

Aug. 17, 1948.

F. C. MOCK
CHARGE FORMING DEVICE

2,447,263

Filed Jan. 21, 1948

2 Sheets-Sheet 1

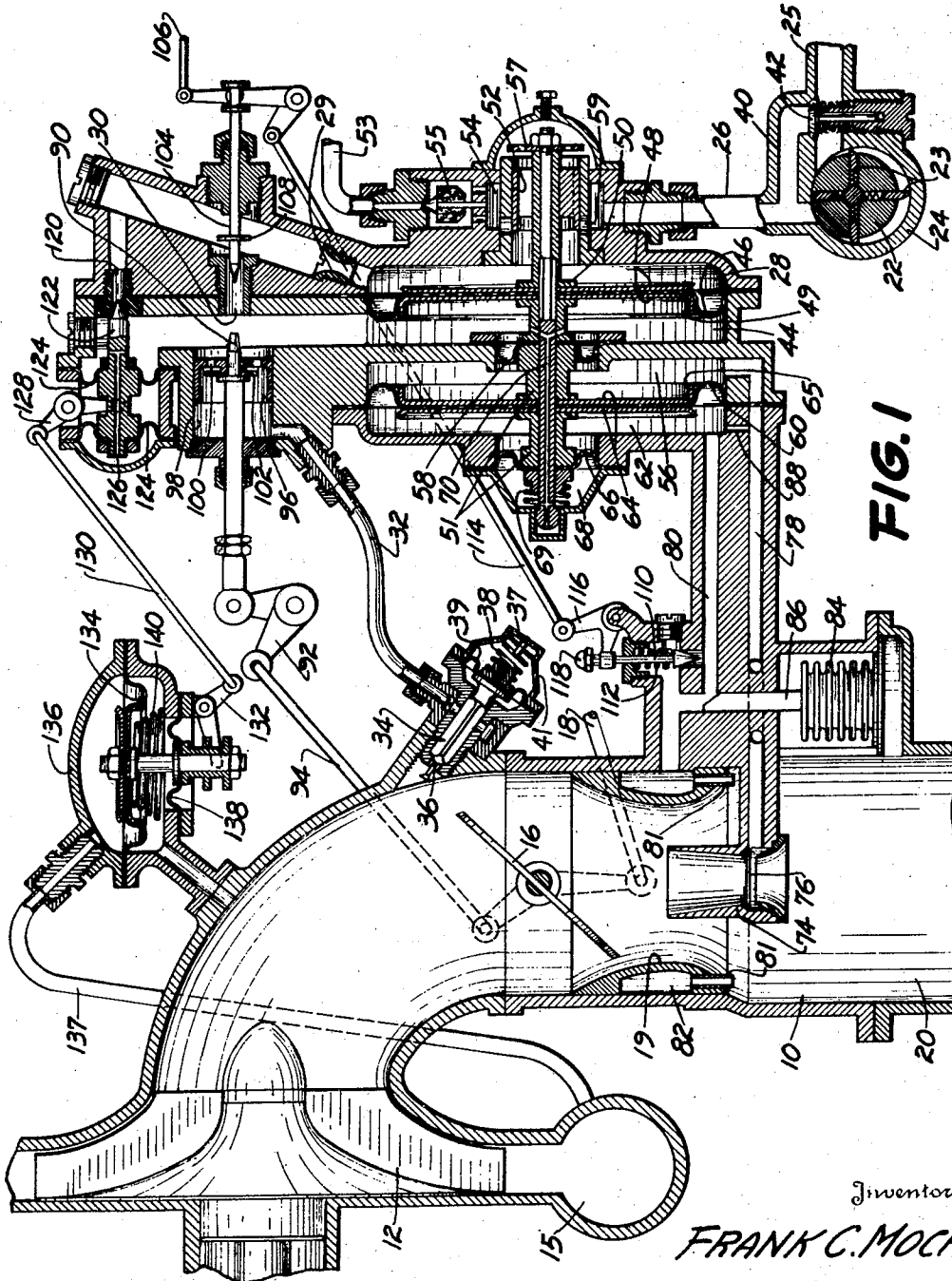


FIG. 1

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2 Sheets-Sheet 2

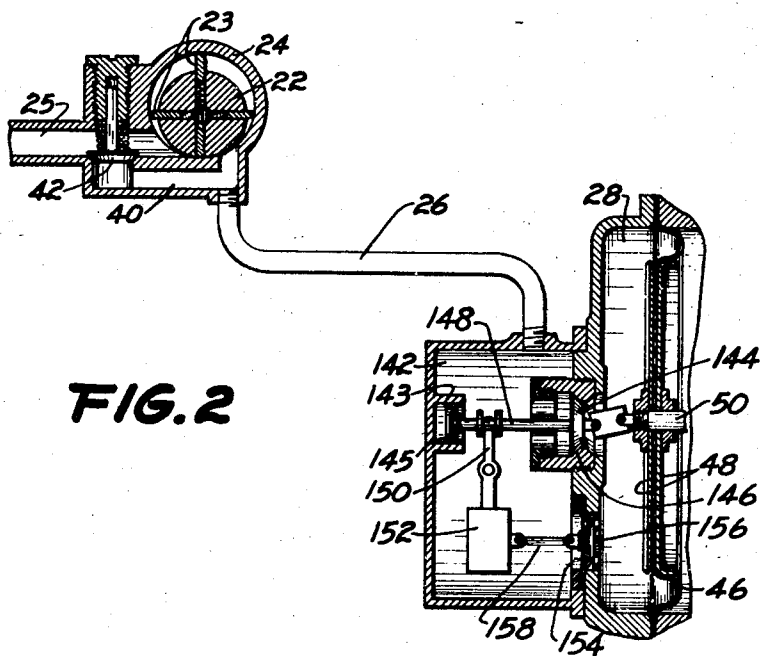


FIG. 2

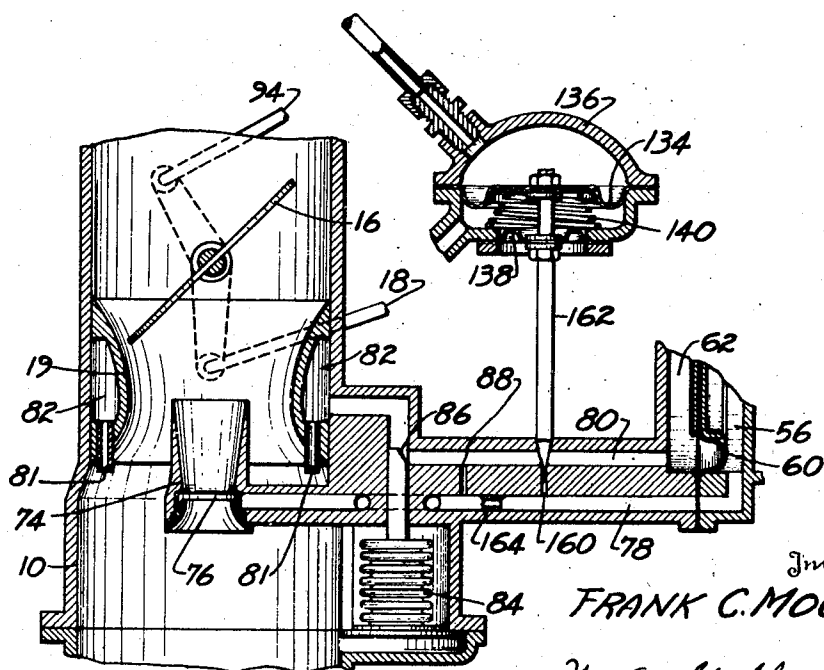


FIG. 3

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UNITED STATES PATENT OFFICE

2,447,263

CHARGE FORMING DEVICE

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Application October 24, 1940, Serial No. 362,572,
which is a continuation of application Serial
No. 118,718, January 2, 1937. Divided and this
application January 21, 1948, Serial No. 3,394

39 Claims. (Cl. 123—119)

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This invention relates to fuel feeding devices or systems for engines or prime movers and more particularly to devices or systems in which liquid fuel is supplied under positive pressure to a fuel discharge nozzle, burner or the like. The invention is principally concerned with a control means for the supplementary fuel supply, or economizer system, for enriching the mixture supplied to the engine under certain conditions of operation, and is particularly adapted for use with supercharged aircraft engines but may be used on engines of other types or for other purposes. This application is a division of my copending application Serial No. 362,572, filed October 24, 1940, which in turn is a continuation of my copending but now abandoned application Serial No. 118,718, filed January 2, 1937.

One of the principal objects of the invention is to supply the liquid fuel under positive pressure, the fuel supply being regulated to maintain proper fuel-to-air ratios throughout the operating range. This arrangement causes the fuel to be atomized under pressure to produce a better mixture in carburetor or injection type engines, or better combustion in burner type prime movers; it also keeps the fuel under atmospheric or superatmospheric pressure at all times thereby eliminating boiling of the fuel and insuring accurate metering.

Another principal object of the invention is to provide an improved power enrichment or economizer system in a pressure type fuel feeding device whereby a relatively lean fuel-to-air ratio will be maintained during low and intermediate power outputs and an enriched mixture during high rates of air consumption corresponding to high power operation.

It is a further object of the invention to provide a fuel feeding system wherein the operator may vary the fuel-to-air ratio between predetermined limits in the low and intermediate power operating ranges without materially varying the fuel-to-air ratio in the high power output range. This allows the pilot to select the richness of mixture best suited for maximum economy during cruising for the wind and weather conditions then obtaining, without permitting him to disturb the richness required for maximum power output.

Another object of the invention is to provide a fuel feeding device or system which will operate properly in any position so that when installed on aircraft the engine will be properly supplied with fuel regardless of whether the engine is operating at low, intermediate, or high

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power output. This is highly important during maneuvers of different kinds at which time an adequate fuel supply is indispensable.

A still further object of the invention is to provide a fuel feeding system wherein both the normal and supplemental fuel supplies are properly compensated in response to variations in altitude.

