March 26, 1957 F. BARFOD 2,786,460

FUEL INJECTION SYSTEM

Filed Aug. 31, 1953 2 Sheets-Sheet 1

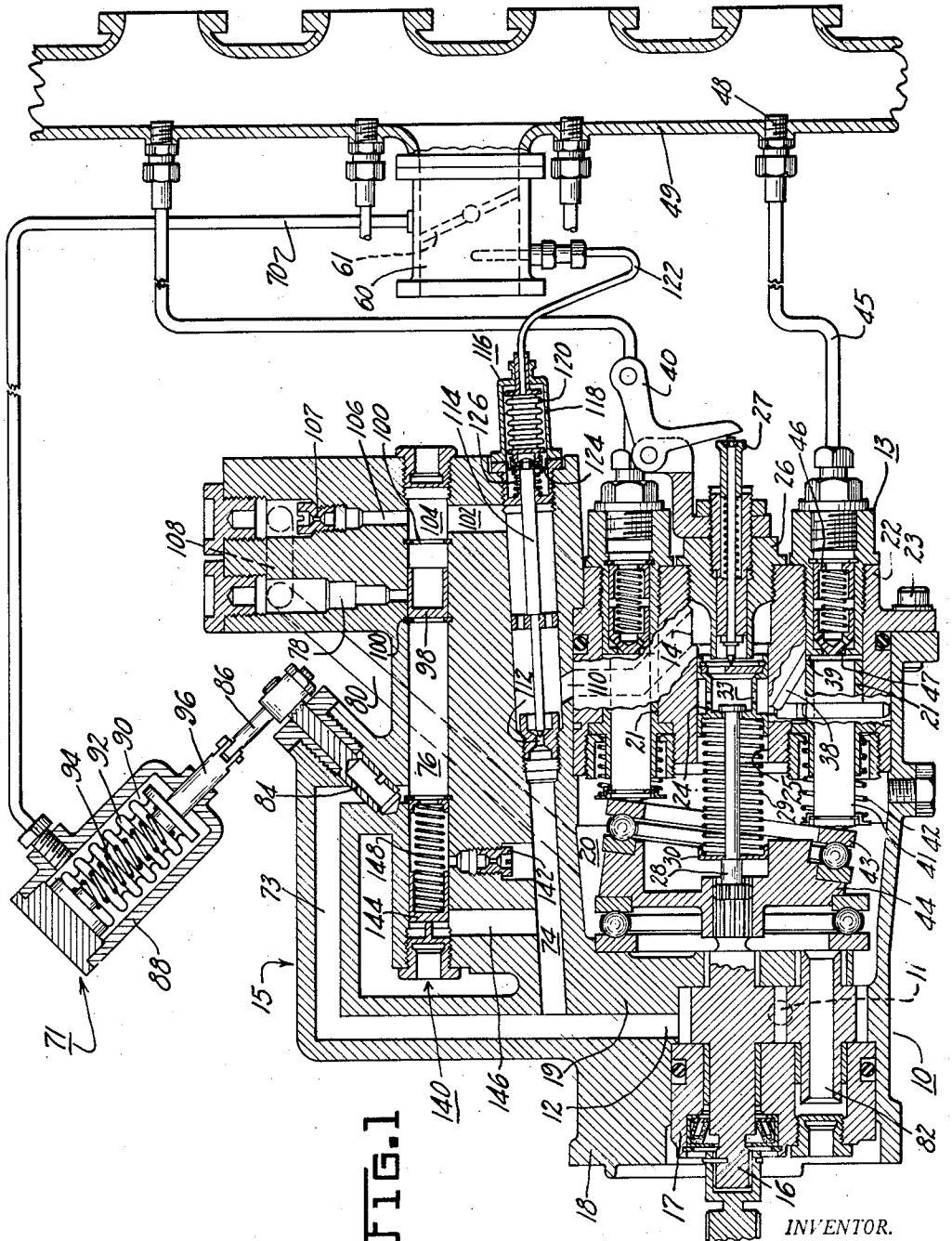


FIG. 1

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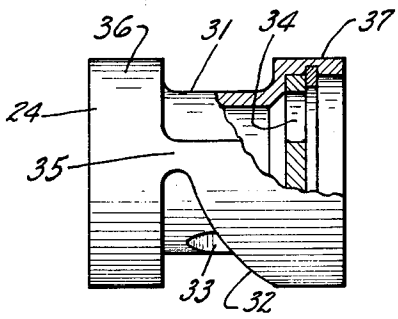


