

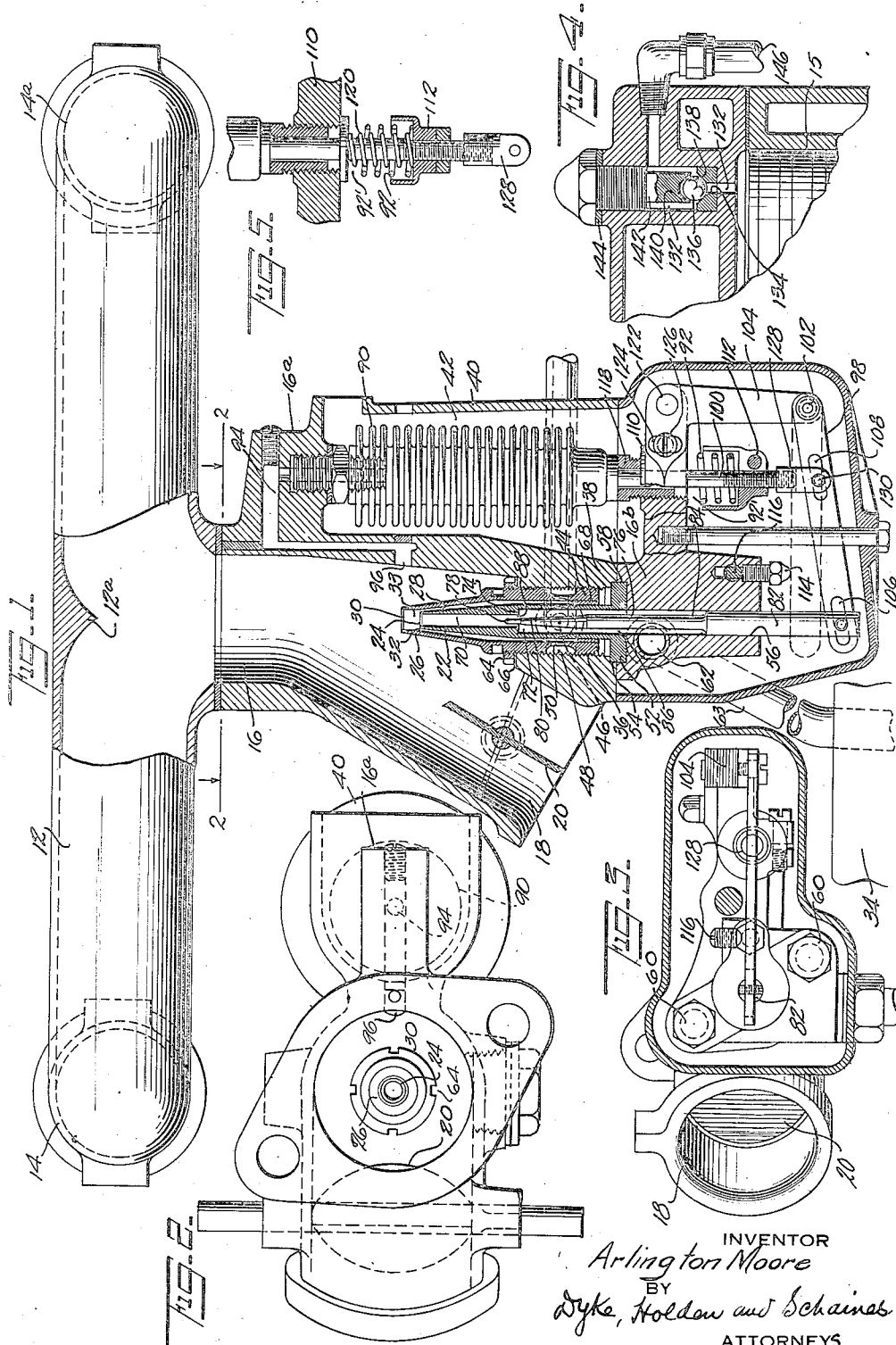
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CHARGE FORMING APPARATUS FOR INTERNAL COMBUSTION ENGINES

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CHARGE FORMING APPARATUS FOR INTERNAL COMBUSTION ENGINES

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My invention relates to improvements in charge forming apparatus for internal combustion engines and particularly transportation engines subject to wide momentary variations in power and speed; and the same has for its object more particularly to provide a simple, efficient and reliable apparatus which effects full quantity delivery to the engine cylinders of a dense charge mixture in which the components are in thoroughly homogeneous admixture with resulting improvement in completeness of combustion, power and economy.

Among the further objects of the invention are the following:

To provide an apparatus of the character specified in which the fuel orifice is subjected to a reduction of pressure throughout the operating range of the engine for effecting the delivery of the fuel at such discharge orifice under atmospheric pressure directly from the main fuel supply tank, such as an automobile fuel supply tank, located in its usual position at a level which may be materially lower than the discharge orifice.

To provide an apparatus of the character specified which introduces both the heavier as well as the lighter constituents of heterogeneous fuels into the air stream going to the engine in a finely divided state so that the heavier constituents are utilized as effectively as the lighter ones, all of said constituents being retained in suspension in said air stream and in homogeneous mixture thereof with without dependence upon application of heat to the charge, or on use of high velocity passages.

To provide an apparatus of the character specified in which the fuel jet is subjected to the inductive effects of inversely varying forces developed by the engine and complementing each other throughout the operating range of the engine for effecting the elevation of the fuel under a head of pressure and the delivery thereof to the engine.