The control apparatus of the present invention, while especially applicable to fuel supply regulating systems for aircraft engines, is also applicable to engines of other types or to various other devices wherein fluids are to be metered and supplied to a fluid consuming or receiving device. The characteristics and advantages of the invention are further sufficiently referred to in connection with the following detailed description of the accompanying drawings, which represent certain preferred embodiments. After considering these examples, skilled persons will understand that many variations may be made without departing from the principles disclosed; and I contemplate the employment of any structures, arrangements, or modes of operation that are properly within the scope of the appended claims.

Figure 1 is a diagrammatic sectional view of a preferred embodiment of the invention as applied to a pressure feed carburetor for internal combustion engines;

Figure 2 is a partial view in section illustrating a modified fuel inlet valve construction; and

Figure 3 is a partial diagrammatic view in section illustrating another embodiment of the invention.

Referring first to Figure 1, a main air intake conduit 10 leads to a rotary blower or supercharger 12 of an internal combustion engine which may be of any desirable type. The conduit 10 is controlled by a throttle 16 which is operated by a rod 18 extending from the pilot's cockpit. The pilot thus controls directly the air charge of the engine while the fuel charge is automatically controlled by the apparatus hereinafter described in detail. Anterior to the throttle is a venturi 19 of any suitable contour. In some cases a second supercharger may be employed to supply air at higher than atmospheric pressure to the entrance 20 of passage 10, and in such cases the supercharger 12 serves both to step up the pressure and as a fuel mixer and distributor. In other cases the entrance 20 is merely flared and opens in the direction of travel of the craft, so that the inertia of the entering air will build up a pressure above atmospheric

at the entrance, which is in such cases usually referred to as a scoop.

An instrumentality such as the blower 12 is not essential to the invention, but is here shown as representing approved practice in aircraft engines, and serves to or assists in atomizing and properly distributing fuel introduced into the air line in the manner presently referred to. The blower discharges into a generally annular chamber 15 from which pipes lead to the intake ports of the various cylinders, as usual in this type of engine.

It is to be understood that the entire air passage between the throttle and the engine intake ports of an internal combustion engine, and the air passage beyond the compressor in burner type engines represents broadly an intake manifold, and the term is to be so construed in this specification.

Any known or suitable fuel pump, capable of delivering fuel under positive pressure, is provided, that shown being of the sliding vane type and comprising a rotor 22 slidably carrying a set of vanes 23 and rotatably mounted in a casing 24.

The casing has a fuel inlet 25, an outlet 26, and a return bypass 40 controlled by a pressure responsive valve 42, so as to maintain a substantially constant outlet fuel pressure, in the known manner. The pump thus delivers fuel to passage 26 thence into the annular fuel chamber 54, through radial ports 59 which are varied in effective area by the movement of sleeve valve member 52, and thence into pressure chamber 28. From chamber 28 the fuel flows through fixed metering orifice 29, an adjustable metering orifice 30, ports 100, and passage 32 to a discharge jet 34 positioned in the conduit 10 posterior to the throttle.

