

Sept. 11, 1934.

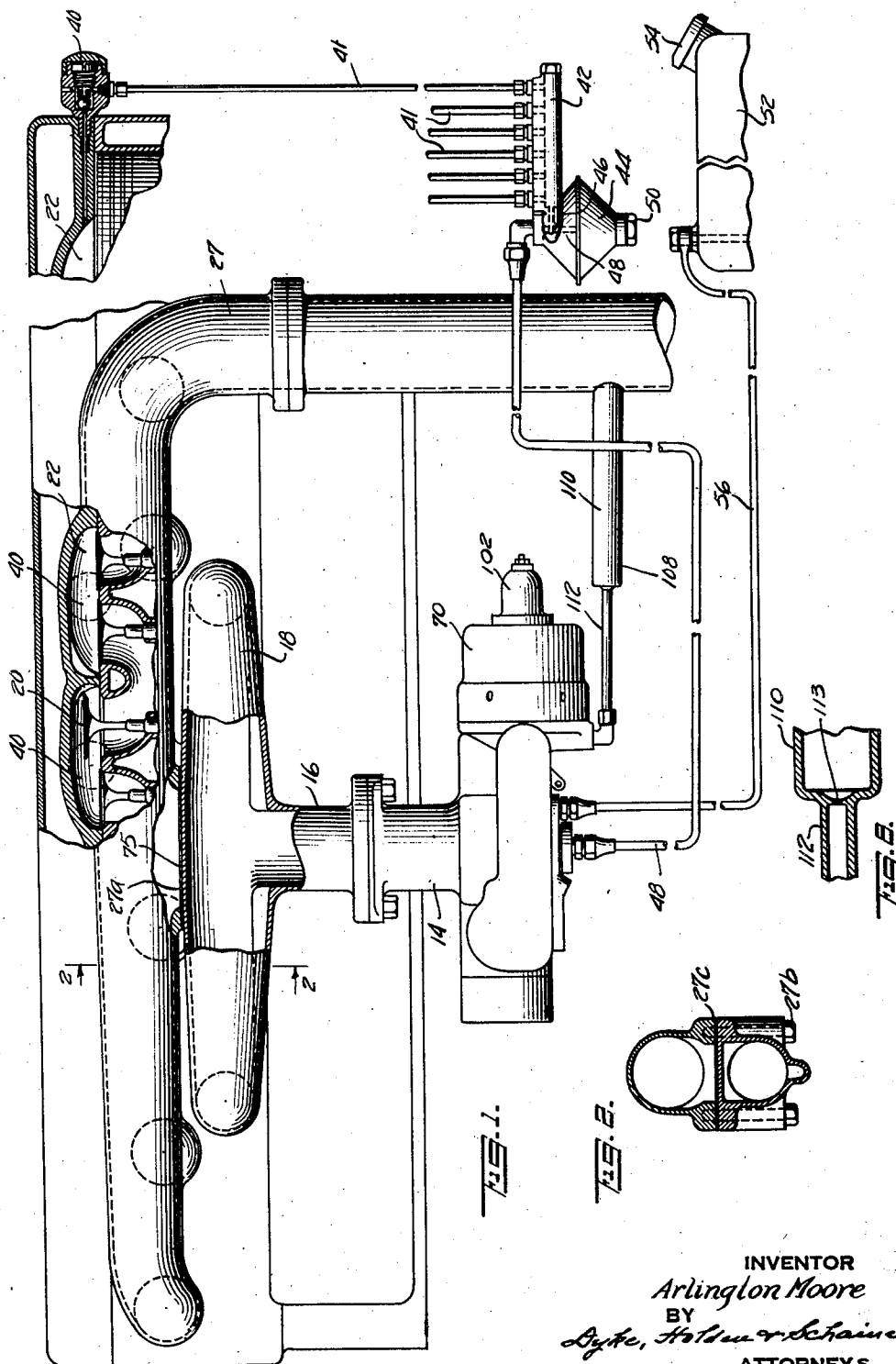
A. MOORE

1,973,496

**PRESSURE CONTROLLED CHARGE SUPPLYING AND MIXING
APPARATUS FOR INTERNAL COMBUSTION ENGINES**

Filed Nov. 8, 1929.

3 Sheets-Sheet 1.



Sept. 11, 1934.

