conductive portion extending below said face and through said cut away portion a distance conforming substantially to the effective thickness of the gasket and bearing against said block, whereby heat in said initial combustion chamber and in said partitioning wall may be directly conducted into the block without

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passing through the gasket, and heat disposal means associated with said block.

22. An internal combustion engine as defined in claim 1 having poppet-type inlet and outlet valves opening into said main combustion chamber and movable inwardly of said main combustion chamber during opening movement thereof, said restricted opening portion being positioned to direct flaming gases flowing outwardly from said initial combustion chamber through said opening in a direction to prevent substantial impingement thereof against either of said valves.

23. An internal combustion engine as defined in claim 1 wherein said initial combustion chamber and said restricted opening are so proportioned with respect to the main combustion chamber that the fire blast issuing from the initial combustion chamber through said opening as a result of ignition within said initial combustion chamber is substantially all absorbed by gases in the main combustion chamber without permitting heavy impingement of the fire blast against the wall of the main combustion chamber.

24. An internal combustion engine as defined in claim 3 wherein said main combustion chamber is not symmetrical, so that zones of differing volume lie upon opposite sides of a centerline projected through the initial combustion chamber and into the main combustion chamber midway between said passages, and wherein said passages are of different effective cross-sectional area, the passage of greater area lying on the side of said centerline toward the zone of said main combustion chamber which is of greater volume.

25. In a piston-type internal combustion engine having a main combustion chamber within which explosions occur to actuate the piston, means for delivering directly into the main combustion chamber a charge of pre-carburated air containing a fuel which is heavier than air, and means for firing the charge in said main combustion chamber comprising a portion defining a pre-combustion chamber, a restricted port providing communication between said pre-combustion chamber and said main combustion chamber, and an igniting device in said pre-combustion chamber, a charge rotating portion within said pre-combustion chamber for imparting angular velocity to a portion of the charge forced into said pre-combustion chamber by said piston, said igniting device being located in the path of heavier components of the charge separated by said charge rotating portion, said restricted port being so proportioned with respect to both the pre-combustion chamber and the main combustion chamber as to direct into the main combustion chamber from the pre-combustion chamber, upon ignition of the charge in the pre-combustion chamber, a fire blast which is projected substantially entirely across the main combustion chamber but of insufficient velocity to impinge heavily against the opposite side of said main combustion chamber.

26. In an internal combustion engine of the type having a cylinder and a piston actuable therein and a main combustion chamber appurtenant to the cylinder and within which explosions occur to actuate the piston, means for delivering directly to said main combustion chamber a substantially homogeneous charge of pre-carburated air containing a fuel having flammable components heavier than air and constituting the entire charge for the cylinder, a pre-combustion chamber, igniting means within said pre-combustion chamber, restricted port-defining portions interconnecting said pre-combustion chamber and said main combustion chamber and constituting the only operative interconnection between said chambers, a charge rotating portion in said pre-combustion chamber adapted to impart angular momentum to a portion of the charge forced into said pre-combustion chamber by movement of the piston toward the main combustion chamber, thereby tending to separate and concentrate such heavier flammable components

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in a predetermined region within said pre-combustion chamber, said igniting means being located in said region, whereby such heavier concentrated components may be ignited by said igniting means, and whereby upon such ignition a tongue of flame is ejected into the main combustion chamber from said pre-combustion chamber through said port-defining portions.

27. The method of operating an internal combustion engine of the piston type having a main combustion chamber within which explosions occur to actuate the piston and having a centrifugal charge-rotating type pre-combustion chamber restrictedly intercommunicating with said main combustion chamber and an igniting device within said pre-combustion chamber, which comprises introducing directly into said main combustion chamber during each charging stroke a full charge of substantially homogeneous pre-carburated mixture which is of leaner than balanced proportions, forcing a portion of said full charge into the pre-combustion chamber by movement of the piston only, and imparting rotary movement to said portion of the charge within the pre-combustion chamber to concentrate heavier proportions of such portion of the charge in the area of the igniting device, igniting such heavier proportion of the charge within said pre-combustion chamber, and directing a flaming blast resulting from such ignition into the main combustion chamber through said restricted intercommunication.