The discharge jet 34 is provided with a valve 36 opening away from the manifold and connected to a flexible diaphragm 39. Fuel pressure entering through the passage 32 acts on the inner face of the diaphragm 39 tending to open the valve 36, and is opposed by a spring 38. A vent 41 to atmosphere is provided in the discharge jet cap to permit free movement of diaphragm 39. Since manifold vacuum is effective on valve stem 36 merely to the extent of its application on an area equivalent to that of the valve orifice, whereas the fuel pressure is effective to the extent of its application on the relatively large area of the diaphragm 39, the fuel discharge pressure is practically unaffected even by large changes in manifold vacuum. The relatively large diaphragm area also enables the valve to change from a nearly closed position to a wide open one (to give low and high rates of fuel discharge) with but a slight change in discharge pressure. This relatively constant pressure feature aids in obtaining accurate metering under variable operating conditions. A fixed stop 37 is preferably provided to limit opening of valve 36 to prevent damage in case of backfire or the like. The discharge jet cap may, if desired, be vented to a source of variable pressure, such as Venturi suction, as is more particularly disclosed in Mock and Partington U. S. Patent No. 2,316,984, issued February 16, 1943.

A second pressure chamber 44 is positioned adjacent chamber 28 and is separated therefrom by a flexible diaphragm 46 which is preferably of the type having no elastic reaction to stress, comprising a fabric sheet secured at its outer edges and having its central portion secured between a pair

of disks 48. The disks 48 are in turn secured to a rod 50 which carries a sleeve valve member 52 which controls the passage of fuel from a peripheral valve chamber 54 to the chamber 28, a suitable perforated disk 57 being provided to limit closing movement of the valve 52. The chamber 54 is preferably connected to the top of the fuel tank, not shown, by a pipe 53 controlled by a float valve 55 to vent back to the tank any vapor present in the fuel supplied by the pump.

Adjacent the chamber 44 is a chamber 56, separated therefrom by a small diaphragm 58. A second large diaphragm 60 separates chamber 56 from another chamber 62, and rod 50 is connected to the disks 64 of this diaphragm in the same manner as to those of diaphragm 46. A second small diaphragm 66 is secured to the end of rod 50 and separates the chamber 62 from a chamber 68 positioned adjacent thereto. A small spring 69 urges the rod 50 in a direction to open valve 52. In order to balance out the pressure effects of diaphragms 58 and 66, chambers 44 and 68 are interconnected by a pressure equalizing passage 70 formed in the rod 50.

The rod 50 carries enlarged cylindrical hub members 51 adjacent the diaphragms 58 and 66 of substantially the same diameter as the flat central portions of the diaphragms on the low pressure sides thereof. The diaphragms are formed with annular grooves as shown, the sides of which lie respectively against the members 51 and outer circular confining walls. Due to this construction the grooves in the diaphragms maintain substantially the same effective radius as the rod 50 moves so that the effective areas thereof remain constant regardless of movement of the rod 50. The same construction is preferably followed in connection with the diaphragms 46 and 60 by providing circular flanges 49 and 65 on the plates 48 and 64 respectively. This is an important feature since it enables the diaphragms always to exert the same force in response to equal pressures regardless of the deflection of the diaphragms.

A small venturi 74 is positioned in the intake conduit 10 concentrically with the venturi 19 and is formed with an annular opening 76 substantially at its throat which is connected through a passage 78 with chamber 56. A similar passage 80 leads from chamber 62 to an annular chamber 82 formed in the venturi 19 and communicating with the inlet end of the conduit 10 through a series of tubes 81 so as to be subject to the pressure of the incoming air. The tubes 81 project out a substantial distance so that any rain or the like washing up the walls of the air conduit 10 will flow around them and will not enter the chamber 82. The passage 80 is controlled by an altimeter or aneroid 84, shown in Figure 1 as a corrugated bellows which carries a valve member 86 which tends to open passage 80 at high barometric pressures (as at ground or sea level) and to close the same at low pressures (as at high altitudes). A calibrated passage 88 connects the lower portion of the chamber 62 to the passage 78 and serves as a drain for any moisture collected in the chamber 62. Passage 88 also serves to draw air from chamber 62 and passage 80 into passage 78 so as to lower the pressure in chamber 62 and reduce the pressure differential acting on diaphragm 60, so as to decrease the richness of the mixture, whenever valve 86 is in a position where it restricts the passage 80, as it will be at all times when the vehicle is at such altitude as to make an altitude correction desirable. The bellows 84 preferably contains some air or other

gaseous medium so that it will be responsive to changes in both temperature and pressure, the amount of temperature response being controlled by the amount of gas within the bellows at the time it is sealed.

The passage 30 is preferably controlled by a valve 90 which is connected through a bell crank 92 and link 94 to the throttle valve 16 to be operated thereby. The valve 90 is so arranged as to throttle the flow of fuel through the passage 30 when the throttle valve 16 is closed to or near the idling position and to open the passage 30 fully as the throttle valve 16 is opened beyond idling position. The valve 90 carries a piston 96 slidably fitting in a cylinder 98 and formed with ports 100 for passage of fuel. A valve disk 102 is slidably mounted on the valve in a position to close the ports 100 so that when the throttle valve 16 is opened suddenly the piston 96 and cylinder 98 form a fuel pump to increase temporarily the flow of fuel to provide a rich mixture for acceleration. When the throttle valve 16 is stationary or is moved slowly the pressure of fuel moves the valve disk 102 to the position shown to uncover the ports 100.

The orifice 30 may further be controlled by a plunger 104 controlled manually from the pilot's seat through a linkage 106 to provide either a rich or lean mixture. When the end of the plunger 104 is projecting into the port 30 as shown the flow of fuel is restricted and a lean mixture results. To obtain a richer mixture the pilot may operate linkage 106 to withdraw the plunger 104 completely from the port 30 to leave it unrestricted. Preferably the plunger 104 carries a disk 108 adapted to close the port 30 completely so that the pilot can cut off the fuel supply at will in case of emergency or when the engine is to be stopped.

A further manual control is provided by a valve 110 in the passage 80 urged onto its seat by a spring 112 and connected to the linkage 106 by a link 114. The link 114 is pivoted to one end of a bell crank lever 116, the other end of which is slidably on the stem of the valve 110 and is adapted to engage a nut 118 on the end thereof. This arrangement provides a lost motion connection so that the plunger 104 can be operated as described above without affecting the valve 110. However, if the linkage 106 is pulled back to its extreme limit the valve 110 will be opened to admit air at intake pressure to the chamber 62 thereby opening the valve 52 further and increasing the richness of the mixture regardless of the position of valve 86.

The control means thus far described provide a mixture of suitable richness for varying speeds, loads, and throttle openings through the idle, low power and intermediate power ranges, and in addition provide compensation for changes in altitude. However, as the engine approaches full power operation an enriched mixture is desired in order to make available the maximum power output from the engine. In addition, an enriched mixture has a cooling effect tending to reduce the engine operating temperatures and therefore has a beneficial effect, quite apart from its effect on the power output, which finds particular usefulness in cooling the engine at high altitudes.

