Dec. 29, 1959 F. C. REGGIO 2,918,912

FUEL SUPPLY SYSTEM

Original Filed Feb. 3, 1939

Fig. 1.

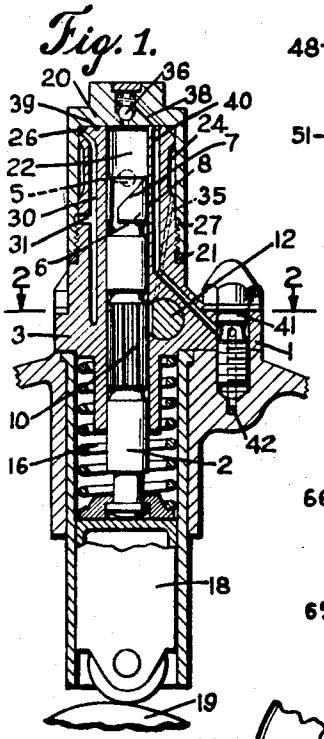


Fig. 2.

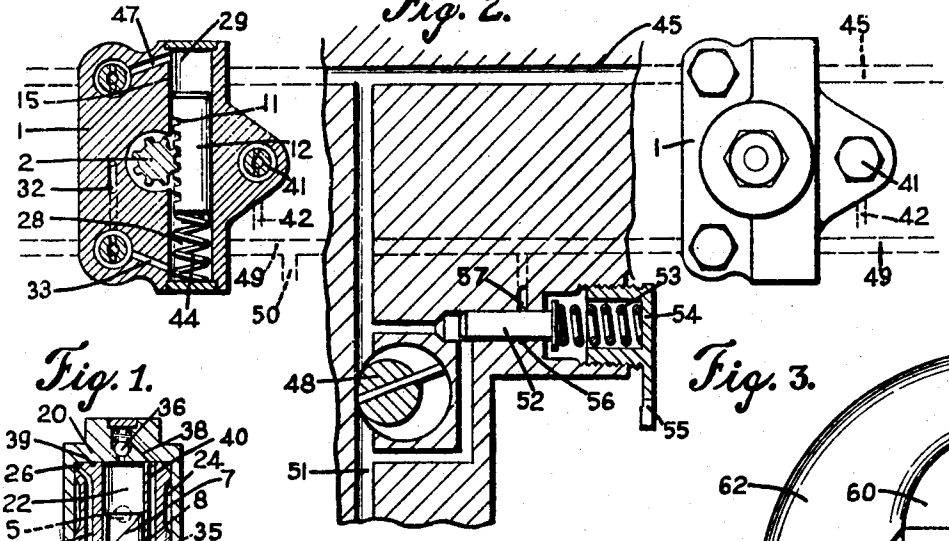


Fig. 3.

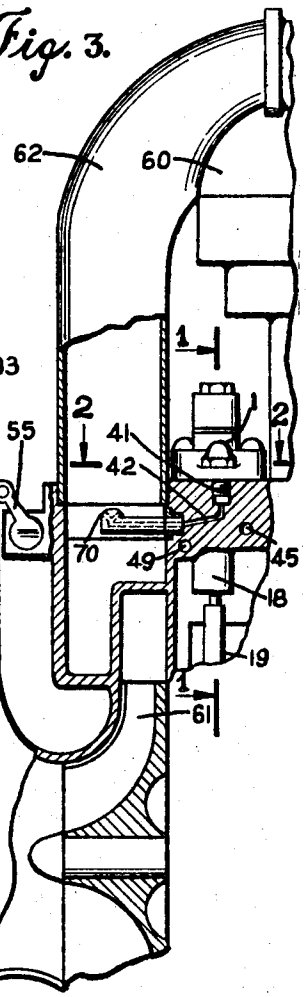


Fig. 4.

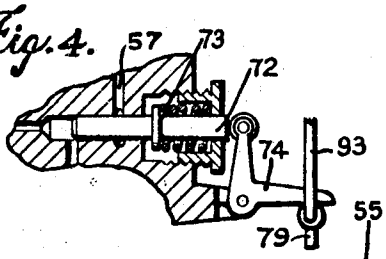
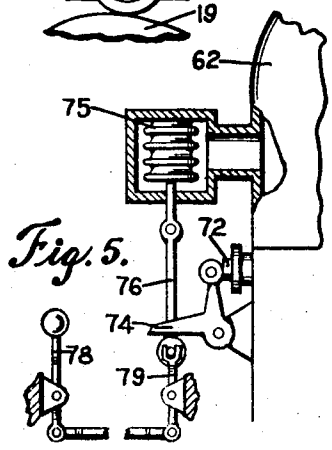


Fig. 5.