To provide an apparatus of the character specified in which variations in the extent of opening of the fuel orifice controlled in response to variations in intake pressure is relied on for metering the fuel in accordance

with the engine requirements while the same is being elevated and delivered as a result of said inductive effects.

To provide an apparatus of the character specified in which the fuel jet is preferably subjected to inductive effects due in part to general intake depression above the throttle and in part to a local reduction of pressure resulting from the passage of a portion of the cylinder gases at high velocity in inductive relation to the discharge orifice while relying upon fuel orifice variation in response to variations in intake pressure for metering the fuel.

To provide an apparatus of the character specified in which the discharge end of the fuel jet and the inlet to the pressure responsive means for controlling the size of the fuel passage opening are so disposed that they are affected practically alike by variations in the intake depression, whereby the extent of the fuel passage opening is varied in substantial synchrony with such pressure variations at the discharge end of the fuel jet.

To provide an apparatus of the character specified in which the pressure responsive means is rendered inoperative to vary the size of the fuel jet orifice upon variations in speed at full engine load.

To provide an apparatus of the character specified in which the fuel orifice controlling means and the pressure responsive means are coordinated to limit the movement of the controlling means between maximum fuel orifice opening position and minimum fuel orifice opening position, and yet cause the same to respond in accordance with the variations in pressure approximately throughout the range thereof.

To provide an apparatus of the character specified in which the sensitiveness of said controlling means is greater over one portion of the pressure range than over another portion thereof to vary the rate of opening of the fuel orifice in substantial correspondence to the requirements for fuel at different loads and speeds.

To provide an apparatus of the character specified in which the fuel and injector nozzles are readily secured in adjusted and con-

centric relation to each other axially of the mixing chamber and in substantially fluid tight relation.

Other objects will in part be obvious and in part be pointed out hereinafter.

To the attainment of the aforesaid objects and ends, my invention consists in the novel features of construction hereinafter more fully described and then pointed out in the claims.

The present application is a continuation-in-part of my copending application Serial No. 280,205, filed May 24, 1928, for supplying and mixing charges for internal combustion engines.

The invention will be best understood from the following description of an embodiment thereof shown in the accompanying drawing, in which:

Fig. 1 is a part side and part vertical sectional view of a fuel supplying and charge preparing device embodying my invention.

Fig. 2 is a plan thereof, viewed from line 2—2 Fig. 1.

Fig. 3 is a bottom plan thereof, the protective casing being in section.

Fig. 4 is a section of a pressure line connection to an engine cylinder.

Fig. 5 is a detail view showing a modification.

Referring to the drawing the intake manifold 12 communicates through ports 14 and the usual inlet valves with the usual engine cylinders 15.

The intake manifold 12 has a mixing chamber 16 formed therein or otherwise constructed to communicate freely therewith. With the construction shown, the mixing chamber 16 formed in a casting or part 16^a replaces the usual intake manifold riser, and has a relatively wide flaring air inlet mouth 18 disposed at an angle to the axis of the mixing chamber, the extent of opening of which is regulated on transportation engines by an air throttle valve 20.

The mixing chamber 16 is preferably of cylindrical formation and adapted for the passage of ample air therethrough into the intake manifold 12 without unnecessary retardation. A nozzle 22 having its tip 24 disposed within the mixing chamber 16 above the throttle 20 serves for the delivery of fuel thereto.

A nozzle 26 surrounding the fuel nozzle 22 in spaced relation thereto provides, with the nozzle 22, an annular passage 28 for conducting gaseous fluid, preferably gases from one or more of the combustion chambers of the engine cylinders, and effecting the discharge thereof through the tip 30 into the mixing chamber 16 at a point slightly beyond the tip 24 of fuel nozzle 22, said gaseous fluid exerting an inductive action upon the fuel for effecting the delivery thereof by blasting it into the air stream in highly com-

minuted state. The nozzle 22, as shown, tapers slightly at the upper portion thereof. The outer nozzle 26 likewise tapers at the upper portion thereof, the tapering end portions providing therebetween the annular passage 28 of gradually decreasing cross-section toward their tips, terminating in a constricted annular orifice 32, the tip 30 of the outer nozzle 26 extending beyond the tip 24 of the fuel nozzle 22 to provide a circumferentially enclosed space 33 beyond said tip 24.

Gaseous fluid under pressure, preferably cylinder gases, pass at high velocity through the constricted orifice 32 past the tip 24 of the inner nozzle 22 and causes together with the intake depression a substantial reduction of pressure within the enclosed space 33 about the tip 24, so that the fuel is elevated by atmospheric pressure from the main tank 34 usually located at a lower level at the rear of the automobile, and forced out through the nozzle 22 and blasted into the air stream in finely comminuted state.

The nozzles 22 and 26 are preferably directed axially of the mixing chamber to discharge vertically against a spreader 12^a in the intake manifold 12.

The nozzles 22 and 26 are secured in position within a threaded opening or bore 36 through the lower portion 38 of the casting 16^a intermediate of the air inlet 18 and the portion 40 of the casting forming a bellows receiving chamber 42. The injector nozzle 26 has a threaded base portion 44 received within and engaging the threaded surfaces of the opening 36. The gaseous fluid from the engine cylinders passes through an opening 46 through the portion 38 into the groove 48 formed in the base portion 44 through the openings 50 into the passage 28. The fuel nozzle 22 has a flange 52 at the lower end thereof received within a recess 54 at the lower side of the portion 38 about the opening 36. When the nozzle 22 is placed in position within the nozzle 26 the flange 52 received within the recess 54 centers the fuel nozzle 22 within the nozzle 26 and maintains the same in concentric relation.