In order to provide such an enriched mixture at high power output, a fuel bypass 120 controlled by a valve 122 is provided around the orifice 30, the valve 122 being controlled by barometric pressure, the pressure at the supercharger inlet, and the pressure at the supercharger outlet. A

pair of diaphragms 124 is connected to the valve 122 to provide a leak-proof packing therefor and the valve is drilled at 126 to connect the outside surfaces of the diaphragms 124 to balance the pressure thereon. The valve 122 is connected to one end of a bell crank lever 128 whose other end is connected through a link 130 with one end of a lever 132, the opposite end of which is connected to a diaphragm 134. A casing 136 encloses the diaphragm 134 and is connected on one side to the air conduit 10 anterior to the supercharger 12 and on its other side through a conduit 137 to the manifold posterior to the supercharger. The casing 136 is closed by a diaphragm 138 and a spring 140 is provided to urge the diaphragm up in a direction to close the valve 122. The diaphragm 138 is exposed on one side to atmosphere and on its other side to the pressure in conduit 10 posterior to the throttle to modify the action of the diaphragm 134, the degree of modification being controlled by the relative sizes of the two diaphragms. By way of example illustrating the function of the control just described, as the air flow to the engine and the power output from the engine increase as the throttle is opened while operating at a given altitude and speed, the air differential pressure across diaphragm 134 will increase, and when the differential reaches some predetermined value the force of spring 140 is overcome and the economizer valve 122 is opened to enrich the mixture as a condition of high power output is attained. Likewise if the quantity of charge supplied the engine and consequently the power output are increased by increasing the engine speed for a given engine charge density, the supercharger pressure rise acting across diaphragm 134 will increase and will open valve 122 to enrich the mixture at high power output. To illustrate the altimetric functioning of the control, consider the case of an airplane rising at a uniform rate of speed from (Condition A) ground level where atmospheric pressure is 30" of mercury to (Condition B) an altitude where atmospheric pressure is 21" of mercury, the throttle being so manipulated during the climb that the pressure at the entrance of the supercharger is maintained at 20" of mercury. At ground level the throttle will be partly closed, and let us say the pressure at the air horn 20 is 30", at the supercharger inlet is 20", and at the supercharger outlet is 27". As altitude is gained, the pilot will gradually open the throttle in order to maintain the same pressure at the supercharger inlet, until Condition B is reached, where a barometric pressure of 21" obtains at the air horn, and the throttle is practically wide open. If we assume for the present that the engine speed remains constant, the 27" pressure will still obtain at the outlet of the supercharger. But because of the decreased pressure in the exhaust line at altitude and since the charge density is constant, the horsepower developed under Condition B will be higher. This increase in power output will cause the engine speed to increase, which in turn will cause the pressure at the supercharger outlet to increase. The conditions therefore obtained will be 20" mercury at the supercharger inlet, and, say, 28" at the supercharger outlet. The increased horsepower output, coupled with the fact that the air is thinner, which decreases its cooling effect, tends to overheat the engine. To correct for this tendency, at Condition B, the increased supercharger rise acting on diaphragm 134 and the decreased atmosphere-to-super-

charger inlet differential pressure acting on diaphragm 138 produce a combined effect tending to open valve 122 to provide an additional flow of fuel which enriches the mixture for the higher power output and also tends to cool the engine.

The operation of the apparatus thus far described is as follows:

Operation at sea level

In normal operation with the engine running and driving the pump 22 and supercharger 12, fuel is pumped into the chamber 28 past the valve 52 and through ports 29 and 30 into the chamber 44. Fuel flowing through the port 30 also passes through the openings 100 in piston 96 and through the pipe 32 to be sprayed into the manifold by the jet 34. Since the pressure variations in chamber 44 are maintained within narrow limits the pressure in chamber 28 will always be higher by an amount equal to the drop through orifice 29 and passage 30, excessive pressure in chamber 28 tending to close valve 52 and deficient pressure therein tending to open this valve. Thus the pressure differential acting on the diaphragm 46 is always a governing function of the flow through orifice 30 regardless of the discharge pressure, which may be high or low depending upon the setting of the jet 34.

Air flowing through the venturi 74 creates a depression at 76 which is transmitted through the passage 78 to the chamber 56. At the same time, due to the fact that the bellows 84 is contracted at sea level to open the valve 86, pressure of the incoming air will be communicated to the chamber 62 through the tubes 81, chamber 82 and passage 80. Thus there will be a pressure differential acting on the diaphragm 60 tending to open the valve 52 in a degree which is proportional to the rate of flow of air through the conduit 10 and venturi 74. Due to the relatively small size of the passage 88 it has substantially no effect when the valve 86 is open so the pressure relationship described is not materially affected by it.

With the system in equilibrium, the differential of pressure on the diaphragm 60, which is a function of the rate of air flow through the device, is balanced by the differential of pressure on the diaphragm 46, which is a function of the rate of fuel flow through the device. If now the pressure of fuel delivered by the pump 22 is increased, as by erratic operation of valve 42, the pressure in chamber 28 will tend to increase, which will cause valve 52 to move toward closed position and restore the pressure in the chamber to its original value. If the engine speed is decreased, by a change in the propeller pitch or from any other cause, the rate of air flow through venturi 74 decreases, decreasing the depression at 76 and chamber 56, causing valve 52 to move toward closed position and slightly decreasing the pressures in chamber 44, tube 32 and at nozzle 36. Valve 34 adjusts itself to the decreased pressure by moving toward closed position, with the result that the rate of fuel discharge is decreased to compensate for the decreased rate of air flow which initiated the adjustment. If the operator moves the throttle toward open position, other factors being constant, the engine speed will increase, increasing the depression at Venturi throat 76 and increasing the fuel flow accordingly. The device thus operates to provide the desired fuel-air ratio at sea level under widely differing conditions of fuel pressure, engine speed, and throttle opening.

Due to the fact that the bellows 84 is responsive to temperature changes, it will expand slightly at high temperatures moving the valve 86 to a position to restrict the passage 80 to an extent dependent upon the temperature. As the passage 80 is restricted the effect of the passage 88 becomes more important and tends to reduce the pressure in the chamber 62, thereby reducing the pressure differential across the diaphragm 60. Consequently the fuel flow will be slightly reduced to provide a leaner mixture as the air density decreases due to rise in temperature.