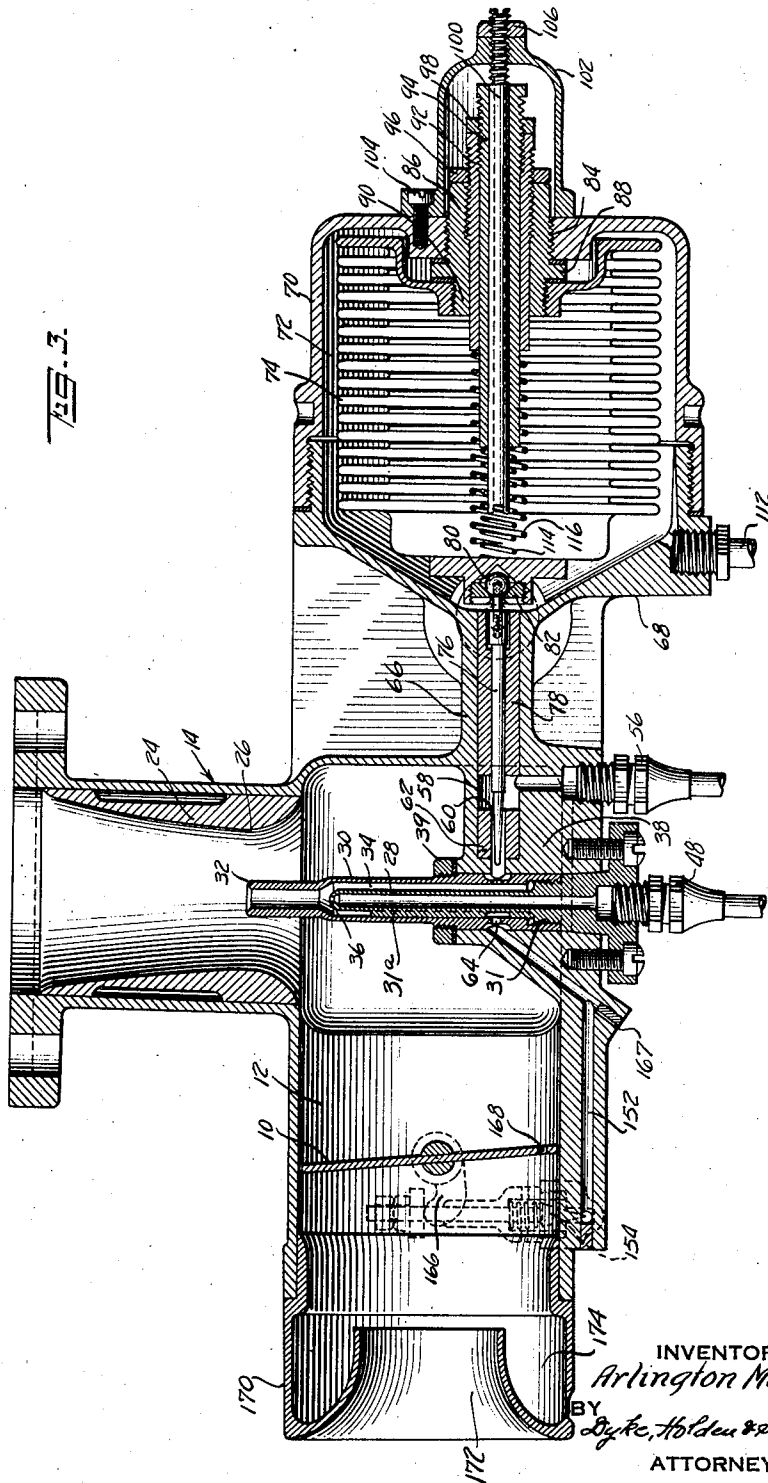
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3 Sheets-Sheet 2



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1,973,496

3 Sheets-Sheet 3

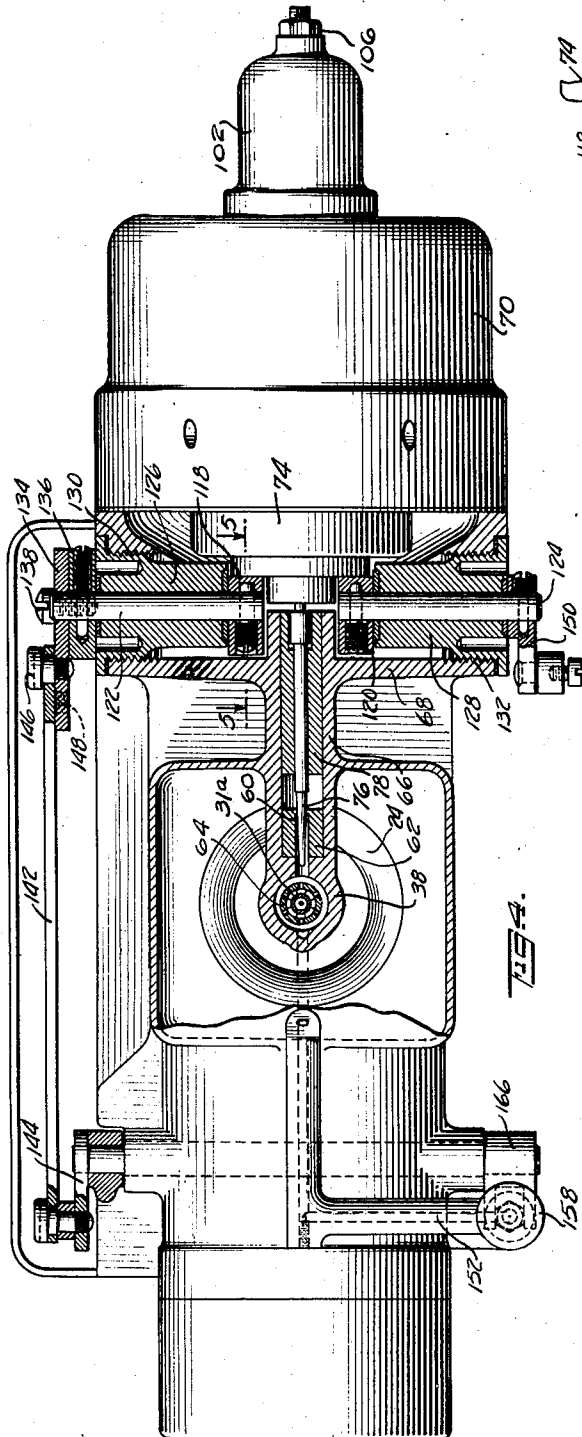


FIG. 4.

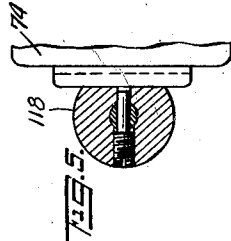


FIG. 5.

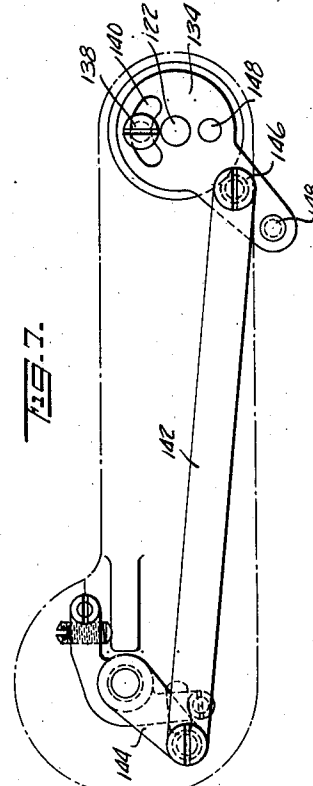


FIG. 7.