The nozzle 22 is locked or secured in position by the part or casting 16^b provided with a vertical opening or bore 56 therethrough terminating in a recess 58 at its upper end receiving the lower portion of the flange 52. The casting 16^b is secured to the casting 16^a by the bolts 60. The casting 16^b is provided with a transverse passage 62 connected by the pipe 63 with the tank 34 and communicating with the vertical passage or opening 56 for supplying fuel through the nozzle 22.

The means for securing the fuel nozzle 22 in position as above described provides a substantially fluid-tight joint preventing leakage of fuel at the juncture of the castings 16^a

16^b. The outer nozzle 26 may be readily adjusted by rotating the same to vary the constricted orifice 32 and the size of the recess 33 to position the parts in the most effective inductive relation. The nozzle 26 when adjusted is secured in position by the nut 64 having a fibre washer 66 interposed between the same and the portion 38 to prevent leakage. A sleeve 68 is interposed between the nozzles 22 and 26 to assist in maintaining the same in concentric relation, and provide a fluid tight joint.

The outer bore portion 70 of fuel nozzle 22 is reduced in diameter as compared with the communicating bore passage 72 thereof, and where these join a shoulder 74 is formed adapted with bore portion 70 to coact with the fuel controlling means 76 for metering the fuel.

The fuel controlling means 76 shown in Fig. 1 in its widest open position is in the form of a needle valve having a cylindrical tip portion 78 of reduced cross-section, which is provided when the valve 76 extends into the jet bore 70 at widest opening in order to pilot the needle valve and to permit if necessary some fuel valve movement taking place upon variation in speed at and near full engine loads without change taking place in the extent of opening of the fuel passage.

Below the cylindrical tip portion 78, fuel valve 76 has a tapered portion 80 to meter the fuel supply as required upon the valve being moved up or down with relation to shoulder 74.

Valve 76 has a cylindrical lower portion 82 guided in the bore 56 below the fuel inlet 62, and extending downwardly below the bore 56. Intermediate of the portions 80 and 82 the valve portion 84 is of reduced cross-section providing with the walls of the registering bores 56 and 72 an annular passage 86 for the fuel.

The valve 76 controls the extent of opening of the fuel jet 22, and provides at 88 an annular orifice of a cross-sectional area relatively constricted compared to that of the outer bore portion 70. The passage of the fuel through this constricted orifice 88 tends to disintegrate the same, and the bore 70 provides a relatively free passage for the fuel without appreciable retardation thereof due to frictional or capillary effects, the bore 70 being preferably larger in cross-section than the orifice of the ordinary fuel jet used in practice.

The valve 76 is controlled by a pressure-responsive device or expansible-contractible element, such as the hollow bellows 90 fixed at one end and a resilient means including spring 92 acting in conjunction therewith. The bellows 90 is disposed within the chamber or recess 42 formed in the casting 16^a and open to the atmosphere. The passage 94 extends to the interior of the bellows through

the fixed end thereof and communicates with the mixing chamber 16 at the inlet 96 substantially coincident with the horizontal plane passing through the tip 30 of the nozzle 26, so that the nozzle and the bellows inlet are affected substantially alike by pressure changes while the exterior of the element 90 is exposed to full atmospheric pressure.

The valve pin 76 is operated in response to variations in the pressure difference between atmospheric pressure and the pressure above throttle 20 at the point 96, the extent of opening of the fuel nozzle 22 increasing as this pressure difference decreases, and vice versa.

In the form shown the bellows 90 operates a lever 98 by means of stem 100; and lever 98, pivoted at 102 to the adjustable arm 104, actuates the fuel modulating pin 76. Pivotal connections are preferably made by slots 106, 108, in lever 98 to facilitate adjustments.

In case the natural contracting and expanding movement of the bellows in response to intake depression varying from zero to say, 20" of mercury is in excess of that permissible without undue fatigue, spring means are used to oppose part or all of the contracting movement and supplement the expanding movement so that the bellows can be made responsive to the full range of intake depression without moving through an unduly great distance.

Contracting movement of bellows 90 responsive to pressure reduction in passage 16 moves valve 76 toward its closing position. Such movement is opposed in the form shown in Figure 1 by spring means including the inherent resiliency of the bellows 90, and the supplementing spring 92. The spring 92 encircles stem 100, and is interposed between the bracket 110 projecting from the part 16^b and adjustable screw collar 112 on the stem 100.

The contracting movement of the bellows is limited by the lever 98 engaging the adjustable stop 114 threaded into the casting 16^b and secured by the set screw 116. The stop 114 also determines the minimum fuel orifice position of the valve 76.

The bearing or bushing 118 is adjustably threaded into the bracket 110, and the same serves to loosely guide the stem 100 and keep the bellows practically straight. The bearing 118 serves as an adjustable stop for limiting the expanding movement of the bellows 90, thus as hereinafter described determining the wide open position of the needle 76, and for maintaining the bellows under initial compression tension.