Idling

When the throttle valve 16 is moved to substantially closed position for idling, the air flow and consequently the suction in venturi 74 drops. As a consequence the pressure differential across diaphragm 60 drops and valve 52 moves toward its closed position under the influence of the decreased pressure differential across the diaphragm 60. At this time the effect of the spring 69 becomes important to urge the rod 50 to the right, thereby requiring a greater pressure differential across the diaphragm 46 to balance it. This results in increased fuel flow and a richer mixture for idling, but in order to insure better control, ease of adjustment and more accurate metering at the low pressures and low flow velocities involved during idling, it has been found desirable to design the spring to give an excessively rich idle and then utilize the valve 90 connected to the throttle to be moved into the passage 30 when the throttle is closed to meter the fuel at this point. The valve 90 can be given any desired configuration to provide the desired rate of fuel flow at closed or substantially closed throttle. Of course, during normal operation the valve 90 occupies substantially the position shown and does not affect the fuel flow.

Operation of the economizer

When maximum possible power is required as in taking off or for emergency operation of other kinds the pilot opens the throttle to deliver mixture to the engine at high pressure. During this time it is desirable to increase the richness of the mixture considerably and for this purpose the diaphragm 134 will be depressed by the increased differential between supercharger outlet and inlet pressures to open the valve 122. At this time the passage 120 conducts additional fuel around the passage 30 to increase the flow to the discharge jet 34 and increase the richness of the mixture. This emergency operation is ordinarily maintained for only a few minutes at a time to avoid overworking of and damage to the engine and as soon as the throttle is returned to cruising position the pressure on top of diaphragm 134 drops permitting it to rise under the influence of the spring 140 to again close the valve 122.

Operation of the plunger 104

When the engine is in operation and conditions are favorable, as when flying under good weather conditions and light load, the pilot may desire to reduce the richness of the mixture to conserve fuel. For this purpose he may operate the linkage 106 to move the plunger 104 more or less into the passage 30 to restrict the same. The rate of fuel flow is thereby restricted to lean the mixture.

Some operators desire to be able to regulate richness of the mixture during emergency operation when the valve 122 is open as well as during

normal cruising, while others prefer that the richness of the mixture during high power emergency operation shall be automatically regulated independently of the control of the pilot. Either of these conditions can be obtained as desired by inclusion or exclusion of the orifice 29 or by properly proportioning the size of this orifice. For example, if the combined area of passage 120 and passage 30 with plunger 104 in the lean position is greater than that of orifice 29, orifice 29 functions as the primary restriction to fuel flow at full power, operation of the plunger 104 then having substantially no effect on the fuel flow. On the other hand, if the restriction formed by the orifice 29 is omitted or the orifice is made larger than the combined areas of passages 120 and 30, fuel flow is metered by these two passages and the pilot, through plunger 104, may control the mixture both during normal and emergency operation.

Operation at higher altitudes

As the craft rises the atmospheric pressure drops and the bellows 84 expands, moving valve 86 toward its closed position. This restricts passage 80 and tends to cause equalization of pressure between chambers 56 and 62 due to the passage 88 so that the valve 52 will be moved toward its closed position to correspondingly reduce the fuel metering differential pressure across orifice 30 and/or orifice 122 acting on diaphragm 46, to thereby reduce the fuel flow to prevent increase in the richness of the mixture with increase in altitude, as would otherwise occur. It may be noted that reducing the fuel metering differential pressure applies an altimetric correction not only to the main fuel supply flowing through orifice 30, but also to any supplemental fuel being supplied through orifice 122. It will be noted that the effective cross-sectional area of passage 80 as limited by valve 86 is varied in accordance with changes either in the temperature or pressure of the air acting on the bellows 84. In case a supercharger is used to supply air to the conduit 10 the bellows 84 is responsive to supercharger pressure and maintains the mixture at the correct value.

Figure 2 illustrates a modified construction for controlling the flow of fuel into the chamber 28 and as shown includes a chamber 142 receiving fuel from the pump through the pipe 26. Communication between the chambers 28 and 142 is controlled by a poppet valve 144 seating on a tapered valve seat 146 and connected to the rod 50 to be controlled thereby. The valve 144 has its stem 148 connected to one end of a lever 150 which is pivoted at its center in the chamber 142 and has its opposite end formed as a weight 152. The weight 152 has substantially the same effective mass as the rod 50 and its related parts such as the disks 48 and 64 and serves to counterbalance any inertia effects on the rod 50 which might change the richness of the fuel mixture.

Fuel pressure on the valve 144 is balanced by a diaphragm 154 exposed on one side to the pressure in the chamber 142 and on its other side to the pressure in the chamber 28 through openings in a plate 156. The effective moment on the lever pivot of the diaphragm 154 is the same as that of the valve 144 and the diaphragm is connected to the weight 152 by a link 158 so as to balance out the effect of fuel pressure on the valve 144.

The openings in plate 156 are preferably made small to provide a dashpot effect tending to damp any vibrations or any tendency of the valve 144 to flutter. If this dashpot effect is not sufficient

a second dashpot may be provided by a cylindrical extension 143 in the chamber 142 slidably receiving a piston 145 carried by the valve stem 148. The piston may have a relatively loose fit in the cylinder, or a suitable bypass may be provided, and since the cylinder will be filled with fuel a liquid dashpot is formed.

Figure 3 illustrates the application of a modified economizer control to the fuel feeding apparatus of Figure 1. In this form the passages 78 and 80 are connected by a calibrated passage 88, as in Figure 1, and by a second passage 160 controlled by a valve 162. The valve 162 is connected directly to the control diaphragm 134 and normally occupies a position in which the passage 160 is open. A calibrated restriction is preferably placed in the passage 78 between the passages 88 and 160. During periods of normal operation air is bled from passage 80 through passage 160 and reduces the suction in chamber 56 to a value below that at the venturi 76. When the supercharger pressure rises, the increased pressure on top of the diaphragm 134 closes the valve 162 eliminating the bleeding action of port 160 and causing the suction in chamber 56 to increase thereby to open the main fuel valve further and increase the richness of the mixture. Air bled through passage 88 will vary the pressure in chamber 62 at such times as valve 86 restricts the passage 80 in response to changes in altitude, as has been previously described in connection with Figure 1. Thus the altitude control is primarily accomplished by bleeding air through passage 88 to modify the pressure in chamber 62 and the economizer control is primarily accomplished by bleeding air through passage 160 to modify the pressure in chamber 56. It will be apparent that each bleed has some effect upon the pressure in the other chamber, the amount thereof being dependent on the relative sizes of the passages, bleeds, and restriction.

It will be understood that, if desired, the altimeter valve could be used to control the passage 78 instead of the passage 80 or that the altimeter and economizer valves could be reversed. It will also be understood that many changes might be made in form and arrangement of parts and it is not intended that the scope of the invention shall be limited to the forms shown and described, nor otherwise than by the terms of the appended claims.