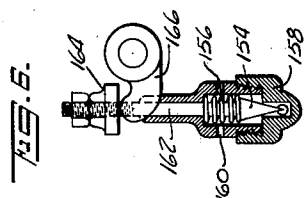


FIG. 6.

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UNITED STATES PATENT OFFICE

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PRESSURE CONTROLLED CHARGE SUPPLYING AND MIXING APPARATUS FOR INTERNAL COMBUSTION ENGINES

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Application November 8, 1929, Serial No. 405,737

26 Claims. (Cl. 123—119)

My invention relates to a charge supplying and mixing apparatus in which the flow of fuel for the engine is controlled as a function of fluid pressure variations.

With my invention the flow of fuel is varied as a direct function of variation in fluid pressure taken from a source which provides pressure varying directly with the weight of charge material supplied to the engine cylinders per unit of time, as, for example, the fuel passage opening is valve controlled as a direct function of variations in the exhaust gas pressure in the exhaust conduit between the engine cylinders and the usual muffler, whereby to supply fuel in proper proportion to the air throughout the load and speed range of the engine.

The air flow is accelerated and the fuel blasted into the intake conduit, preferably at a region in the intake between the throttle and the inlet valves, by gases under pressure, preferably gases from the engine cylinders, discharged in inductive relation to the air and fuel of the charge and adapted to lift the fuel from a low level supply tank, comminute the fuel so that all parts are readily vaporized, and homogenize the charge.

Among the objects of my invention are the following:

To provide pressure responsive means which varies the fuel passage opening at rates substantially conforming to the rates of variation of exhaust gas pressure substantially throughout the range thereof; to provide means for supplementing the pressure responsive means in supplying additional fuel when required, such as upon accelerating or starting the engine or both; to provide means for controlling the inductive effect on the fuel jet, whereby to improve the fuel flow at idling; to provide means operated adjunctively to throttling for actuating said supplementing means and said means for controlling said inductive effect; to provide fuel and injector nozzles which are readily assembled in fluid-tight relation to each other and to their support and are productive of efficient injecting action; to provide fuel passage controlling means so located relative to the nozzles as to properly meter the fuel without interfering with the injector action; and finally to provide means for reducing undesirable noises due to passage of air into the intake past the throttle.

These and other features of the invention will be best understood in connection with the accompanying drawings of a preferred form of apparatus.

In said drawings:

Figure 1 is a side elevation of an engine equipped with apparatus in accordance with my invention, the same being partly in section;

Fig. 2 is a detail sectional view on the line 2—2 of Fig. 1;

Fig. 3 is a vertical section of an apparatus for replacing the usual carburetor and fuel lifting mechanism, the parts being shown in position for engine idling;

Fig. 4 is a bottom plan thereof with parts in section;

Fig. 5 is a detail sectional view on the line 5—5 of Fig. 4 looking in the direction of the arrows;

Fig. 6 is a detail sectional view of means for controlling the inductive effect on the fuel nozzle at idling;

Fig. 7 is a side elevation of throttle operated actuating means for the means shown at Figs. 4 and 5, and

Fig. 8 is a sectional detail.

Air admitted by the manually operated throttle valve 10 passes through a passage 12 in an apparatus 14, which I designate a blast charger, through the manifold riser 16, the manifold 18, and past the inlet valves 20, open on the intake stroke, into the combustion chamber 22 of the engine. The air passage preferably contains a venturi 24 having a throat 26. The exhaust conduit is indicated at 27.

In the unobstructed region between the throttle and the intake valves I deliver a blast of gaseous fluid toward the engine cylinders through nozzle 28 disposed within the fuel nozzle 30, the latter being threaded thereon at 31, and directed therewith in the direction of air flow. The nozzles 28 and 30 are maintained in spaced relation to each other by the longitudinal ribs 31^a spaced from each other. Nozzle 30 has the mouth 32 thereof disposed within the throat 26 of venturi 24 which is made of relatively large diameter so that it is effective principally during wide open throttle operation. With such arrangement the gaseous blast aspirates and atomizes the fuel and also augments the flow of air to the engine cylinders.

The nozzles 28 and 30 are arranged to provide fuel passages 34 between the ribs 31^a. The orifice 36 of the nozzle 28 terminates inwardly from the end 32 of the fuel nozzle 30, the gaseous fluid and fuel aspirated by said fluid passing through the cylindrical passage of the outer portion 32 of the nozzle 30 into the venturi 24. The composite nozzle structure is inserted into the blast charger 14 through housing 38, the contacting portions of the nozzle 28 and housing 38 being

tapered so that the structure may be drawn tightly into place by screws. By inserting the gas nozzle 28 within the fuel nozzle 30, the areas of the passages and the concentricity of the nozzles need not be critically adjusted to obtain proper fuel flow and atomization thereof, and the gas discharge orifice 36, being a simple round hole, is not subject to fouling. The two nozzles may be readily removed or inserted. A fluid-tight connection with the housing 38 is obtained by the gasket and nut, indicated at 39.

The gaseous fluid for the blast preferably consists of gases from the engine cylinders, which are available at pressures increasing with the increase of charge quantity and contain products of combustion such as CO₂ and H₂O together with nitrogen adapted to form anti-detonating constituents of the charge mixture permitting increase of compression ratio without detonation. The gases are permitted to pass adjustably-limited-motion-ball check valves 40 in passages formed in the engine and providing if so desired communication from the combustion chambers 22 of the engine cylinders through separate conduits 41 to a common manifold or conduit 42, preferably formed integral with the separator 44. The gases are freed from undesirable particles by centrifuging in separator 44, into which they are tangentially discharged through pipe 46, and from which they pass out to nozzle 28 through pipe 48 having an inlet at substantially the center of the separator. The separator 44 is provided with a cleanout plug 50.