The initial tension imposed on the bellows by stop 118 is preferably such as to prevent contraction of the bellows upon variation in speed at full load, the resulting decrease in pressure usually of the order of two or three inches of mercury, due to such increase in speed being ineffective to move the

bellows as initially tensioned. Over the portion of the range of variation of the intake pressure resulting from throttle movement between wide open position and a position at somewhat less opening the inherent resiliency of the bellows under said initial tension is relied on for opposing the pressure differential acting to contract the bellows and for this purpose spring 92 when fully expanded preferably leaves a clearance at 92' within which such movement can be obtained free from any effect of spring 92. Over the remaining portion of the range of pressure variation due to throttle movement between such intermediate position and substantially closed or idling throttle position, and of course, variations in engine speed, the spring 92 as shown is operative and serves to supplement the inherent resiliency of the bellows. For this purpose the screw collar 112 is adjusted so that the spring 92 is fully relaxed during variation over the first mentioned portion of the pressure range leaving a clearance 92' at full loads and said spring 92 only becomes tensioned at the desired point during the last named portion of the pressure range. By adjusting either the stop bushing 118 or the collar 112, or both, the compression tensions of the respective spring components may be adjusted to render the bellows of the desired sensitiveness throughout the movement thereof over the relatively short distance traveled between the stops 114 and 118.

In instances where the size of the bellows is such that the inherent resiliency thereof is insufficient to hold the bellows against movement during variations in intake depression upon variations in speed at full load a relatively light constantly acting auxiliary spring, such as the spring 120 shown at Fig. 5 is interposed between the bracket 110 and the collar 112.

Inherent resiliency of the bellows augmented by the spring 120 holds the bellows against movement away from stop 118 in response to variations in pressure resulting from variations in speed at full load. For further range of pressure variation resulting from the variations in throttle position from wide open to an intermediate smaller opening and also from engine speed, the same factors, namely inherent resiliency of the bellows and spring 120, control the movement of the bellows in response to such pressure variations. For the higher range of intake depression and all the way to closed or idling position of the throttle, the spring 92 becomes operative to supplement the spring 120 and the inherent resiliency of the bellows, securing response in a limited-movement range of the bellows, and, consequently, of the fuel metering pin 76, to these higher ranges of intake depression. The described arrangement and the consequent de-

crease in rate of change of opening of the fuel passage from relatively greatest at throttle openings and speeds somewhat under those for full loads when intake depression is relatively low, to relatively least at times of high intake depression, results in the delivery, in response to pressure prevailing about the fuel jet, of fuel proportioned substantially to the engine requirements.

The leverage of the member 98 which multiplies the movement of the modulating pin 76 for a given movement of the bellows 90, the leverage being for example, a three to one ratio, is adjusted by the arm 104 which is pivoted at 122 to the bracket 110. The arm 106 has an arcuate slot 124 receiving a set screw 126 threaded into the bracket 110. When the set screw 126 is loosened the arm 104 may be adjusted about its pivot 122 and then locked. By adjusting the arm 104 the rate of movement of the pin 76 is varied relative to the bellows movement.

The movement of the valve pin 76 relative to the bellows 90 is also varied by adjustment of the pivotal connection between the stem 100 and the lever 98. For this purpose a clevis 128 is threaded on the end of stem 100 and carries a pivot pin 130 riding in the slot 108. When the pivot pin 130 and lever 98 are disconnected from the member 128, the latter may be adjusted through one or more 180° turns and the parts reconnected thereto. The angularity of the lever 98 resulting from adjustment of the clevis 128 and the position of the stop 118 determine the wide open position of the pin 76.

The gaseous fluid discharged at the nozzle 26 into the mixing chamber 16 in the construction shown is preferably taken from the engine cylinder or cylinders 15. The means for supplying the cylinder gases consists of a hollow pressure element 132 open at its upper end secured upon or formed within the head of the cylinder and surrounded by the water-containing spaces thereof for cooling the element. The outlet 134 from the cylinder through the element 132 is controlled by a ball-check 136 disposed upon the conical seat 138 within the pressure element and adapted to be lifted by the escaping cylinder gases so that the outlet 134 is open at all times when the pressure on the cylinder side exceeds the pressure on the other side of the ball. The ball 136 is freely movable except for its own weight, and is kept in proper position for coaction with its seat by entering the conical recess 140 in the centering and movement limiting plug 142 threaded into and closing the open end of the pressure element 132. Washers 144 of any desired thickness may be used to permit desired play of ball check 136. The interior of the pressure element 132 communicates through the tube 146 with the nozzle 26. The outlet 134 through the conical seat

138 is sufficiently large so as not to become readily clogged by any carbon or other solids present in the gases.

The conical recesses 138 and 140 have the surfaces thereof at an angle of substantially 45° to the axis so that the conical surfaces thereof as the ball 136 strikes the same are normal to the radii of the ball and the stresses imposed on the ball are transmitted towards the center thereof and not eccentrically. This prevents the ball from becoming flattened or distorted, prolonging the life thereof and insuring that the ball will evenly seat to prevent leakage even after considerable use thereof.

The ball 136 and seat 138 are preferably made of heat resisting chrome steel, chrome nickel steel or the like.

The plug 142 is also so adjusted that the maximum size of the opening produced by clearance between the ball 136 and its seat 138 when the ball is lifted is substantially less than the size of the outlet passage 134. The maximum clearance is such as to not unduly decrease the pressure within the cylinders, and the rapid vibratory movement of the ball serves to maintain said clearance space substantially free from solid matter.