FIG. 2

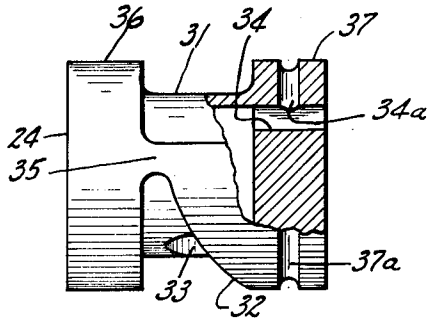


FIG. 4

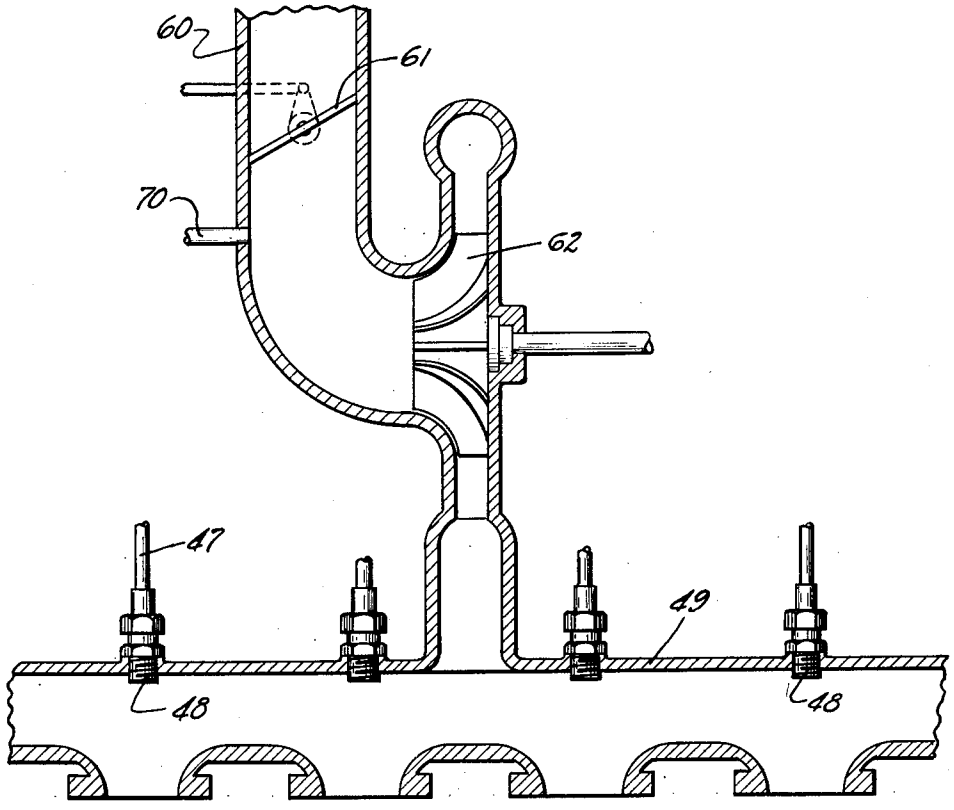


FIG. 3

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FUEL INJECTION SYSTEM

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16 Claims. (Cl. 123—119)

This invention relates to fuel supply systems or devices for internal combustion engines and more particularly to devices or systems in which liquid fuel is supplied under positive pressure.

An object of the present invention is to provide an improved combination of fuel injection pump and metering system therefor.

Another object of the invention is to provide an improved fuel supply system which is readily adapted for use with various internal combustion engines having different operating characteristics and fuel requirements.

Another object of my invention is to provide a fuel injection system capable of accurately metering small quantities of fuel and delivering said fuel to a multiple cylinder internal combustion engine as separate charges for each cylinder.

A further object of my invention is to provide a system for supplying fuel under positive pressure to the manifold of an internal combustion engine in the form of small individual charges for each cylinder.

A still further object of my invention is to provide a fuel feeding system in which the fuel flow is automatically regulated in accordance with certain engine variables such as, for example, engine speed and engine charging pressure.

Other objects and advantages will be readily apparent from the following detailed description taken in connection with the appended drawings in which:

Figure 1 is a diagrammatic view partially in section showing the general arrangement of parts of one form of my improved fuel supply system as applied to an internal combustion engine;

Figure 2 is an enlarged view partially in section of the rotary distributor valve shown in Figure 1;

Figure 3 is a partial view of the manifold of an internal combustion engine showing a supercharger in the induction passage;

Figure 4 is an enlarged view partially in section of a modified form of the rotary distributor valve.