I claim:

1. A device for supplying fuel to an internal combustion engine comprising an induction passage, a throttle controlling the same, an engine-driven supercharger in the induction passage posterior to the throttle, an engine-driven fuel pump, a connection from said pump to the induction passage anterior to the supercharger to supply fuel thereto under pressure, a metering orifice in said connection, regulating means for regulating the pressure of fuel at the inlet side of said orifice, a bypass around said orifice, and means responsive to supercharger pressure to control said bypass.

2. A device for supplying fuel to an engine comprising an engine-driven fuel pump, a connection from said pump to the engine to supply fuel thereto, a metering orifice in said connection, regulating means for regulating the pressure of fuel on said orifice, a supercharger for supplying air to the engine, a bypass around said orifice, means responsive to supercharger pressure to control said bypass, and manual means to con-

trol said orifice thereby to regulate the flow there-through.

3. A device for controlling the supply of fuel to an engine comprising a connection for supplying fuel to the engine, regulating means for controlling the flow of fuel through said connection, passages connecting said regulating means to fluid pressure sources to operate the regulating means, a valve controlling one of said passages, an orifice connecting said passages, a valve controlling said orifice, means responsive to the density of air supplied to the engine to control one of said valves, and means responsive to an engine condition to control the other of said valves.

4. A device for supplying fuel to an engine comprising an air conduit, a supercharger connected to said conduit to force air therein to the engine, a throttle in the conduit anterior to the supercharger, a venturi in the conduit anterior to the throttle, a fuel conduit for supplying fuel to the engine, a valve to control the fuel supply, a diaphragm connected to the valve, connections from said venturi and from the conduit anterior to the throttle to opposite sides of said diaphragm, a passage between said connections, and means responsive to supercharger pressure to control said passage.

5. A device for supplying fuel to an engine comprising an air conduit, a supercharger connected to said conduit to force air therein to the engine, a throttle in the conduit anterior to the supercharger, a venturi in the conduit anterior to the throttle, a fuel duct for supplying fuel to the engine, a valve to control the fuel supply, a diaphragm connected to the valve, connections from said venturi and from the conduit anterior to the throttle to opposite sides of said diaphragm, a passage between said connections, a pair of valves controlling one of said connections and said passage respectively, means responsive to the density of air in said conduit for controlling one of said valves, and means responsive to supercharger pressure for controlling the other valve.

6. A device for supplying fuel mixture to an internal combustion engine comprising an induction passage, a connection for supplying fuel to the induction passage, regulating means responsive to pressures varying as a function of the rate of air flow to the engine to control the supply of fuel by said connection, a supercharger in said induction passage, and means controlled in accordance with the pressure at the supercharger outlet to increase the supply of fuel through said connection as the supercharger outlet pressure rises.

7. In a charge forming device for an internal combustion engine adapted to receive a supercharger posterior thereto, an induction passage having a throttle, a source of fuel, a connection from said source to the engine, means for controlling the normal rate of fuel supply to the engine, a valve in said connection arranged to increase the fuel supplied to the engine at certain operating conditions and means jointly responsive to the pressure posterior to the supercharger, the pressure between the throttle and supercharger and substantially atmospheric pressure for controlling said valve.

8. In a charge forming device having a supercharger on the down-stream side thereof, an induction passage, a fuel source, a connection from said source to the induction passage, area restricting means in said connection for metering the fuel flow therethrough, and means responsive jointly to atmospheric pressure and pres-

ures anterior and posterior to the supercharger for increasing the area of said area restricting means.

9. In a charge forming device having a supercharger, a fuel discharge nozzle, fuel control means for controlling the normal fuel supply to the nozzle, means for supplying supplementary fuel to the nozzle and a valve responsive jointly to the pressure difference created by the supercharger and to atmospheric pressure for controlling said supplying means.

10. In a fuel feeding device for an engine having a supercharger, means for supplying supplementary fuel to the engine under certain operating conditions, a valve controlling said means, and means responsive jointly to barometric pressure, supercharger inlet pressure and supercharger outlet pressure for actuating said valve.

11. In a fuel feeding device for an engine having a supercharger, means for supplying supplementary fuel to the engine, a device controlling the supplementary fuel supply and means for actuating said device comprising a pair of spaced diaphragms, a rod connecting said diaphragms, a connection for subjecting the outer face of one diaphragm to supercharger outlet pressure, a connection for subjecting the inner faces of both diaphragms to supercharger inlet pressure, and means for subjecting the outer face of the other diaphragm to a source of substantially atmospheric pressure.

12. A device for controlling the supply of fuel to an engine comprising an air supply pipe, a fuel conduit for supplying fuel from a fuel source to the engine, regulating means for controlling the flow of fuel to the engine, pressure ducts leading from spaced points in said pipe to the regulating means for operating it, a restriction in one of said ducts, restricted passageways interconnecting said ducts on opposite sides of the restriction, means for controlling one of said ducts, and separate means for controlling one of said passageways.

13. Fuel supply means for a throttle controlled carburetor having an air entrance and a mixture outlet connected to a supercharger comprising, a source of fuel supply under pressure, pressure reducing means therefor, automatic means responsive to the absolute pressure at the discharge side of the supercharger for controlling the pressure reducing means, and automatic means responsive to the drop in pressure from the air entrance to the mixture outlet created by the throttle for controlling the pressure reducing means whereby the pressure on the fuel at the low pressure side of the pressure reducing means is responsive to the drop in pressure due to the throttle and also to the absolute pressure created by the supercharger.

14. Fuel supply means for a throttle controlled carburetor having an air entrance and a mixture outlet connected to a supercharger comprising, a source of fuel supply under pressure, pressure reducing means therefor, automatic means responsive to the absolute pressure at the discharge side of the supercharger for controlling the pressure reducing means, and automatic means responsive to the differential in pressure between substantially atmospheric pressure and the pressure in the mixture outlet for controlling the pressure reducing means whereby the pressure on the fuel at the low pressure side of the pressure reducing means is responsive to the said pressure differential and also to the absolute pressure created by the supercharger.

15. A carburetor having fuel supply passage means including a metering orifice fixed against orifice area varying movement in response to changes in engine operation, an air supply passage including means for creating a differential of pressures proportional to air flow, a fuel inlet valve in said fuel supply passage movable to vary the supply of fuel to said orifice means, valve actuating means including a plurality of diaphragms, one responsive to changes in said differential of pressures in said air passage and another normally balancing said first mentioned diaphragm and acted upon by fuel pressures on opposite sides of said orifice, and means movable proportionally with and responsive to changes in pressures in said air passage for unbalancing said diaphragms and effecting displacement of said valve to increase the fuel flow through said valve to enrich the mixture and restore the balance of said diaphragms in the new position of the valve.