Air supply

Upon the completion of the exhaust piston stroke, all gases have been driven out of the cylinder except those occupying the clearance space. Upon the intake stroke of the piston, with the inlet valve open, such filling of the piston-swept space in the cylinder as takes place is produced by the atmospheric or other available exterior pressure forcing air past the air throttle, through the mixing chamber and the intake manifold and cylinder inlet ports, and finally into the cylinder region of initial low pressure. There is, of course, a graduated reduction of pressure below atmospheric all along the line from the outer atmosphere to the cylinder. This pressure reduction increases with increase in friction and retardation generally to air travel. It also obviously increases with increase in piston speed.

The principal factor in creating resistance to air movement from the atmosphere to the engine cylinder and communicating spaces, is the position of the air throttle. When the throttle is nearly closed, for example, the pressure reduction in the mixing chamber may be as much as ten pounds per square inch, or thereabouts. When the throttle remains in fixed position, variations in pressure reduction in the mixing chamber, due to varying piston speeds, however, will not ordinarily exceed about one or two pounds per square inch, depending on the particular position occupied by the throttle.

Thus the air supply varies substantially directly with variation in the extent of open-

ing of the air inlet passage and also substantially directly with the variation in engine speed, while the general reduction of pressure below atmospheric in the mixing chamber (called general pressure reduction to distinguish from localized pressure reduction referred to below), varies substantially inversely with the extent of opening of the air inlet and substantially directly with the engine speed.

Fuel delivery to mixing chamber

The fuel nozzle is subjected to the pressure reduction existing generally in the mixing chamber and to this extent atmospheric pressure is available for forcing in the fuel. With the very considerable pressure reduction of as much as ten pounds per square inch, above referred to, it will be evident that fuel can be raised by the atmospheric pressure more than twenty feet, if desired, and still be discharged into the mixing chamber at a considerable velocity.

The pressure reduction generally throughout the mixing chamber, however, practically vanishes under certain conditions, as for example at low piston speeds with wide open throttle. Under full engine load conditions the pressure reduction generally in the mixing chamber is inconsiderable, and at the same time, the fuel requirements approach the maximum. Thus the general intake depression in the mixing chamber cannot be utilized throughout the range of engine operation for raising fuel and supplying same directly to the charge without intervention of provision for temporary fuel storage as in the ordinary vacuum tank, carburetor float chamber and the like. In order to supply fuel when the general intake pressure reduction is slight, the fuel nozzle is also made subject to localized pressure reduction of magnitude dependent upon the velocity of cylinder gases discharged into the mixing chamber in efficiently inductive relation to the fuel nozzle.

The pressure and velocities at which cylinder gases are available are substantially maximum at full engine load, and least at idling, or when the engine is being turned over by the starting motor, though not inconsiderable even then. Thus the localized pressure reduction produced by the velocity discharge of the cylinder gases into the mixing chamber has a complementary or inverse relation to the general pressure drop in the mixing chamber, and with the fuel nozzle subjected to both the general pressure reduction and this localized pressure reduction, the response of atmospheric pressure thereto suffices for fuel raising and delivery thereof to the mixing chamber through the range of engine operation, and fuel can be raised to an extent which can readily be considerably in excess at all times of requirements encountered in automobile practice, including continuous climb-

ing of the steepest grade, enabling vacuum tanks, fuel pumping devices and the like to be dispensed with.

5 *Fuel comminution*

Constricted intake manifolds with sharp corners, etc., have been resorted to for the purpose of imparting high velocity and turbulence to the air stream carrying fuel therewith. The endeavor with this practice is to keep the fuel in the air and off the manifold walls as far as possible. While the desired result is accomplished to some extent, an enormous sacrifice of volumetric efficiency and engine power results because of the high frictional and other retardation to travel of the charge stream.

Also application of heat has been made to the charge material, usually through a part of the manifold walls, and in this way some fuel is vaporized and kept in the air stream, but only at great sacrifice of charge density, with resulting decrease in weight of charge material entering the cylinder, thus sacrificing a portion of the engine power output otherwise available.

With my invention, the fuel is put into and retained in thorough suspension in the air stream by first discharging the fuel through a narrow passage and then subjecting it to the blasting and disintegrating action of the stream of cylinder gases into which it is delivered by the fuel nozzle, and the fuel, in comminuted state comparable to fine fog, or smoke, is mixed with the air stream by the blasting action of the cylinder gases and discharged against the spreader 12^a so that it remains homogeneously incorporated with and suspended in the air stream without reliance upon excessive manifold velocity, or application of heat sufficient to produce impairment of volumetric efficiency; and constricted sharp-turning manifolds, hot spots and the like expedients can advantageously be eliminated. Even at starting, with no more than compression cylinder pressure available the fuel disintegration is sufficient to ensure good mixtures for starting and for getting good engine operation with minimum of "warming up". Under practically all conditions of engine operation the entire body of fuel metered including "heavy ends", and even though cold, is put into and maintained in thorough admixture with and suspension or flotation in the air. The relatively cold charge material of high density and thorough homogeneity so obtainable permits of the delivery of an advantageously high weight of charge to the engine cylinders in a state adapted for securing complete combustion upon being compressed and ignited.

Fuel metering

The fuel supply is raised and delivered as above described by excess of atmospheric

pressure over the pressure at the fuel nozzle, due in part to the general pressure reduction in the mixing chamber and in part to the localized pressure reduction about the fuel nozzle. The quantity of fuel delivered under the pressures so made available is regulated by varying the extent of opening of the fuel passage, due care being taken to have a proper correspondence between the size of opening and the effective pressure.