Referring now to the drawings and in particular to Figure 1, numeral **10** designates a gear pump, having an inlet **11** and an outlet **12**. A multi-plunger fuel injection pump is shown at **13** having a fuel inlet **14** in communication with the outlet of the gear pump through a fuel metering control generally shown at **15**. The gear pump is adapted to be driven by shaft **16** which is journaled at one end in a member **17** secured in the housing **18** and at the other end in a partition **19** which is formed in the housing and separates the gear pump from the chamber **20** of the injection pump. Opening into this chamber are pump cylinders **21** circularly disposed in an end member **22** which is secured to a flange on the housing by suitable bolts **23**.

Shaft **16** is adapted to be driven by the engine (not shown) whereby the fuel discharged by the gear pump varies as a function of engine speed. The fuel discharged by the gear pump is metered by the control unit **15** as a function of engine charging pressure and/or

temperature. A quantity of metered fuel, depending on engine operating conditions and characteristics of the particular engine being supplied by my fuel feeding system, is by-passed to the inlet of the gear pump. The remainder of the metered fuel flows to the injection pump which delivers the fuel to the manifold of the engine in small individual charges for each cylinder.

The size of each charge is varied by a rotary distributor valve **24** which is slidably disposed in a cylindrical chamber **25**. This chamber is located in the end member **22** concentrically with pump cylinders **21**. The outer end of chamber **25** is closed by a plug **26** in which a spring loaded abutment member **27** is slidably carried.

A drive shaft **28** is splined at one end in common splineways with shaft **16** and is keyed at the other end with the valve **24** whereby the valve is free to move longitudinally on the shaft but is fixed for rotation therewith. A spring **29** encircles the shaft and is held in abutting relationship with the valve by a spring retainer **30**. The rotary distributor valve is cylindrically shaped and has a reduced central portion **31** on which is formed a helical land **32** (Figure 2). A bore **33** traverses the reduced central portion, and an axial bore **34** connects the hollow interior of the valve with the inlet **14** of the injection pump. The helical land **32**, as shown in Figure 2, terminates in a narrow raised portion **35** which extends across the reduced portion between end lands **36** and **37**. The interior of the valve **24** is normally in communication with the pump cylinders **21** through bore **33**, passages **38** and port **39**. Communication between the interior of the valve and the pump cylinders is, however, adapted to be cut off during a certain portion of the rotation of the valve **24** by the helical land **32** coming into registration with passage **38**. An abutment member **27** is provided to prevent spring **29** from moving the helical land out of registry with passage **38** and determines the minimum fuel flow during normal operation of the engine. The abutment member **27**, however, may be moved to the left as viewed in Figure 1, by an idle cut-off lever **40** to cause land **37** to move into registration with passage **38** and thereby cut off communication between the fuel inlet **14** and pumping cylinders **21**.

An alternate means for providing idle cut off is shown in Figure 4 wherein a radial bore **34***a* connects the bore **34** with annular groove **37***a* in the end land **37**. With this arrangement the idle cut-off lever **40** moves groove **37***a* into registration with passage **38** establishing continuous communication between the inlet **14** and the pumping cylinders **21** allowing the cylinders to fill with fuel on each suction stroke but causing the fuel to be returned to the inlet **14** rather than expelled through the discharge port **47** on each pumping stroke whereby the pump discharge is cut off.

The number of pumping cylinders provided in the injection pump is correlated with the number of cylinders in the engine with which the fuel feeding system is adapted for use. Preferably, the pumping cylinders are alike in construction, and hence the description of one will suffice for all. Pumping plunger **41** is slidably disposed in the cylinder **21** and is urged toward retracted position by a spring **42**. The plunger is urged in the pumping direction in opposition to said spring, by a bearing ring **43** mounted on wobble plate **44** which is secured to an extension of shaft **16** and adapted for rotation therewith. A conduit **45**, containing a check valve **46** connects the discharge port **47** in the end of the pumping cylinder with nozzle **48** located in the manifold **49**. Although the nozzle shown is discharging into the manifold, it is to be understood that the nozzle could equally well be located in the cylinder wall of the engine.