The adjustment of the ball valves for controlling the pressure reduction and the size of outlet from nozzle 28 are preferably such as to provide blasting pressure in the pressure line up to about 100 pounds per square inch, the permissible pressure increasing according to design of intake manifold, area of intake valves, and timing.

The manifold because of the thorough comminution of the fuel accomplished by blasting need not be designed for securing high velocity to suspend fuel into admixture with the air, but can advantageously be made with the generously large cross-sectional areas and sweeping turns adapted to reduce friction and furnish substantially maximum air supply to the engine cylinders. A free sweep of the gases into the combustion chambers, and maximum area and period of opening of intake valves, are desirable in order to secure maximum efficiency of operation. I preferably vary the ball valve adjustment slightly for the several cylinders and thereby secure identical compression pressures in each, with resulting smooth engine performance.

Fuel is supplied to the nozzle 30 from the source of fuel supply, as the tank 52 vented to the atmosphere at 54, through pipe 56, chamber 58 in housing 38, and metering orifice 60 in member 62 communicating with passages 34 through opening 64 formed in the lower portion of the wall of the nozzle 30, preferably at the side thereof opposite the throttle 10. The metering orifice 60 extends transversely of the nozzles 28 and 30 exteriorly of and in close proximity thereto so as to meter the fuel as close as possible thereto without interfering with the injector action. The intermediate portion of the pipe 56 is relatively low compared to the ends thereof to prevent the fuel from entirely draining back into the tank 52 when the engine ceases operation so that fuel is available in the fuel line for quickly starting the engine.

A tubular portion or sleeve 66 forms an ex-

tension for the chamber 58 and terminates at its remote end in a wall portion 68 which with the cap 70 detachably threaded thereon forms a chamber or enclosure 72 for receiving the bellows or pressure responsive device 74 with the axis thereof disposed transversely relative to the axes of the nozzles 28 and 30.

The portion 75 of the manifold 18 facing the fuel injector nozzle system at the upper end of the intake riser 16 is preferably heated by means of the hot exhaust gas so that the comminuted fuel discharged against the same will not condense. For this purpose the exhaust manifold 27 is provided with an opening 27^a exposing the part 75 to the heated gas. The manifolds 18 and 27 are secured together to provide a tight joint at this point by means of the bolts 27^b and the interposed gasket 27^c. This arrangement prevents precipitation or condensation of the comminuted fuel upon the impact thereof with the portion 75, and this is accomplished without unduly heating the air component and thereby decreasing the volumetric efficiency.

I lift the fuel for the engine by subjecting the fuel nozzle to suction from several sources so related as to complement, replace and reinforce one another throughout the full range of engine operation from idling to high speed operation with the throttle wide open, comprising suction due to induction by cylinder gas blasting, to air flow as augmented by the cylinder gas blast, and to intake depression as reduced by air bleed or by the discharge of cylinder gases into the intake. The suction from the several sources thereof is amply sufficient throughout the range of engine operation, so that in the case of the automobile engine, for example, changes in fuel level when operating on level road do not appreciably affect the rate of fuel flow, and the fuel for the engine may be lifted, without dependence upon other fuel lifting devices, even during travel up the steepest grades. The comminution of fuel issuing from nozzle 30 is approximately uniform, since its two producing causes, blasting by cylinder gas and discharge into partial vacuum, are of substantially complementary magnitude throughout the range of engine operation.

I regulate the extent of opening of the fuel passage so as to supply the required fuel in response to the suction thereon. In the form shown the extent of opening of the fuel conduit is controlled by the tapered metering pin or valve 76 slidably guided in the bearing 78 within the sleeve 66 and coacting with the port 60. Pin 76 is controlled by bellows 74 to which it is flexibly connected as by means of the spherical headed screw member 80 and ring nut 82.

The cap 70 has an opening 84 into which is threaded a bushing 86 having a gasketed flange 88 at the inner side of the cap. The bellows 74 is threaded on the inner end 90 of the bushing 86, the cap 70 and bellows 74 being drawn up tight against the flange 88 to prevent leakage through the opening 84. A tubular member 92 is threaded into the bushing 86 which member 92 in turn receives the tubular member 94 threaded into the same. The members 92 and 94 at their inner ends provide abutments for coil springs and are secured in adjusted positions by the nuts 96 and 98. A tubular member 100 open at both ends is disposed within the member 94 to provide communication between the interior of the bellows and the exterior there-

of, whereby to expose the interior of the bellows to atmospheric pressure.

Tubular member 100 acts as a stop to prevent contraction of the bellows beyond that necessary to provide a fuel orifice of predetermined maximum size. The member 100 is threaded into a cap 102 enclosing bushing 86 and members 92 and 94 and secured by screws 104 to the outer end of the closure 70. The member 100 may be adjusted axially without removing the cap 102 and then locked by nut 106. By unscrewing the cap 70 the bellows 74 and valve 76 may be removed as a unit therewith for inspection, repairs or replacement.

The casing 70 provides a substantially airtight enclosure for the bellows 74, forming about the bellows a "dead end" air chamber 72 which communicates through the pressure line or conduit 108 with the interior of the exhaust gas conduit 27. The pressure line 108 preferably comprises an enlarged outer portion 110 near the exhaust conduit 27 having a volume which is as great as or greater than the increase in volume of the chamber 72 when the bellows has contracted to its maximum extent, the portion 110 preferably communicating with the interior of the bellows casing through a tubular portion 112 of reduced cross-section. The opening 113 between the tube portions 110 and 112, as shown at Fig. 8, is constricted sufficiently relative to the cross-section of tube 112 to smooth out the exhaust gas pressure pulsations.