Fuel requirements vary substantially directly with air supply. While relatively lean mixtures give good results at the higher engine speeds, the mixture can advantageously be somewhat richer at the lower engine speeds.

I deliver fuel in accordance with these requirements by controlling the extent of opening of the fuel passage in accordance with the variations in the pressure reductions below atmospheric in the mixing chamber at such point therein in the vicinity of the discharge nozzle that the value of the variations in pressure controlling the extent of opening of the fuel nozzle is substantially the same as that of the variations in pressure on the fuel nozzle jet.

As has been seen, this general pressure reduction substantially decreases with increase in extent of opening of the air inlet and consequent freer entry of air under atmospheric pressure, and it also increases for a given throttle opening, with increase of the engine speed. By using spring means to increase and means responding to intake pressure reduction to decrease the extent of fuel passage opening, I am enabled to vary the fuel supply in substantial consonance with the air supply at an economical fuel to air ratio and yet have the desirable richer power mixture for low speed operation at full throttle opening.

Thus, for example, with the air throttle wide open, and the engine operating at such low speed as not to materially increase the general pressure reduction in the intake, the fuel passage can be open to the maximum with the cylindrical tip of valve 76 in the passage 56 and will supply the desirably rich, or power mixture, whereas if the torque resistance is lowered and the engine speeds up with the throttle still wide open, the general intake pressure reduction is increased without decrease in the size of the fuel orifice because of the initial tension of the bellows, adjusted to prevent closing movement of the needle under such condition.

Undesirably great leanness of mixture is prevented because the localized pressure drop together with the intake depression about the fuel nozzle also increases directly with the speeding up of the engine, thus making at-

mospheric pressure available to an increased extent for delivery of fuel at the fuel nozzle.

Acceleration

5 Upon quickly moving the throttle from one partly open position to a somewhat wider partial throttle opening for speeding up the engine, it is important in transportation engines to have a good power mixture for ensuring powerful pick-up, yet not to have a mixture which is so unduly rich that power reduction and "strangling" can ensue from temporarily excessive fuel supply and/or limited air supply. When extent of opening of the throttle 20 is increased for accelerating the intake depression drops. Thereupon, the spring 92, which is highly tensioned at this stage of operation causes the fuel passage opening to be enlarged to an extent for supplying the requisite fuel for acceleration.

I employ the more powerful supplemental spring 92 for opposing the intake depression variations only during movement of the throttle from closed or nearly closed position to an intermediate position, and back towards closed position, so that the rate of the movement of the needle valve is made less compared to the rate of movement thereof over the range of intake pressure variation where the opposing spring tension due to the inherent resiliency of the bellows 90 alone or to such resiliency supplemented by the spring 120, Fig. 5, is less. Hence when the intake depression is relatively high the opposing spring tension is greater and the responsiveness to variations in pressure is less and when the intake depression is lower, the opposing spring tension is made less to increase the responsiveness of the bellows to pressure variations. Further, by this arrangement of cooperating springs, the bellows may be made to respond at a lower point in the intake depression range upon closing movement of the throttle from wide open position, and yet be retained by the less powerful spring means against movement upon variations in speed at full load.

Engine starting

50 When the engine is not running, the fuel valve is wide open. Upon starting the engine, the first discharge of gaseous fluid through nozzle passage 26 is principally of air at the compression pressures developed by the turning over the engine by the starting motor. The throttle being practically closed, there is a resulting general pressure reduction in the intake due to piston movement, and this, together with the inductive pressure reduction at the fuel nozzle, is sufficient to produce fuel raising by atmospheric pressure, and the fuel is discharged in a finely comminuted state into admixture with the air passing the throttle. The fuel valve is moved somewhat from its initially open position, but only to

the extent corresponding to the general intake pressure drop produced by the starter motor, should this reduction in pressure exceed the initial tension of the bellows, and not sufficiently to unduly restrict the extent of opening of the fuel passage, thus insuring delivery of a sufficient quantity of fuel for easy starting. As soon as the motor begins to fire the system takes up its orderly functioning as above described.

It will be seen that by means of apparatus such as described, the fuel required throughout the range of engine operation can be raised through a considerable height if necessary by direct application of atmospheric or other available pressure upon the surface of the fuel supply, the extent of opening of the fuel passage and the pressure effective for delivery of fuel can be interrelated so as to deliver the fuel in quantities to suit the air supply and the varying requirements of the engine. The fuel is blasted into and entrained in the air stream, and both the fuel and air admixed into a state of thorough homogeneity until combustion. This homogenized charge material can be substantially as cold, dense and heavy as may be required, and with the provision of ample and relatively unrestricted air passages, and resort to superatmospheric driving pressure, if desired, can be delivered in full quantities.

The various features of the invention dispense with numerous complicated arrangements heretofore in use, and enable the securing of very efficient combustion, power and economy.

It is understood that the foregoing is intended to afford an understanding of the invention and not for limitation, and that the scope of the invention is as defined in my claims.

I claim:

1. In apparatus for supplying and mixing charges for internal combustion engines, an intake conduit, an air throttle therein, a fuel nozzle beyond the air throttle, means for discharging gaseous fluid in injective and disruptive relation to the fuel nozzle outlet, a fuel valve, means for operating the fuel valve comprising an elastic air bellows subjected to the differential between atmospheric and intake pressures, means for limiting the bellows movement within its elastic limits, and spring means for opposing bellows movement due to said pressure differential, whereby to render the bellows responsive within the limits of movement thereof to pressure differences that in the absence of said spring means would cause the bellows to exceed its elastic limits.