INVENTOR

F. C. Reggio

United States Patent Office 2,918,912
Patented Dec. 29, 1959

2,918,912

FUEL SUPPLY SYSTEM

Ferdinando Carlo Reggio, Norwalk, Conn.

Application July 27, 1943, Serial No. 496,296, which is a continuation of application Serial No. 254,355, February 3, 1939. Divided and this application June 7, 1956, Serial No. 589,977

26 Claims. (Cl. 123—119)

The present application is a division of my application Serial No. 496,296 filed July 27, 1943, which is a continuation of application Serial No. 254,355 filed February 3, 1939, both now abandoned.

This invention relates to fuel supply systems for internal combustion engines and in particular to mechanisms for the control of the relative proportion of fuel and air composing the combustible mixture of internal combustion engines. It is chiefly, although not exclusively, applicable to spark-ignition aircraft engines including a fuel injection system discharging liquid fuel into the engine cylinders or the engine induction manifold.

Spark-ignition engines having a fuel injection system are usually provided with means for controlling the fuel supply and means for controlling the air supply of the engine. It is important that the adjustment of the fuel and air control means be inter-related so that the engine cylinders may be charged with a combustible mixture having a suitable fuel-air ratio. Extensive experimental work connected in particular with the development of aircraft engines has shown that the most suitable value of fuel-air ratio varies with the engine operating conditions such as, for example, the air pressure or density in the induction manifold. The fuel-air ratio corresponding to "best economy" operation, required for instance in a cruising airplane, is different from that corresponding to maximum power operation which is necessary for take-off. It is therefore advantageous that, while the means for controlling the engine supply of one of the components of the combustible mixture (either the air or the fuel) may be directly actuated by the operator, the supply of the other component may be controlled by automatic means so as to produce the desired fuel-air ratio.

One of the objects of the present invention is to provide, in combination with an internal combustion engine including fuel metering means, control means whereby the fuel-air ratio of the combustible mixture may be automatically regulated as a function of certain engine operating conditions such as the induction air density.

Another object is to provide, in combination with a spark-ignition engine having a fuel injection system, automatic devices for controlling the engine fuel supply, including mixture control means whereby the fuel-air ratio of the combustible mixture is determined by the adjustment of said mixture control means and for a given adjustment thereof is substantially independent of the engine operating conditions. The mixture control means may be adjusted by the pilot.

The above and other objects of the invention will be apparent as the description proceeds; and while I have illustrated and described the preferred embodiments of the invention as they now appear to me, it will be understood that such changes may be made as fall within the scope of the appended claims. In the following description and in the claims various details will be identified

by specific names for convenience, but they are intended to be as generic in the application as the art will permit.

In the drawings: Figure 1 is a sectional elevation of a fuel metering pump; Figure 2, in part a section along line 2—2 of Figure 1, shows two fuel metering pump units together with means for feeding fuel at variable pressure thereto; Figure 3 diagrammatically indicates a fuel metering pump applied to a radial aircraft engine and control means therefor; Figure 4 shows a modification of the fuel pressure regulating means of Figure 2; and Figure 5 diagrammatically illustrates means responsive to the air induction system pressure or density for regulating the engine fuel supply.

As shown in Figure 1, a fuel pump 1 has a plunger 2 reciprocating in a barrel 3 having a port 5. At its upper end, beyond an annular groove 6, the plunger 2 has edges 7, 8 which limit the plunger surface in contact with the bore of the barrel 3. Below the groove 6 and at suitable distance therefrom, plunger 1 has a splined portion 10 formed as a pinion and meshing with a rack 11 formed in a piston 12 slidable in a bore 15 of the barrel 3. The lower end of the plunger 2 is urged by a spring 16 against a lifter 18 operated by a cam 19 driven by the engine. A cup-shaped cap 20 screwed on the upper end of the barrel 3 closes the pumping chamber 22 and provides, between barrel and cap, an annular chamber or reservoir 24 communicating through port 5 with the pumping chamber 22 and through annular apertures of very small area provided between barrel 3 and cap 20 with the annular chambers 26 and 27. A gasket 21 prevents fuel leakage between barrel 3 and cap 20.