The inherent resiliency of the bellows 74 is supplemented in opposing contraction thereof to enlarge the opening at 60 by a relatively light constantly acting coil spring 114 disposed about the lower end of member 100 between the bellows and the adjustable tubular abutment 94 and a stronger spring 116 disposed about member 94 between the bellows and the abutment 92, the spring 116 being fully relaxed when the bellows is expanded and becoming effective only after the bellows has contracted to some extent.

I have found in the operation of internal combustion engines that the exhaust gas pressure varies from slightly above atmospheric pressure upwardly, and in case of automotive apparatus employing mufflers the maximum pressure may be several pounds above atmospheric as the quantity of cylinder charge increases. The pressure of the exhaust gas is indicative of the charge weight, and hence of the fuel requirements for various engine loads and speeds. These pressure variations are therefore ideal for controlling the fuel passage area to vary the fuel supply in accordance with the requirements, and the range of pressure variation is sufficiently wide to impart the required movement to the bellows to vary the fuel passage opening substantially from the minimum to the maximum required.

With the hereinbefore described arrangement the pressure variations within the exhaust manifold 27 are impressed on the air within the pressure line 108 and chamber 72 and cause the bellows 74 to move in accordance therewith, the portion 110 of the pressure line serving to exclude the heated exhaust gas from circulating or passing into chamber 72 into contact with the bellows, so that the latter remains cool. The bellows 74 is therefore controlled by the variations in differential between the super-atmospheric exhaust gas pressure and atmospheric pressure, that is, by the variations in the "gauge" pressure of the exhaust gas, which pressure varies in the right direction and to the required extent to cause variation of

the fuel supply directly therewith substantially throughout entire ranges of engine operation.

As the exhaust gas pressure increases the bellows 74 contracts causing movement of valve 76. The opening movement of the valve as the bellows contracts is resisted first by the light spring component 114 including the resiliency of the bellows itself, and then additionally resisted by the stronger spring component 116, thus, the bellows is made initially sensitive to inches of water pressure. The inherent resiliency of the bellows and the springs 114 and 116 serve when the bellows expands upon the reduction of exhaust gas pressure to produce a correspondingly opposite or closing movement of the fuel metering pin.

With the control of the fuel passage as described compensation for barometric changes is automatically obtained. The springs which tend to reduce the fuel passage area are of course unaffected by barometric change and the exhaust gas gauge pressure tending to open the fuel passage varies directly with barometric change because of corresponding variation in the weight of charge with the result that, for example, in passing from a region of higher pressure to one of lower pressure, as in climbing with an airplane, the fuel supply passage is reduced to supply fuel in reduced quantity corresponding with the reduced air weight available.

The closing movement of the metering pin 76 and expansion of the bellows is limited by the stop cams 118 and 120 which engage the free end of the bellows 74 in the expanded position thereof to determine the minimum fuel passage opening. The bellows is preferably retained thereby under slight initial compression, the resulting resiliency of the bellows and the spring 114 retaining the bellows firmly seated on the cams in the expanded or idling position of the bellows. The cams 118 and 120 are detachably secured to the inner ends of shafts 122 and 124 rotatably received within the plugs 126 and 128 threaded into the openings 130 and 132 at opposite sides of the part 68. The plugs 126 and 128 may be readily removed from and inserted in place and maintain the casing 70 fluid tight at the points where the shafts 122 and 124 enter the same.

The shaft 122, which is arranged in parallelism with the pivot of throttle 10, is actuated adjacently to throttling through the crank member 134 mounted on the outer end of the shaft 122 for adjustment rotatively about the same, and adapted to be secured to the member 136 fastened to the shaft 122, the crank 34 being locked in various positions by the screw 138 which passes through the slot 140 in the member 134 and is threaded into member 136.

A link 142 pivotally connects the throttle arm 144 with the crank 134, the link 142 being connected to the crank 134 by the pivot pin 146 received in hole 148. The direction of movement of the bellows and the disposition of the shaft 122 in parallel with the throttle pivot permits of the employment of a simple connection between the throttle and shaft 122 which positively moves the cam in both directions without interfering with the free movement of the bellows over the higher portion of the exhaust gas pressure range. As the throttle 10 is opened the shaft 122 is rotated to a slight extent causing the cam 118 to compress the bellows to enlarge the fuel passage opening. Thus, upon accelerating from engine idling, the exhaust gas pressure then being low, the initial and additional fuel required for accelerating is supplied by mechanically supplementing the ex-

haust gas pressure in causing bellows contraction. As the exhaust gas pressure increases, the bellows contracts disengaging the cam 118 which at open throttle positions is located to provide the proper fuel at minimum speeds full load.

The shaft 124 is actuated from a distant point, such as by a wire control from the dash board of a motor vehicle connected to the arm 150 which is secured to the outer end of shaft 124. The fuel passage opening may thus be enlarged manually through cam 120 for engine starting.

In order to supply the fuel component of the charge to the engine steadily at idling, I preferably reduce the suction effective on the fuel by bleeding air into admixture with the fuel at a point intermediate the metering orifice 60 and the discharge end 32 of the fuel nozzle. This permits of a corresponding increase of the fuel passage opening at 60 and materially reduces the friction and fluctuation at 60. The bled air is delivered through the passage 152 in part 38 at the throttle side of the nozzles into the fuel conduit 34 where the fuel is aerated.