2. In apparatus for supplying and mixing charges for internal combustion engines, an intake conduit, means for controlling the passage of air through said conduit, means for conveying fuel into said conduit, a valve for

controlling the extent of opening of the fuel passage, an element responsive to pressure variations in said intake conduit beyond said air controlling means connected to said valve
 5 for actuating the same, and resilient means for moving said element and said valve in one direction as the intake pressure increases and rendering said element more sensitive to pressure variations over the upper portion
 10 of the intake pressure range than over the lower portion thereof.

3. In apparatus for supplying and mixing charges for internal combustion engines, an intake conduit, means for controlling the pas-
 15 sage of air through said conduit, means for conveying fuel into said conduit, a valve for controlling the extent of opening of the fuel passage, and an element responsive to pres-
 20 sure variations in said intake conduit beyond said air controlling means connected to said valve for actuating the same; said pressure responsive means having a resiliency acting
 25 in opposition to intake pressure throughout the intake pressure range to move said valve in one direction as the intake pressure increases, and spring means supplementing said
 resiliency and operative only over the lower portion of the intake pressure range.

4. In apparatus for supplying and mixing charges for internal combustion engines, an intake conduit, means for controlling the pas-
 30 sage of air through said conduit, means for conveying fuel into said conduit, a valve for controlling the extent of opening of the fuel passage, an elastic element responsive to
 35 pressure variations in said intake conduit beyond said air controlling means and connected to said valve for actuating the same, and a supplementing spring operative over
 40 one portion of the range of intake pressure to move said element in one direction as the intake pressure increases and inoperative as the intake pressure varies over another por-
 tion of the range thereof.

5. In apparatus for supplying and mixing charges for internal combustion engines, an intake conduit, means for controlling the
 45 passage of air through said conduit, means for conveying fuel into said conduit, a valve for controlling the extent of opening of the fuel passage, means for actuating said valve
 50 and comprising an element responsive to variations in pressure in said intake conduit beyond said air controlling means; said element being under initial tension for retain-
 55 ing said valve against movement during the variations in intake pressure resulting from variations in engine speed at full load, and resilient means for rendering said element
 60 less sensitive to pressure variations over one portion of the intake pressure range than another.

6. In apparatus for supplying and mixing charges for internal combustion engines, an
 65 intake conduit, means for controlling the

passage of air through said conduit, means for conveying fuel into said conduit, a valve for controlling the extent of opening of the fuel passage, and means for actuating said
 70 valve and comprising an element responsive to variations in pressure in said intake conduit beyond said air controlling means; said element having spring means opposing said
 75 variations in pressure over the intake pressure range, and spring means supplementing said first named spring means and operative only over the lower portion of the intake
 pressure range, and said first named spring means being adjusted to retain said valve
 80 against movement as the intake pressure varies upon variations in engine speed at full load.

7. In apparatus for supplying and mixing charges for internal combustion engines, an intake conduit, means for controlling the
 85 passage of air through said conduit, a valve for controlling the extent of opening of the fuel passage, an elastic element for controlling said valve in response to pressure
 90 variations in said intake conduit, means for restraining said element against movement beyond its elastic limits, and for maintaining the same under initial tension; said element
 95 having a spring tension for moving the same in one direction as the intake pressure increases substantially over the intake pressure range, and serving to retain said element
 against movement upon variations in speed at full load, and spring means operative only
 100 over the lower portion of the intake pressure range for augmenting said spring tension.

8. In apparatus for supplying and mixing charges for internal combustion engines, a part having an intake passage therein at one
 105 side and a bellows receiving portion at the other side thereof; said passage having an air inlet disposed at an angle thereto, a portion at the base of said part intermediate of
 110 said air inlet and said bellows receiving portion having a bore therethrough, a fuel nozzle, an injector nozzle, and means for securing said nozzles within said bore in con-
 centric relation to each other.

9. In apparatus for supplying and mixing charges for internal combustion engines, a
 115 part having an intake passage therein having an air inlet disposed at an angle thereto, a portion at the base of said part having a bore therethrough, and a recess at the base of said
 120 bore, an injector nozzle secured within said bore, a fuel nozzle disposed within said injector nozzle, and having a flange received within said recess and serving to center said
 125 nozzles relative to each other, and a second part secured to said first named part, and having a passage therein aligned with the passage of said fuel nozzle, and a recess at
 the upper end of the passage in said second
 130 part for receiving the lower portion of said flange.

10. In apparatus for supplying and mixing charges for internal combustion engines, a part having an intake conduit, a chambered portion, and a portion at the base of said conduit having a bore, an injector nozzle disposed within said bore, a fuel nozzle centered within said injector nozzle, a second part secured to said first named part and having a fuel passage aligned with the passage through said fuel nozzle and serving to secure the latter in place, a needle valve movable axially within said passages, a bellows received within said chambered portion and communicating with said intake conduit, and mechanism on said secured part for adjusting said valve and said bellows and actuating the valve from the bellows.

15. In apparatus for supplying and mixing charges for internal combustion engines, means for supplying fuel thereto, an elastic element operated by variations in pressure differential for varying the fuel passage opening, stop means for restraining said element against movement beyond its elastic limits and determining the minimum and maximum fuel passage openings, and a supplemental spring for said elastic element effective over the higher portion of the pressure differential range in opposing increases in pressure differential, said spring being ineffective over the lower portion of the pressure differential range.