16. A fuel feeding device having a fuel supply passage including a metering orifice fixed against orifice area varying movement in response to changes in engine operation, an air supply passage including means upstream from the throttle for creating a differential of pressures proportional to air flow, a fuel valve in said fuel supply passage movable to vary the supply of fuel to said orifice means and normally balanced by opposing pressures of unmetered fuel being delivered to said orifice means, valve actuating means responsive to changes in said differential of pressures in said air passage and normally balanced by fuel pressures on opposite sides of said orifice for maintaining a substantially constant fuel air ratio, economizer means for effecting an increased fuel flow through said fuel supply passage to enrich the mixture and likewise controlled by changes in a differential pressure created in said air supply passage, and pressure responsive means for modifying the action of said differentials of pressures on said actuating means and on said economizer means in accordance with variations in the density of the air at different altitudes.

17. A fuel feeding device having a fuel supply conduit including a main metering orifice fixed against orifice area varying movement in response to changes in engine operation and an economizer orifice in parallel with said main orifice, an air supply passage including means for creating a differential of pressures proportional to air flow, a fuel valve in said fuel supply passage, valve actuating means including a diaphragm responsive to the differential of pressures in said air passage and also including a diaphragm acted upon by metered and unmetered fuel, and an economizer valve for effecting an additional flow of metered fuel and controlling the operation of said first mentioned valve by controlling the flow through said economizer orifice and having an actuating movable wall means actuated under high engine power output conditions by a differential of pressures increasing with increase in engine power output.

18. A device for controlling the supply of fuel to an engine having a fuel supply conduit, a metering orifice in said conduit, an air supply passage, means in said passage for creating a differential of air pressures proportional to air flow, a fuel valve for varying the supply of fuel to said metering orifice, valve actuating means including a plurality of diaphragms, one responsive to changes in said differential of air pressures and

another normally balancing said first mentioned diaphragm and acted upon by fuel pressures on opposite sides of said orifice, and means actuated by a differential of pressures in the air passage which increases with increase in power output of the engine for unbalancing said diaphragms and effecting displacement of said valve to increase the fuel flow through the fuel supply passage to enrich the mixture and restore the balance of said diaphragms in the new position of the valve.

19. A charge forming device for an internal combustion engine having a fuel supply conduit, a metering orifice in said conduit creating a differential of fuel pressures variable with variations in flow therethrough, an air supply passage, means in said passage for creating a differential of air pressures variable with variations in air flow therethrough, fuel valve means for varying the supply of fuel to said metering orifice, diaphragms operably connected to said fuel valve means and responsive to said air and fuel differential pressures, said air differential and fuel differential respectively tending to increase the fuel supply with increase and decrease in said air and fuel differential pressures respectively, a bypass around said metering orifice, a valve normally closing said bypass, and means actuated by an air differential pressure increasing with increase in air flow to the engine for opening said bypass valve to enrich the mixture under high power output conditions of operation of the engine.

20. A device for controlling the supply of fuel to an engine comprising an induction passage for supplying air to the engine, a throttle controlling the same, air differential pressure creating means in the passage anterior to the throttle, a fuel conduit for supplying fuel to the engine, valve means controlling the flow of fuel through said conduit, a fuel metering orifice in the fuel conduit for creating a fuel differential pressure therein, means responsive to said air and fuel differential pressures for controlling said valve means to regulate the fuel differential pressure in accordance with the air differential pressure, a bypass around said orifice, and means including a valve controlling the bypass and operative under engine operating conditions corresponding to relatively high engine power output for opening said bypass to thereby increase the richness of the mixture.

21. The invention defined in claim 20 comprising in addition means responsive to variations in barometric pressure corresponding to variations in altitude for modifying the quantity of fuel flowing through said orifice and bypass.

22. A device for supplying fuel to an engine comprising a connection for supplying fuel to the engine, area restricting means in the connection creating a differential fuel pressure, valve means in said connection for varying the fuel supply, regulating means responsive to said differential fuel pressure and to pressures variable in response to changes in the rates of air flow to the engine for actuating said valve means to control said differential fuel pressure, and means automatically operated under conditions of relatively high power output of the engine for increasing the area of said area restricting means to thereby increase the richness of the mixture supplied to the engine.

23. A fuel feeding device having fuel supply passage means including a metering orifice fixed against orifice area varying movement in response to changes in engine operation, an air supply passage including means for creating a differential

of pressures proportional to air flow, a fuel valve in said fuel supply passage movable to vary the supply of fuel to said orifice means, valve actuating means including a plurality of diaphragms, one responsive to changes in said differential of pressures in said air passage and another normally balancing said first mentioned diaphragm and acted upon by fuel pressures on opposite sides of said orifice, and means responsive to variations in pressure in the air supply passage and becoming operative under engine operating conditions corresponding to relatively high engine power output for unbalancing said diaphragms and effecting displacement of said valve to increase the fuel flow through said valve to enrich the mixture and restore the balance of said diaphragms in the new position of the valve.

24. A fuel feeding device for an engine comprising a fuel supply conduit including fuel metering orifice means, an air supply passage including means for creating a differential of pressures proportional to air flow, a fuel valve in said fuel supply movable to vary the supply of fuel to the fuel metering means, valve actuating means including a plurality of diaphragms urged in one direction by said differential of pressures in said air passage and balanced by the differential in the fuel pressures on opposite sides of said orifice urging the diaphragms in the opposite direction, and means for unbalancing said diaphragms and effecting displacement of said valve to increase the fuel flow through said valve and restore the balance of said diaphragms in the new position of the valve whereby the mixture is enriched under conditions of high engine power output.

25. A carburetor having a fuel supply conduit including area restricting fuel metering means, an economizer valve for varying the effective area of said metering means, an air supply passage including means for creating a differential of pressures proportional to air flow, a fuel inlet valve in said fuel supply passage, valve actuating means including a diaphragm responsive to the differential of pressures in said air passage and also including a diaphragm acted upon by metered and unmeasured fuel, and means for opening said economizer valve under high engine power output conditions for effecting an additional flow of metered fuel and controlling the operation of said first mentioned valve by controlling the flow through said fuel metering means.