The air bleed passage 152 is controlled from a point contiguous to the end of the throttle pivot opposite the crank 144 by a valve 154 which is normally held closed by spring 156. The valve 154 and spring 156 are disposed within a valve casing 158 having bleed openings 160 and communicating with the passage 152. The stem 162 has a head 164 adjustable axially of the stem and co-operating with the finger 166 secured to the pivot of throttle 10 and adapted to open valve 154 as the throttle closes. By adjusting the head 164 the extent of opening of the air bleed at idling, and hence the induction, may be accurately controlled to supply the requisite fuel at idling without necessitating adjustment of the minimum fuel passage area at 60. As the throttle opens the air supply through the bleed holes 160 is gradually shut off. The passage 152 is also provided with a relatively small air bleed 167 to prevent the passage 152 from filling with fuel.

The throttle 10 is preferably provided with a bleed opening 168 for admitting air at idling when the throttle is closed. When the air for idling is supplied through a very small crescent form passage over the edge of the nearly closed throttle, as in ordinary practice, the friction causes the air supply to be erratic, and this is avoided by the use of bleed opening 168.

The shaft of throttle 10 is located eccentrically within the air passage to permit of sensitive control and automatic closing of the throttle should the throttle spring break.

As the throttle opens substantially the air bleed passage 152 closes so as to maintain the highest vacuum possible upon the fuel orifice. This can be advantageously done because the fuel passage areas are then larger and frictional resistance to fuel flow is greatly reduced.

The inlet of the air passage 12 at the atmospheric side of the throttle 10 receives a member 170 constructed to deaden noise due to the passage of air into the intake past the throttle. The member 170 comprises a truncated open ended tubular portion 172 extending into the body of member 170 in spaced relation to the wall thereof and providing an air inlet of gradually decreasing cross-section towards the throttle and an annular pocket 174 intermediate the portion 172 and the outer wall of member 170.

Engine starting

Upon turning over the engine, the gases dis-

charged through the nozzle 28 elevate the fuel and cause the discharge thereof in a comminuted state into the intake, supplying the requisite fuel for starting, even though the intake depression should be quite low. Thus the continuous blasting of the fuel by the gases from the cylinders prevents stalling during the warming up period without entire dependence upon air velocity or intake depression which fluctuate undesirably. The fuel passage can be increased if needed by manual operation of cam 120.

Idling

At the small air passage openings for idling and slightly beyond idling, the inductive effect on the fuel of the blast of cylinder gases is not considerable, since the cylinder gas pressure is low because the charge weight is low. The intake depression, however, is substantially maximum because of the limited extent of throttle opening, and there is a very high suction on the fuel from this source, and since very little fuel is needed, the fuel passage must be restricted by moving the pin 76 toward closing position, providing a fuel passage opening which at idling is of minimum area. I have found, however, that at idling operation highly constricted fuel and air passages with the resulting frictional retardation of the passage of fuel and air often cause erratic operation, due to the fuel and air supply fluctuating undesirably. I insure steady, smooth and economical operation at idling and lower fractional loads by bleeding air with the fuel passage into passage 34. This bleed reduces the intake depression acting on the fuel and hence permits of the use of a larger fuel passage opening at 60 during idling than could otherwise be used, which larger opening reduces the frictional retardation and steadies out the fuel flow.

When the throttle is closed, the air bleed opening 168 in throttle 10 supplies the requisite air for idling without undue friction opposing the passage thereof.

Fractional load or torque range

During torque range of operation, that is, beyond idling and below full load operation at open throttle, in which range engine torque up to maximum obtainable is controlled by manually opening the throttle, the intensity of the cylinder gas blast, inductive effect of cylinder gases on the fuel, accelerating effect thereof on the air, and quantity of air admitted past the throttle, all vary directly with the manually controlled throttle opening. While the intake depression becomes less as the opening of the throttle is increased and also becomes less because of the increasingly large quantity of cylinder gas being blasted at increased pressure into the intake, there is, nevertheless, throughout this range ample suction to lift and deliver the fuel into the intake, such suction being due to induction of cylinder gas blast and to intake depression, the latter being dependent largely on throttle position and substantially complementary in magnitude to the induction of cylinder gas blast, and, to a lesser extent, to air flow (as augmented by the blast of cylinder gases).

During this stage of operation the variations in exhaust gas pressure due to variations in charge material quantity are transmitted to the bellows, resulting in variation of the fuel passage area directly with the air supply.

Unless a bellows of sufficiently large capacity is made use of adapted to respond very positively

to small pressure changes, the fuel passage opening for small throttle openings beyond idling is secured by supplementing means, such as by mechanical control through the throttle, the throttle movement being also utilized for closing the air bleed, thereby increasing the inductive effect and further increasing the fuel flow.

Full load range

10 At wide open throttle the intake depression is very low. As the speed increases at full load there is an increase in cylinder gas induction and the quantity and velocity of air increase at a rapid rate with the increase in engine speed and thus at full load with the fuel nozzle located within the venturi 24 ample suction is obtained for full load fuel delivery, due principally to induction by cylinder gas blast augmented by air velocity.

15 In this range of operation the fuel requirements increase with increase in engine speed. I accordingly utilize the variations in exhaust gas pressure occurring upon speed changes at full load for varying the fuel passage area directly therewith through movement of the pin 76, and, by combination of suction and fuel passage area control, supply the requisite fuel in suitable proportion to the air throughout the speed range at wide open throttle.

20 By my invention I can operate internal combustion engines either on the present customarily used fuels or on fuels of much higher boiling point than used with the customary carburetor, and am enabled to put all the fuel for the whole range of operation through a simple nozzle and eliminate the various compensating jets and mechanisms employed in conventional carburetors, and generally increase the over-all efficiency of internal combustion engines.

25 Having thus described my invention, what I claim and desire to secure by Letters Patent is:

30 1. In apparatus for supplying and mixing charges for internal combustion engines, an intake, a throttle therein, a housing portion having a bore in alignment with the riser portion of said intake, a nozzle for high pressure gases received within said bore, a fuel nozzle disposed about said first named nozzle and detachably secured thereto, said housing portion having a passage therein disposed transversely of said nozzles and communicating with the interior of said fuel nozzle, said passage having a portion of relatively reduced cross-section in close proximity to said nozzle, a bearing disposed in said passage, a fuel metering valve slidable in said bearing and cooperating with said relatively reduced portion of the passage, and pressure responsive means at the opposite end of said bearing connected to said valve.