The annular chambers 26 and 27 communicate with a chamber 28 at one end of the bore 15 by means of ducts 30, 31, 32 and 33. The chamber 29 at the opposite end of the bore 15 communicates with the reservoir 24 through the duct 35. At the upper end of the pumping chamber 22 a spring-loaded check valve 36 admits fuel, through duct 38, annular groove 39, duct 40 and hollow fastening bolt 41, to a conduit 42 leading to the nozzle. A spring 44 acting on the piston 12 is provided in the chamber 28. In the preferred embodiment, a multicylinder engine has a number of pumps 1, each arranged near the corresponding cylinder. As indicated in Figure 2, a fuel transfer pump 48, connected through a pipe 51 with a fuel tank, not shown, delivers fuel to a conduit 45 which communicates, through a hollow bolt similar to bolt 41 and a duct 47, with chamber 29 and reservoir 24 of each pump 1, while chamber 28 of each pump communicates, through a duct 33 and another hollow bolt, with a fuel return line 49 and a pipe 50 leading fuel back to the tank. Between outlet and inlet ports of the transfer pump 48 a bypass is provided, controlled by a pressure regulating valve including a piston 52 biased by a spring 53 whose load may be varied by screwing or unscrewing the threaded cap 54 provided with a lever arm 55. A groove 56 and a duct 57 lead fuel leakage back to the return line 49.

As the delivery of the transfer pump 48 is substantially larger than the total requirement of pumps 1 under all operating conditions, excess fuel flows past the regulating valve 52, and the fuel pressure in the feed line 45 and in the chambers 29 of the pumps 1 will therefore be controlled by the load of the spring 53 and the adjustment of lever 55. Changes of pressure in the chamber 29 axially displace the piston 12 and vary the angular adjustment of the plunger 2.

In Figure 3 a pump 1 is shown equipping an aircraft engine of the radial type having a cylinder 60 to which air supplied by a superchanger 61 is fed through the induction pipe 62. A throttle valve 63 controlled by a lever 64 and control lever 65 is provided to regulate the

air charge. A second control lever 66 adjusts the angular position of the lever 55 shown in detail in Figure 2. The fuel conduit 42 communicates with the nozzle 70 through which fuel is injected into the pipe 62 during part of the suction stroke of the cylinder 60. The nozzle 70 may obviously be mounted in any other suitable position, such as near the intake cylinder port or valve, or inside the cylinder.

In the position shown in Figure 1, the plunger 2 is at the end of its suction stroke and has uncovered the port 5 allowing fuel to flow into the pumping space 22. As the plunger rises, operated by the cam 19, the surface comprised between the edges 7 and 8 covers the port 5. The pressure rises rapidly in the space 22 and lifts the check valve 36, and through the nozzle 70 fuel is injected in the induction pipe 62 and carried by the incoming air into the cylinder 60. The injection continues until the edge 8 uncovers the port 5 which now functions as a pressure relief port through which the remaining fuel displaced by the plunger is bypassed into the reservoir 24.

While the engine is in operation, the fuel pressure in the grooves 26 and 27, substantially the same as in chamber 28 and fuel return line 49, is lower than in the reservoir 24, and a continuous flow of fuel is vented through the annular apertures of very small area provided between the reservoir 24 and the grooves 26 and 27. The volume flowing through an orifice under a given difference of pressure being for a gas or a vapor several times larger than for a liquid, the area of said apertures may be made such that under the existing difference of pressure, vapor or gas separating from the fuel in the reservoir 24 can be eliminated therefrom, while only a relatively small volume of liquid fuel escapes through said apertures. As said annular apertures surround the port 5, whatever the orientation of the pump 1 may be relative to the vertical line, gas or vapor bubbles can be vented from the reservoir 24 at some point higher than the port 5, thereby reducing the risk of such bubbles being drawn into the pumping space 22 where they might interfere with the correct operation of the pump.