26. A device for controlling the supply of fuel to an engine comprising fuel supply passage means including fuel metering orifice means therein fixed against orifice area varying movement in response to changes in engine operation, air flow passage means, means therein for setting up a differential of pressures proportional to air flow through said last mentioned means, valve means for varying the fuel flow to said orifice means, and means responsive to changes in said differential of pressures for effecting displacement of said valve means to deliver through said orifice means sufficient fuel to produce a predetermined fuel air ratio during normal engine power output conditions and during high engine power output conditions, and mixture enrichment mechanism biased against operation save under higher than normal engine power output conditions and including additional fluid pressure responsive means, subject to pressures producing a differential of pressures varying with and in response to changes in air flow throughout high engine power output conditions, for effecting further displacement of said valve means to

superimpose on said predetermined fuel air ratio an increased fuel flow producing an enrichment of the mixture, and having said additional pressure responsive means movable while said first mentioned pressure responsive means continues to effect its own displacement of said valve means.

27. A carburetor having fuel supply passage means including metering orifice means fixed against orifice area varying movement in response to changes in engine operation and an additional orifice in parallel with said orifice means, air supply passage means including means for setting up a differential of pressures proportional to air flow, valve mechanism including a fuel inlet valve in said fuel supply passage means, valve actuating means including a diaphragm responsive to changes in the differential of pressures in said air passage means and also including a diaphragm acted upon by measured and unmeasured fuel, and an economizer valve for effecting an additional flow of metered fuel and controlling the operation of said first mentioned valve by controlling the flow through said additional orifice and having an actuating diaphragm actuated under high engine power output conditions by a differential of pressures varying in response to changes in engine speed and the rate of air flow to the engine.

28. Fuel control means for an airplane engine carburetor connected to a supercharger, manual means for controlling the fuel supply to provide a lean fuel-air mixture for normal operation, and absolute pressure responsive means automatically operative upon the attainment of a predetermined absolute pressure in the supercharger discharge for rendering said manual control means inoperative, whereby a rich fuel-air mixture is provided when operating at maximum power at low altitude with air of high density.

29. In a fuel metering device, means providing a passage for the supply of air for combustion of fuel, means providing a pressure supply of fuel for combustion by said supply of air, means automatically operative in response to variations in conditions of the air flowing through said passage for varying the fuel supply to maintain a predetermined fuel-air quantity ratio, manual means to control the effect of said automatic means to provide a lean fuel-air mixture for normal operation, a supercharger connected with said passage for receiving air passing therethrough, and means responsive to a predetermined pressure developed by said supercharger for rendering said manual means inoperative whereby to provide a rich fuel-air mixture at said predetermined pressure.

30. In a fuel metering device, means providing a passage for the supply of air for combustion of fuel, means providing a pressure supply of fuel for combustion by said supply of air, means automatically operative in response to variations in conditions of the air flowing through said passage for varying the fuel supply to maintain a predetermined fuel-air quantity ratio, manual means to control the effect of said automatic means to provide a lean fuel-air mixture for normal operation, a supercharger connected with said passage for receiving air passing therethrough, and means responsive to a predetermined pressure developed by said supercharger for rendering said manual means substantially ineffective whereby to provide a rich fuel-air mixture at said predetermined pressure.

31. In a fuel metering device, means providing a passage for the supply of air for combustion of fuel, means providing a pressure supply of

fuel for combustion by said supply of air, means automatically operative in response to variations in conditions of the air flowing through said passage for varying the fuel supply to maintain a predetermined fuel-air quantity ratio, manual means to control the effect of said automatic means for varying at will the richness of the mixture during normal operation, a supercharger connected with said passage for receiving air, passing therethrough, and means responsive to a predetermined pressure developed by said supercharger for rendering said manual means substantially ineffective for varying the mixture richness.

32. Supercharged engine fuel injection system including first means for increasing the engine fuel supply with increase of engine supercharged air pressure and decrease of surrounding atmospheric pressure, and additional engine operative condition responsive means independent of said first means for altering said supply.

33. A device for controlling the supply of fuel to an engine comprising a connection for supplying fuel to the engine, metering orifice means in said connection, regulating means for regulating the pressure of fuel on said orifice means, a supercharger for supplying air to the engine, a bypass around said orifice means, means responsive to supercharger pressure to control said bypass, manual means to control said orifice means thereby to regulate the flow therethrough, and a restriction in said connection anterior to and of less area than the combined area of said orifice means and bypass whereby said manual means will not substantially affect fuel flow when the bypass is open.

34. A device for controlling the supply of fuel to an engine comprising a connection for supplying fuel to the engine, a metering element in said connection, area restricting means in the connection in series with the element, means operable from a point remote from the engine for varying the effective area of said area restricting means, means for increasing the effective area of said area restricting means under certain conditions of engine operation to form a supplementary fuel supply, and regulating means for controlling the fuel flow through said connection.

35. A device for controlling the supply of fuel to an engine comprising a connection for supplying fuel to the engine, regulating means responsive to pressures variable in response to changes in the rates of air and fuel flow to the engine for controlling the quantity of fuel supplied through said connection, a fixed metering orifice and area restricting means in series in said connection, means for varying the effective area of said area restricting means, and a valve controlled bypass around said area restricting means and in series with said metering orifice.

36. A device for supplying fuel to an internal combustion engine having an induction passage, a venturi in said passage, a conduit leading from a source of fuel to the engine, a pair of metering

elements in series in said conduit, means operable from a point remote from the engine for varying the effective area of one of said elements, a bypass around said one element, and means responsive to variations in the pressures at spaced points in said conduit and at said venturi for controlling the quantity of fuel supplied to the engine through said conduit.

37. A device for supplying fuel to an engine having a throttle controlled induction passage, a venturi in said passage anterior to the throttle, a fuel source, a connection from said source to the induction passage posterior to the throttle, a metering restriction in said connection, area restricting means in series with the metering restriction, means for varying the effective area of said area restricting means, and means responsive to the pressure at said venturi and to the drop in pressure across the metering restriction and area restricting means for controlling the quantity of fuel flowing through said connection.

38. A device for controlling the supply of fuel to an engine comprising a connection for supplying fuel to the engine, regulating means responsive to pressures at spaced points in the connection for controlling the quantity of fuel supplied through said connection, and area restricting means in the connection between the spaced points, said last named means including a fixed orifice, a valve controlled orifice in series with the fixed orifice for enriching the mixture during normal operation, and a valve-controlled bypass in parallel with the valve controlled orifice and in series with the fixed orifice.

39. In a device for controlling the fuel flow to an engine comprising a fuel conduit for supplying fuel to the engine, a metering orifice in said conduit, variable area metering means in said conduit in series with said orifice, manual means for varying the effective area of said metering means for varying the richness of the mixture supplied the engine during periods of normal power output, and automatic means for increasing the effective area of the metering means during periods of high engine power output, the effective area of the metering orifice being greater than that of the metering means during periods of normal power output but less than that of the metering means during periods of high power output.

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