A throttle body **60** will a throttle valve **61** mounted therein is secured to the manifold by suitable bolts (not

shown). As shown in Figure 3, a supercharger 62 of conventional design may also be included in the induction passage. A passageway 70 communicating with the induction passage on the engine side of the throttle and anterior to the supercharger, if included, supplies the engine charging pressure to the control unit 71 in the fuel metering unit 15. The latter unit is interposed between the gear pump 10 and the injection pump 13 to receive the entire output of the gear pump through passages 73 and 74 and to deliver a metered portion of that output to the inlet 14 of the injection pump. The remainder of the fuel is returned to the inlet of the gear pump through by-passes connected to each of the passages 73 and 74.

Passage 73 is connected to the gear pump outlet 12 and the inlet 11 through conduit 76, passageway 78, passage 80, chamber 20 and bore 82. Valve 84 controls passage 73 and is connected to control unit 71 by a suitable linkage 86. The control unit comprises a housing 88 defining a chamber 90 containing a bellows 92 urged toward extended position by an internally carried spring 94. A rod 96 secures one end of the bellows to the linkage 86.

Conduit 76 is controlled by a pressure equalizing valve 98 which is freely reciprocable in said conduit between toroidal members 100 to control the communication between conduit 76 and passageway 78. The outlet 12 of the gear pump is also connected to the inlet 11 through a by-pass consisting of passages 74, 102, 104, 106, restriction 107, passages 108, 80, chamber 20 and bore 82. The passage 104 is separated from conduit 76 by valve 98 which is responsive to the pressure differential existing between the two conduits.

A conduit 110 connects passage 74 posterior the metering restriction 112 to the inlet 14 of the injection pump. A temperature responsive valve 114 controlled by unit 116 extends into the metering restriction 112 and regulates the flow therethrough. The unit 116 consists of a housing 118 containing a bellows 120 which is connected to a temperature bulb in the intake manifold through a tube 122. Valve 114 is centrally secured to a diaphragm 124 which seals one end of the housing. The bellows upon being heated expands to urge the diaphragm in a valve closing direction and is opposed in this movement by a spring 126.

A power enrichment system is provided at numeral 140, consisting of a power enrichment jet 142 connecting conduit 74 with conduit 76. The power enrichment jet is controlled by a valve 144 which on one side is subjected to gear pump outlet pressure through conduits 74 and 146 and on the other side to the force of a spring 148 and the pressure in conduit 76. At low and medium speeds the jet is open thereby by-passing a portion of the fuel from conduit 74 to the conduit 76 causing the quantity of fuel delivered to the inlet 14 of the injection pump to be decreased. At high speeds the gear pump discharge pressure is sufficient to move valve 144 to close the jet, thereby cutting off the by-pass and causing an increase in the quantity of fuel delivered to the injection pump.

In the operation of my fuel supply system, fuel under substantially constant pressure is supplied from a source (not shown) to the gear pump inlet 11. The gear pump drive shaft 16 is adapted to be driven by the engine whereby fuel under a pressure varying as a function of engine speed is discharged through outlet 12 to metering restriction 112 and valve 84 through conduits 74 and 73 respectively.

The size of the metering jet 112 is varied by valve 114 as a function of manifold air temperature. Fuel passing through jet 112 is therefore metered as a function of engine speed and engine temperature. A portion of the fuel, thus metered, flows through passages 102 and 104 to act on one face of the pressure equalizing valve 98 and to urge said valve in a direction to close passage 78. With passage 78 closed, the entire output of the gear pump is confined to passage 74. The closing of valve 98 by fuel under pressure in passage 104, however, is opposed by fuel under pressure in conduit 76 acting on the opposite side of valve 98. The fuel pressure in conduit 76 is controlled by valves 84, 144 and 98.

Valve 84 is controlled by unit 71 which is responsive to engine charging pressure. As the air charging pressure increases, valve 84 is moved toward closed position reducing the fuel pressure in passage 76 and causing valve 98 to move in a direction to close passage 78. Conversely, as air charging pressure decreases, valve 84 is moved toward open position increasing the fuel pressure in passage 76 causing valve 98 to move in a direction to open passage 78. With passage 78 open, the portion of the gear pump discharge delivered to conduit 73 is by-passed to the pump inlet 11.

During low and medium speeds the power enrichment jet 142 is open, connecting conduit 74 with conduit 76 and thereby causing the fuel pressure in conduit 76 to be increased. During high speed operation, however, the pressure of the fuel in conduit 146, which varies as a function of engine speed, is sufficient to move the valve 144, in opposition to spring 148, to a position to cut off the fuel flow through jet 142 thus causing a decrease in fuel pressure in the conduit 76. A decrease in fuel pressure in conduit 76 causes valve 98 to close passage 78 thereby effecting an increased flow through metering jet 112.