The plunger 2 being provided with at least one substantially helical control edge, the duration of its effective delivery stroke and thereby the weight of fuel delivered per stroke may be varied by a turning adjustment of the plunger obtained by adjusting the fuel pressure regulating valve 55. In the preferred embodiment of the invention the fuel supply system is so arranged that changes in fuel pressure in the conduit 45 and the corresponding variations in the delivery per cycle of the pumps 1 are proportional. Owing to the fact that the axial displacement of the valve piston 52 corresponding to changes in the fuel flow through the valve is very small and the spring 53 is very flexible, changes in the load of the latter due to said axial displacement of the piston 52 are practically negligible, the variations of angular adjustment of the lever 55 and the corresponding changes of fuel delivery per cycle of the pumps 1 may also be considered proportional. To secure proper venting and cooling of the pumps 1 under all conditions, it is advisable that the zero delivery angular adjustment of the plunger 2 correspond to a predetermined pressure in the feed line 45 higher than in the fuel return line 49. Figure 4 indicates an alternative form of pressure regulating valve wherein a highly resilient spring 73 is adjusted to exert on a valve piston 72 a load which balances said predetermined fuel pressure that corresponds to said zero delivery angular adjustment of the plunger 2. Since, as previously stated, the maximum axial displacement of the valve piston 72, under extreme operating values of fuel flow through the port controlled by the piston 72, is very small and the spring 73 is very flexible, if no load is applied to the outer end of the piston 72, the fuel pressure in the conduit 45 is maintained by the spring 73 substantially constant at said predetermined value independently

of changes of delivery of the fuel transfer pump 48, and the plungers 2 are maintained angularly adjusted for zero delivery. If a further load is applied to the valve piston 72, for instance by means of the lever 74, the fuel pressure in conduit 45 is increased beyond said predetermined value and the plungers 2 are turned to deliver to corresponding quantity of fuel. Hence in the preferred embodiment of the invention, as already pointed out, the fuel delivery per cycle of the pumps 1 is proportional to the load transmitted to the piston valve 72 by the lever 74.

One of the advantage of this fuel supply system is that control of fuel delivery is obtained by adjusting the pressure regulating valve, which may be performed by automatic devices of very little energy, especially if compared with fuel pumps of the same general characteristics in which turning adjustment of the pump plunger is obtained by means of links positively inter-connecting all plungers with the control means, whereby if a plunger is scored and cannot be turned in its barrel, it may prevent the adjustment of all other pump plungers and put the engines out of control. In the fuel supply system which is herein described, a failure occurring to one pump does not interfere with the operation of the other pumps.

The arrangement of Figure 3 in which the air and fuel supplies are controlled by distinct levers 65, 66 is not suitable for spark-ignition engines, which require a combustible mixture having definite fuel-air ratio. According to the invention, a more convenient arrangement, shown in Figure 5, includes pressure responsive means, such as a resilient and evacuated bellows 75 surrounded by fluid having the same pressure as in the induction pipe 62, transmitting to a fuel pressure regulating valve 72, through a link 76 and a lever 74, a load proportional to the induction pressure. The operating distance of link 76 from the fulcrum of lever 74 may be varied by lever 79 connected with the control lever 78 whereby the ratio of fuel delivered per cycle to induction pressure depends on the adjustment of the control lever 78 and is independent of engine operating conditions or altitude. This simple device, applied to an internal combustion engine in which the induction temperature, or temperature of the air in the engine manifold 62, is substantially constant, as may be the case where an intercooler is used and in which the cylinder air charge is proportional to the induction pressure, automatically controls the fuel delivery so as to maintain, for each adjustment of lever 78, a corresponding constant value of fuel-air ratio in the combustible mixture. This device is intended to be used in combination with means for controlling the air supply of the engine, such as for instance that indicated by numerals 63 to 65 in Figure 3, by which the induction pressure in manifold 62 may be regulated. The main control of the engine is throttle lever 65, and the fuel-air ratio may be adjusted by the mixture lever 78. In combination with engines in which the variations in induction temperature are small but not negligible, it may be convenient in order to compensate for variations in air density and engine air supply due to small changes of temperature in manifold 62, to provide in the bellows 75 a certain weight of fluid, the pressure to which increases with the temperature, the arrangement being such that the temperature of the bellows 75 be the same as in the pipe 62 whereby, for a given pressure in said pipe, the fuel delivery is reduced when the induction temperature increases and the density of the air in the manifold 62 correspondingly decreases.