28. The method of operating an internal combustion engine of the piston type having a main combustion chamber within which explosions occur to actuate the piston and having a centrifugal charge-rotating type pre-combustion chamber restrictedly intercommunicating with said main combustion chamber, and an igniting device within said pre-combustion chamber, which comprises introducing directly into said main combustion chamber during each charging stroke a full charge of substantially homogeneous pre-carburated air containing a fuel which is heavier than air, varyingly throttling the charge, and concurrently varying the air-fuel proportioning of said charge between a substantially balanced mixture at full throttle and a mixture substantially leaner in fuel than a normal mixture at part load throttle settings, forcing a portion of said charge into the pre-combustion chamber by movement of the piston, imparting rotary movement to said portion of the charge within the pre-combustion chamber, igniting such portion of the charge within said pre-combustion chamber, and directing flame resulting from such ignition into the main combustion chamber by way of said restricted intercommunication.

29. In an internal combustion engine of the type having a cylinder and a piston actuable therein and a main combustion chamber appurtenant to the cylinder and within which explosions occur to actuate the piston, passage means for delivering directly to said main combustion chamber a substantially homogeneous charge of pre-carburated air containing a fuel which is heavier than air and constituting the entire charge for the cylinder, a carburetor having an air inlet portion, a fuel supplying portion, a carbureting portion for charging the air with fuel, an outlet for the carburated air mixture, said outlet communicating with said passage means, a throttle valve for regulating the flow of the air-fuel mixture, a fuel valve movable between a restricting position and a full flow position to vary the flow of fuel from said fuel supplying portion to the carbureting portion, said fuel valve having a restricting portion which, when said fuel valve is in the restricting position, permits a flow of fuel substantially less than that required to fully charge the air to balanced proportions, means interconnecting the fuel valve and the throttle valve to move the fuel valve to said restricting position as the throttle valve is moved toward a closed position, and to move the fuel valve to the full flow position which permits a flow of fuel sufficient to supply a balanced mixture when the throttle valve is opened, a pre-combustion chamber,

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igniting means within said pre-combustion chamber, restricted port-defining portions interconnecting said pre-combustion chamber and said main combustion chamber and constituting the only operative interconnection between said chambers, a charge rotating portion in said pre-combustion chamber adapted to impart angular momentum to a portion of the charge forced into said pre-combustion chamber by movement of the piston toward the main combustion chamber, thereby tending to separate and concentrate such heavier flammable components in a predetermined region within said pre-combustion chamber, said igniting means being located in said region, whereby such heavier concentrated components may be ignited by said igniting means, and whereby upon such ignition a tongue of flame is ejected into the main combustion chamber from said pre-combustion chamber through said port-defining portions.

30. An engine as defined in claim 29 wherein the throttle valve is continuously variable between said open position and an idle position, and said interconnecting means moves the fuel valve to an increased flow position as the throttle valve is moved to the idle position.

31. An engine as defined in claim 29 wherein the throttle valve is continuously variable between said open position and an idle position, and said interconnecting means moves the fuel valve to an increased flow posi-

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tion as the throttle valve is moved to the idle position, and causes continuous variation of the position of the fuel valve during movement of the throttle valve through a range of intermediate positions.

32. The method defined in claim 28 wherein the air-fuel proportioning is continuously varied between said substantially balanced mixture at full throttle and said leaner mixture at part throttle including the further step of increasing the fuel-to-air ratio above that of said leaner mixture as the throttle setting is reduced below such part load setting and to an idle setting.

33. A method as defined in claim 28 wherein the air-fuel proportioning is varied continuously during at least a portion of such varying of the throttling of the charge.

34. An engine as defined in claim 29 wherein said restricting portion of the fuel valve is graduated to provide a continuously varying amount of restrictive effect during movement of the fuel valve through a range corresponding to movement of the throttle valve throughout a part throttle range.

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