35 2. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake, means for supplying fuel thereto, and pressure responsive means subject to the variations in pressure in said exhaust conduit for controlling the fuel flow, comprising spring means for opposing movement of said pressure responsive means as the exhaust gas pressure increases, said spring means including a component effective in opposing movement of said pressure responsive means over a portion only of the exhaust gas pressure range.

40 3. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake, means for supplying fuel thereto, and pressure responsive means subject to variations in pressure in said exhaust conduit

for controlling the fuel flow, comprising spring means for opposing movement of the pressure responsive means in response to increases in exhaust gas pressure substantially coextensively with the range thereof, said spring means including a more powerful component effective in opposing movement of the pressure responsive means over the upper portion only of the exhaust gas pressure 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.

4. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake, means for supplying fuel thereto, elastic pressure responsive means for controlling the fuel passage area, stop means for limiting the movement of said pressure responsive means in both directions and determining the minimum and maximum fuel passage openings, means for subjecting said elastic pressure responsive means to the variations in pressure in said exhaust conduit, and spring means supplementing said resiliency for opposing movement of said pressure responsive means as the exhaust gas pressure increases.

5. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake, 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 fuel passage openings, means for subjecting said pressure responsive means to the variations in pressure in said exhaust conduit, and spring means for opposing movement of said pressure responsive means as the exhaust gas pressure increases, said spring means being more effective over the upper portion of the exhaust gas pressure range than over the lower portion thereof, whereby to vary the rate of opening of the fuel passage in accordance with the rate of variation of the exhaust gas pressure.

6. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake, means for supplying fuel thereto, pressure responsive means subject to the variations in exhaust gas pressure for controlling the fuel flow, and spring means for opposing movement of said pressure responsive means as the exhaust gas pressure increases, said spring means including a component providing appreciable opposition to the movement of said pressure responsive means over the upper portion of the pressure range and a component providing less opposition to the said movement over the lower portion of said range.

7. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake, means for supplying fuel thereto, an elastic pressure responsive element subject to the variations in pressure in said exhaust conduit for varying the fuel passage opening, stop means for retaining said element against movement beyond its elastic limits and determining the minimum and maximum fuel passage openings, and a supplementing spring for said elastic element effective over the upper portion of the exhaust gas pressure range in opposing increases in exhaust gas pressure, said spring being inactive over the lower portion of said pressure range.

8. In apparatus for supplying and mixing charges for internal combustion engines, an ex-

haust conduit, an intake, means for supplying fuel thereto, an elastic expansible-contractible element in communication with said exhaust conduit and subject to the variations in pressure

therein 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, said element in the expanded condition thereof being held against one of said stops under a lesser spring tension to prevent fuel passage area variation at the lower end of the exhaust gas pressure range when the variations thereof are relatively slight, while permitting of contraction of said element relatively early upon greater increases in exhaust gas pressure, and supplemental spring means for increasing the opposition to the contraction of said element coming into action over the higher portion only of the exhaust gas pressure range.

9. In apparatus for supplying and mixing charges for internal combustion engines, an intake, means for supplying fuel thereto, an enclosure, a bellows disposed within said enclosure and secured at one end thereto, a tubular open ended stop extending into said bellows through the secured end thereof and exposing the interior thereof to atmospheric pressure, means for exposing the exterior of said bellows within said enclosure to pressure variations, and a valve connected to said bellows for controlling the fuel supply.

10. In apparatus for supplying and mixing charges for internal combustion engines, means for supplying fuel thereto, an enclosure having a removable cap, said enclosure and said cap forming a single chamber, an expansible-contractible bellows element received within said enclosure and carried by said cap, and means connected to said element for controlling said fuel supplying means.

11. In apparatus for supplying and mixing charges for internal combustion engines, an intake, means for supplying fuel thereto, a tubular portion having a bearing and terminating in a wall portion, a cap removably secured to said wall portion and forming therewith an enclosure, a bellows received within the enclosure and secured at one end to said cap, and a needle valve flexibly connected to said bellows at the opposite end thereof and slidable in said bearing for controlling said fuel supplying means, said bellows and said valve being removable as a unit with said cap.

12. In apparatus for supplying and mixing charges for internal combustion engines, an intake, means for supplying fuel thereto, an enclosure, a bellows disposed therein and secured at one end thereto, a tubular abutment extending into said bellows through the secured end thereof, an open ended tubular stop extending into said bellows through said tubular abutment, a spring interposed between said bellows and said abutment around said stop, and means for controlling the fuel supply from the bellows.

13. In apparatus for supplying and mixing charges for internal combustion engines, an intake, means for supplying fuel thereto, an enclosure, a bellows disposed therein and secured at one end thereto, concentric tubular abutments extending into said bellows through the secured end thereof, an open ended tubular stop extending into said bellows through the inner of said tubular abutments, springs interposed between said bellows and said tubular abutments, one of

said springs coming into action after partial contraction of the bellows, and valvular means connected to the bellows for controlling the fuel supply.

14. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake, means for supplying fuel thereto, an enclosure, a bellows received within said enclosure and secured at one end thereto, axially adjustable concentric tubular abutments extending into said bellows through the secured end thereof, a closure for the outer ends of said tubular abutments, an open ended tubular stop carried by said closure and adjustable axially therein and extending into said bellows through the inner of said tubular abutments, springs interposed between said bellows and said tubular abutments, one of said springs coming into action after partial contraction of the bellows, means for subjecting the exterior of the bellows within said enclosure therefor to exhaust gas pressure variation, and valvular means connected to the bellows for controlling the fuel supply.

15. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake, a throttle therein, means for supplying fuel to the intake, means responsive to variations in exhaust gas pressure for controlling the fuel supply, and a member operated by the throttle for mechanically actuating said pressure responsive means to increase the fuel supply upon opening of the throttle.

16. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake, a throttle therein, a nozzle for supplying fuel to the intake beyond the throttle, means responsive to variations in exhaust gas pressure for controlling the fuel passage opening, an air bleed communicating with said nozzle, a valve normally closing said air bleed, and means actuated from the throttle for opening the bleed valve as the throttle closes and mechanically actuating said pressure responsive means to enlarge the fuel passage as the throttle opens.

17. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake, a throttle therein, means for supplying fuel to the intake, means responsive to variations in exhaust gas pressure for controlling the fuel passage area and including spring means for closing off the fuel passage, and a member operated by the throttle and adapted to move said pressure responsive means against the spring tension thereof for enlarging the fuel passage area as the throttle opens.

18. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake, a throttle therein, means for supplying fuel to the intake, means responsive to variations in exhaust gas pressure for controlling the fuel passage area and including spring means for closing off the fuel passage, and a member operated by the throttle and adapted to move said pressure responsive means against the spring tension thereof for enlarging the fuel passage area as the throttle opens, said member serving as a stop for preventing undue reductions in the fuel passage area upon decreases in exhaust gas pressure at open throttle positions.

19. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake, a throttle therein, means

for supplying fuel to the intake, an element responsive to variations in exhaust gas pressure for controlling the fuel passage area and including spring means for closing off the fuel passage, and plural means adapted to coact with said pressure responsive element for mechanically actuating the same, one of said plural means being actuated adjunctively to throttling, and the other thereof being independently actuated in starting the engine.

20. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake, a throttle therein, means for supplying fuel to the intake, means responsive to variations in exhaust gas pressure for controlling the fuel passage area, a cam coacting with said pressure responsive means, and a connection between said throttle and said cam, whereby to mechanically enlarge the fuel passage area as the throttle opens.

21. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake, a throttle therein, means for supplying fuel to the intake, means responsive to variations in exhaust gas pressure for controlling the fuel passage area and including spring means for closing off the fuel passage, cams disposed at the free end of said pressure responsive means, means for actuating one of said cams from the throttle to enlarge the fuel passage as the throttle opens, and means for independently actuating the other of said cams for enlarging the fuel passage in starting the engine.

22. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake having a laterally disposed air inlet, a throttle therein, a fuel nozzle extending into said intake, a fuel passage having a metering orifice disposed in close proximity to said nozzle, and communicating therewith, a bearing in alignment with and beyond said metering orifice, a valve slidably guided in said bearing and cooperating with said metering orifice, an enclosure beyond said bearing, an expansible-contractible element disposed within said enclosure and connected at the inner end thereof to said valve, said element having the axis thereof disposed in alignment with said valve, and means for subjecting the exterior of said element to the pressure variations in said exhaust conduit.

23. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake having a laterally disposed air inlet, a pivoted throttle therein, a fuel nozzle extending into said intake beyond said throttle, a fuel passage having a metering orifice disposed transversely of and communicating with said nozzle at the side thereof opposite said throttle, a bearing in alignment with and beyond said orifice, a valve slidably guided in said bearing and cooperating with said metering orifice, an enclosure beyond said bearing, an expansible-contractible element disposed within said enclosure and connected at the inner end thereof to said valve, said element having the axis thereof disposed in alignment with said

valve, means for subjecting the exterior of said element to the pressure variations in said exhaust conduit, a shaft disposed in parallelism with the pivot of said throttle and extending into said enclosure in fluid tight relation thereto, a member on the inner end of said shaft adapted to coact with said element for contracting the same, and a link connection between said throttle and said shaft, whereby to supplement the exhaust gas pressure mechanically in causing enlargement of the fuel passage opening upon opening movement of the throttle.

24. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake, means for supplying fuel to the intake, pressure responsive means for controlling the fuel supply, and tubular means for transmitting the pressure variations from said exhaust conduit to said pressure responsive means including an enlarged portion contiguous to said exhaust conduit and a smaller portion contiguous to said pressure responsive means, said smaller portion having a relatively constricted part forming an orifice adapted to smooth out pulsations in exhaust gas pressure.

25. In apparatus for supplying and mixing charges for internal combustion engines, an exhaust conduit, an intake having a laterally disposed air inlet, a pivoted throttle therein, a fuel nozzle extending into said intake beyond said throttle, a fuel passage having a metering orifice disposed transversely of and communicating with said nozzle at the side thereof opposite said throttle, a bearing in alignment with and beyond said orifice, a valve slidably guided in said bearing and cooperating with said metering orifice, an enclosure beyond said bearing, an expansible-contractible element disposed within said enclosure and connected at the inner end thereof to said valve, means for subjecting the exterior of said element to the pressure variations in said exhaust conduit, a shaft disposed in parallelism with the pivot of said throttle and extending into said enclosure in fluid tight relation thereto, a member on the inner end of said shaft adapted to coact with said element for contracting the same as the throttle opens, a link connection between one end of said throttle and said shaft, an air bleed passage communicating with said nozzle, a valve controlling said air bleed passage, and means on the opposite end of said throttle for actuating said valve to open the same as the throttle closes.

26. In apparatus for supplying and mixing charges for internal combustion engines, an intake, air controlling means therein, means for supplying fuel to the intake beyond said air controlling means, means for controlling the fuel passage opening, an air bleed passage communicating with said fuel supplying means, valvular means for controlling said air bleed passage adjunctively to throttling, and an auxiliary permanently open air bleed into said air bleed passage for preventing passage of fuel thereinto when said valvular means is closed.

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