As shown in Figure 5, the bellows 75 is enclosed in a housing whose walls are preferably heat-insulated, connected with the induction pipe 62 by means of a large and short conduit. Eddy currents or turbulence in said conduit and housing caused by the high velocity of the air flow in the pipe 62 as well as the pulsations of pressure therein, produce an active thermic exchange, by con-

duction and convection, between the air flowing in pipe 62 and bellows 75. The thermal capacity of such bellows usually is, or may be made, extremely small. Hence, as previously pointed out, the air flowing through the pipe 62 and the expansible fluid within the bellows 75 will have substantially the same temperature.

It is to be expressly understood that the invention is not limited to the specific embodiments shown, but may be used in various other ways, and changes, modifications, substitutions, additions and omissions may be made in the construction, arrangement and manner of operation of the parts without departing from the limits or scope of the invention as defined in the following claims. Where the claims are directed to less than all of the elements of the complete system disclosed, they are intended to cover possible uses of the recited elements in installations which may lack the non-recited elements.

I claim:

1. In a multi-cylinder fuel injection engine having a supercharger, an air entrance leading thereto, a throttle in said entrance, air exits leading from said supercharger to said cylinders, engine operated metering fuel pumps adapted to discharge fuel charges for each cylinder, a fuel supply pump adapted to deliver fuel under a variable fuel pressure to all of said metering fuel pumps, mechanical means for varying the quantity discharged by each individual fuel pump responsive to said variable fuel pressure, control means for regulating said variable fuel pressure responsive to the pressure created by said supercharger.

2. A supercharged engine having fuel injection units, fluid pressure actuated delivery control means in each of said units, a source of pressure fluid, conduit means connecting said source and units, and supercharged air pressure responsive means for controlling the fluid pressure actuating said delivery control means.

3. A supercharged engine having fuel supply units, fuel pressure actuated delivery control means in said units, a source of pressure fuel, conduit means connecting said units with said source, and engine supercharged air pressure responsive means for controlling the fuel pressure actuating said delivery control means.

4. A multicylinder engine having fuel supply units, each of said units intermittently supplying pressure fuel to a corresponding engine cylinder, individual fluid pressure actuated delivery control means for each of said units, fluid conduit means connecting said control means, and engine induction air pressure responsive means for controlling said fluid pressure.

5. An engine having individually fluid pressure controlled fuel injection units, a valve for regulating the fluid pressure controlling said units, said valve being subject to the same fluid pressure, and engine manifold air pressure responsive means for exerting an operative load on said valve against said fluid pressure.

6. An engine having individually fluid pressure controlled fuel supply units, valve means for regulating the fluid pressure controlling said units, said valve means being exposed to said fluid pressure, and engine manifold air pressure and temperature responsive means for actuating said valve means against said fluid pressure.

7. An engine fuel supply system including individually fluid pressure controlled injection units, valve means for regulating the fluid pressure controlling said units, said valve means being subject to the same fluid pressure, means for applying an operative load proportional to the engine induction air pressure to said valve means against said fluid pressure, and means for varying the ratio between said induction air pressure and said load.

8. A fuel injection system for radial engines including individually interchangeable injection units; each of said units having a radially arranged plunger reciprocable from a common engine-driven cam coaxial with the engine shaft; variable pressure fluid containing means and delivery control means operated by the fluid pressure therein; a source of pressure fluid, conduit means for interconnecting said source and containing means, valve means for regulating the pressure in said fluid containing means, and means responsive to engine induction air pressure for actuating said valve means.

9. For use with an engine having a fuel injection system including at least one injection pump; plunger means in said pump; means in said pump for imparting reciprocatory motion to said plunger means; conduit means in said pump for the discharge of high pressure fuel displaced by said plunger means; fuel inlet means in said pump for admitting comparatively low pressure fuel to said pump; variable-pressure fuel containing means connected with said fuel inlet means; and resiliently loaded slidable control means in said pump actuated upon changes of pressure in said fuel containing means for varying the effective stroke of said plunger means whereby the rate of fuel discharge of the pump varies with the pressure in said fuel containing means: a fuel metering device including slide valve means whose adjustment affects the fuel pressure in said fuel containing means; duct means through which flows engine intake air; and pressure and temperature responsive means connected with said duct means for actuating said slide valve means.