11. In apparatus for supplying and mixing charges for internal combustion engines, means for supplying fuel thereto, and pressure responsive means for controlling the fuel flow, comprising spring means for opposing movement of said pressure responsive means as the pressure differential increases, said spring means including a component effective in opposing movement of said pressure responsive means over a portion only of the pressure differential range.

12. In apparatus for supplying and mixing charges for internal combustion engines, means for supplying fuel thereto, and pressure responsive means for controlling the fuel flow, comprising spring means for opposing movement of the pressure responsive means in response to increases in the pressure differential substantially coextensive with the range thereof, said spring means including a more powerful component effective in opposing movement of the pressure responsive means over the higher portion only of the pressure differential range, whereby to cause the fuel flow to vary at a slower rate over the upper portion of said range than over the lower portion thereof.

13. In apparatus for supplying and mixing charges for internal combustion engines, means for supplying fuel thereto, pressure responsive means for varying the fuel passage opening, stops for limiting the movement of said pressure responsive means in both directions and determining the minimum and maximum openings of said fuel passage, and spring means for opposing movement of said pressure responsive means as the pressure differential increases, said spring means being more effective over one portion of the pressure differential range than another, whereby to differentially vary the rate of opening of the fuel passage.

14. In apparatus for supplying and mixing charges for internal combustion engines, means for supplying fuel thereto, pressure responsive means for controlling the fuel flow, and spring means for opposing the movement of said pressure responsive means

as the pressure differential increases, said spring means including a component providing appreciable opposition to the movement of said pressure responsive means over the higher portion of the pressure differential range and a component providing less opposition to said movement over the lower portion of said range.

15. In apparatus for supplying and mixing charges for internal combustion engines, means for supplying fuel thereto, an elastic element operated by variations in pressure differential for varying the fuel passage opening, stop means for restraining said element against movement beyond its elastic limits and determining the minimum and maximum fuel passage openings, and a supplemental spring for said elastic element effective over the higher portion of the pressure differential range in opposing increases in pressure differential, said spring being ineffective over the lower portion of the pressure differential range.

16. In apparatus for supplying and mixing charges for internal combustion engines, means for supplying fuel thereto, an elastic expansible-contractible element for controlling the fuel passage area, stop means for limiting the movement of said element in both directions and retaining the same under initial tension in one position thereof, said stop means determining the minimum and maximum openings of the fuel passage, and a supplemental spring for said element adapted to be ineffective over the lower portion of the pressure differential range and becoming effective in opposing movement of said element as the pressure differential increases over the higher portion of the range thereof.

17. In apparatus for supplying and mixing charges for internal combustion engines, means for supplying fuel thereto, an elastic element operated by variations in pressure differential for controlling the fuel passage area, a stop adapted to limit the expansion of said element, a stop adapted to limit the contraction of said element, said stops determining the minimum and maximum openings of the fuel passage, and being relatively adjustable to permit of variations of the range of fuel passage opening, and retaining said resilient element under initial tension in one position thereof and restraining the same against movement beyond its elastic limits, and spring means becoming effective only to oppose contraction of said element as said element approaches its more contracted condition, whereby to vary the fuel passage opening at different rates over different portions of the pressure differential range.

18. In apparatus for supplying and mixing charges for internal combustion engines,

- means for supplying fuel thereto, an elastic expansible-contractible element responsive to variations in pressure differential occurring in engine operation for controlling the fuel passage area, stops for restraining said element against movement in both directions beyond its elastic limits, and determining the minimum and maximum fuel passage openings, one of said stops retaining said element in the expanded condition thereof under initial tension, whereby to prevent fuel passage area variation at the lower end of the pressure differential range when the variations thereof are relatively slight while permitting of contraction of said element relatively early upon greater increases in pressure differential, and supplemental spring means for increasing the opposition to the contraction of said element coming into action at a higher portion only of the pressure differential range.
19. In apparatus for supplying and mixing charges for internal combustion engines, an intake, means for supplying fuel thereto, an elastic expansible-contractible element responsive to variations in pressure reduction in the intake for controlling the fuel passage area, stops for restraining said element against movement in both directions beyond its elastic limits, and determining the minimum and maximum fuel passage openings, one of said stops retaining said element in the expanded condition thereof under initial tension of an order to prevent fuel passage area variation upon variations in pressure reduction in the intake resulting from variations in speed at full load while permitting of contraction of said element relatively early upon greater increases in pressure reduction, and supplemental spring means for increasing the opposition to the contraction of said element coming into action as the reduction of pressure in the intake further increases.
20. In apparatus for supplying and mixing charges for internal combustion engines, an intake conduit, means for controlling the passage of air through said conduit, a nozzle extending into said conduit beyond said air controlling means for supplying fuel subject to intake depression, and a pressure responsive device for controlling the fuel flow in inverse relation to the variations in intake depression, said device having a passage independent of the fuel passage communicating with said intake conduit at a point lying on substantially the same transverse plane as the discharge end of said nozzle.
21. In apparatus for supplying and mixing charges for internal combustion engines, an intake, means for supplying fuel thereto, and a valve responsive to variations in intake depression for varying the fuel passage area in inverse relation thereto, said valve having a tip portion of uniform cross-section to prevent variations in fuel passage area upon speed variations at full load.
- In testimony whereof, I have signed my name hereto.
- ARLINGTON MOORE.