10. Engine fuel supply system comprising a fuel control unit for controlling a fuel injection pump of the type including: plunger means, tappet and spring means for imparting reciprocating motion of constant stroke to the plunger means, conduit means for the intermittent discharge of high pressure fuel displaced by the plunger means, fuel inlet means for admitting low pressure fuel to said pump, and spring loaded slidable control means which move upon changes of fuel pressure in said fuel inlet means to vary the effective stroke of the plunger means whereby the rate of fuel supply of the pump varies as a predetermined function of the fuel pressure in said fuel inlet means; said fuel control unit including: fuel duct means connected with the fuel inlet means of said pump upstream with respect thereto, orifice means in said duct means, slidable valve means controlling the orifice means, the adjustment of said valve means being affected by fuel pressure variations in said duct means, the adjustment of the same valve means in turn affecting the fuel pressure in the fuel inlet means of said pump, and pressure and temperature responsive means connected with an element of the engine intake air system for actuating said valve means.

11. For use with an engine having an air induction system; at least one pump driven from the engine; plunger means in said pump; means for imparting reciprocating motion to said plunger means; conduit and nozzle means for the discharge of high pressure fuel displaced by said plunger means; fuel inlet means in said pump for admitting low pressure fuel thereto; resiliently loaded control means actuated upon changes of fuel pressure in said fuel inlet means for varying the effective stroke of the plunger means; and fuel metering means including fuel duct means connected with the fuel inlet means of said pump; orifice means in said duct means; a valve for controlling said orifice means to cause pressure variations in the fuel inlet means of said pump; and air temperature and pressure responsive means connected with said air induction system for actuating said valve.

12. In a fuel system for an internal combustion engine: a fuel supply pump; a connection for conducting fuel from the pump to the engine; means including a pumping member driven by the engine for delivering fuel to the engine; means for varying the fuel flow to the engine; a passageway for transmitting a variable fuel control pressure created by the first mentioned means to the varying means; and engine induction pressure responsive means for varying the control pressure.

13. For use with an engine and a fuel supply pump driven from the engine, a fuel system comprising a con-

duit adapted to connect the pump with the engine; means for creating a fuel pressure in and effecting a flow of fuel through said conduit means for controlling said flow; means adapted to contain a control pressure developed by the first mentioned means and acting on the second mentioned means for influencing the functioning thereof; and air pressure and temperature responsive means and manually controlled means for varying the control pressure.

14. In a fuel system for an internal combustion engine: a source of fuel; a conduit connecting said fuel source with the engine; means for creating a fuel pressure in and effecting a flow of fuel through said conduit; means for controlling said flow; means adapted to contain a control pressure developed by the first mentioned means and acting on the second mentioned means for influencing the functioning thereof; and temperature responsive means for varying the quantity of fuel supplied to the engine.

15. The invention defined by claim 14 and including a manually controlled valve for modifying the control pressure.

16. For use with an engine having an air induction system, a fuel supply pump, and an injection pump having fuel delivery control means and fuel pressure responsive means connected with said pump for actuating said control means to vary the fuel delivery as a predetermined function of the fuel pressure on said pressure responsive means; valve means for variably regulating said fuel pressure, and means responsive to air induction pressure and temperature for actuating said valve means.

17. For use with an engine having an induction system, a source of pressure fuel, and an injection pump including delivery control means and fuel pressure responsive means for sensing pressure variations in the fuel supplied to the pump and actuating said control means to vary the fuel delivery of the pump in predetermined relation to said fuel pressure; a control device including: conduit means for leading fuel from the source to the injection pump; valve means connected with said conduit means; and manually operable control means and induction air pressure and temperature responsive means for positioning said valve means.

18. In a fuel control for an internal combustion engine having an air passage, a fuel conduit, a fuel injection pump for receiving fuel from the conduit and delivering it to the engine, servo-motor actuated means for controlling the effective stroke of the pump to thereby control the flow through the fuel conduit, and means responsive to the resultant of opposed forces created by air and fuel pressures for controlling the servo-motor.

19. In a fuel injection system for an engine, a fuel injection pump, a fuel conduit leading from the pump to a cylinder of the engine for supplying individual charges of liquid fuel thereto in timed relation with the engine, a fuel control element for varying the quantity of fuel in the individual charges, a fuel passage for supplying fuel to the pump, an air passage for supplying air to the cylinder, a control element for varying the quantity of air supplied to the cylinder, pressure fluid means actuating said fuel control element and means responsive to air and fuel pressures for controlling said pressure fluid means.

20. In a charge forming device, a fuel injection pump, an air passage, a first element controlling the effective pumping capacity of the pump, a second element controlling the air passage, means for manually actuating said second element, a movable pressure responsive member for actuating said first element, means for subjecting the member to fuel pressure, and means responsive to air and fuel pressures for varying the fuel pressure on the member to control said first element.

21. In a fuel injection system for an engine, a fuel injection pump, a fuel conduit leading from the pump to

a cylinder of the engine for supplying individual charges of liquid fuel thereto in timed relation with the engine, a fuel control element for varying the quantity of fuel in the individual charges, an air passage for supplying air to the cylinder, an air control element for varying the quantity of air supplied to the cylinder, manual means for actuating said air control element, a movable pressure responsive wall operatively connected to the fuel control element, means including a fuel conduit for supplying fuel to the pump and the wall, and means responsive to air and fuel pressures for varying the pressure of the fuel on said wall for operating the fuel control element.

22. In combination with an engine having an air-intake conduit provided with a throttle and fuel supply means having an output proportional to engine speed and whose output at any given speed is variable, a member movable to control the output of said fuel supply means, automatic fuel-air ratio controlling mechanism functioning to vary the admission of fuel to said fuel supply means to obtain predetermined fuel-air ratios for all operating positions of the throttle, and a movable element operatively connected to said member and subjected directly to the fuel admitted to said fuel supply means for regulating the effective delivery of said fuel supply means in response to variations in the pressure of said fuel.

23. In a fuel mixture control for an internal combustion engine, an air passage, a fuel conduit, a throttle for controlling the flow through the air passage, a servo-motor actuated means for controlling the flow through the fuel conduit, and means responsive to the resultant of opposed forces created by air and fuel pressures for controlling the servo-motor.

24. In a fuel injection system for internal combustion engines of the type comprising a charge pump driven by the engine and supplying fuel to the engine and a feed pump driven by the engine for supplying fuel to the charge pump, a fuel metering valve disposed between the charge and feed pumps for varying the amount of fuel delivered to the charge pump and thereby controlling the speed of the engine comprising a body having a passageway communicating with each of the pumps, a valve member movable endwise for progressively increasing and decreasing the fuel flow through the passageway depending upon the position of the valve member, said valve member having an end surface subjected to the pressure of fuel in the passageway, a spring seat slidably mounted for movement toward and away from the valve member, a spring between the valve seat and the valve member opposing movement of the valve in response to said pressure, and means for variously positioning the valve member in said passageway comprising means for moving the spring seat.

25. In a fuel injection system for internal combustion engines of the type comprising a charge pump driven by the engine and supplying fuel to the engine and a feed pump driven by the engine for supplying fuel to the charge pump, a fuel metering valve disposed between the charge and feed pumps for controlling the speed of the engine comprising a body having a passageway communicating with each of the pumps, a valve member movable endwise and connected with said passageway for progressively increasing and decreasing the fuel flow through the passageway depending upon the position of the valve member, said valve member having an end surface subject to the pressure of fuel in the passageway, a spring seat slidably mounted for movement toward and away from the valve member, a spring between the valve seat and the valve member opposing movement of the valve in response to said pressure, and means for variously positioning the valve member in said passageway comprising actuating means extending transversely of the passageway and operable from the exterior of the valve for moving the spring seat.

26. In a fuel injection system for internal combustion engines, a charge pump driven by the engine and supply-

ing fuel to the engine cylinders, a feed pump driven by the engine for supplying fuel to the charge pump under pressure responsive to engine speed, means forming a feed passageway between the feed pump and charge pump, a movable valve operatively associated with the passageway for varying the fuel flow in the passageway and having a surface subjected to the pressure of fuel

supplied to the passageway by the feed pump, a spring operatively connected to the valve for opposing movement of the valve responsive to fuel pressure, and means movable relative to the valve for adjusting the force of the spring.

No references cited.