It is apparent that the quantity of fuel entering passage 74 is dependent upon the quantity of fuel discharged by the engine driven gear pump and the quantity of fuel by-passed through conduit 73 which is controlled by air charging pressure responsive valve 84 and power enrichment jet 142. The quantity of fuel passing through the metering jet 112 and temperature responsive valve 114 is, therefore, metered in response to engine speed, engine charging pressure and air inlet temperature.

A portion of this metered fuel, the amount of which is determined by a particular engine operating characteristic, is by-passed through passages 102, 104, 106, 108, 80, chamber 20 and bore 82 to the inlet 11 of the gear pump.

The remainder of the metered fuel passes through conduit 110 to the injection pump inlet 14 which is controlled by a rotary distributor valve 24 slidably mounted on an engine driven shaft for rotation therewith. The valve 24 is cylindrically shaped having a hollow interior in communication with the inlet 14 through the axial bore 35 and with the pumping cylinders 21 through radial bore 33, passage 38 and port 39. The helical land 32 is adapted to close off the passage 38 during a portion of a rotation of the valve 24 thereby preventing the return of fuel from pumping cylinders 21 during at least a portion of the pumping stroke. The effective pumping capacity or amount of fuel delivered per stroke of the injection pump 13 may therefore be easily varied by varying the amount of time per pumping stroke that the helical land 32 is in registration with the passage 38 which in turn is determined by the longitudinal position of the valve 24 with respect to the passage 38. The longitudinal position of the valve 24 is affected by the force of metered fuel acting on one side of the valve which, in opposition to spring 29, urges the land 33 into increasingly greater registration with passage 38 to cause an increase in the size of the charge delivered by the pumping cylinder.

I have discovered that in order to supply the correct fuel-air mixture to the engine, when the quantity of fuel delivered to the metering unit varies as a function of engine speed, a certain portion of the metered fuel, depending upon the particular engine characteristics, must be by-passed. In my fuel feeding system I provide a means for by-passing a portion of the metered fuel consisting of passages 102, 104, 106, 108, 80, chamber 20 and bore 82. The quantity of fuel by-passed in any

particular engine is determined by the size of restriction 107 and the pressure differential across it. This pressure differential is that which exists between the gear pump inlet pressure and metered fuel pressure, which in turn is a function of the spring rate of spring 29 that opposes the movement of valve 24 in a direction to increase the pumping of metered fuel.

In an installation where it is desired to by-pass an approximately constant quantity of fuel, a spring is selected having a low spring rate so that a relatively small increase in metered fuel pressure is required to move valve 24 from minimum to maximum flow position. This results in a relatively small increase in the pressure differential across restriction 107 whereby the amount of fuel by-pass is held between narrow limits approaching constant flow. In other installations the quantity of fuel by-passed may be changed simply by selecting the proper restriction 107 and/or spring 29 to satisfy the requirements of any particular engine.

Fuel for idling is provided by the raised portion 35 on the valve 24 which is kept in registration with the passage 38 by abutment 27 when the fuel pressure acting on one side of valve 24 is less than the force of spring 29. The idle cut-off lever 40 forces the abutment member 27 to move the valve 24 in a direction to cause land 37 to come into registration with passage 38 whereby all fuel is cut-off to the pumping cylinders 21.

Extreme compactness of the fuel metering system is obtained by locating the single rotary distributor valve concentric with the circularly disposed pump plungers and axially aligning the valve with the gear and injection pumps whereby a common drive shaft may be utilized. This structure not only provides a greater compactness but also a greater freedom from injection errors caused by faulty timing of the component parts of the system.

I have discovered that by obtaining the engine charging pressure on the engine side of the throttle valve anterior to the supercharger that I am able to eliminate unpredictable errors such as manifold back pressures and the like whereby I am able to more accurately provide the correct fuel air mixture to the engine under all operating conditions than the known devices which utilize the charging pressure posterior to the supercharger.

While only one preferred embodiment of my invention has been described it will be readily apparent to those skilled in the art that many changes or arrangements of parts may be made without departing from the spirit of my invention.

I claim:

1. In a fuel supplying system for an internal combustion engine; a fuel conduit, a passage connecting said conduit to the engine, a metering restriction in said passage, pumping means in said conduit for pressurizing fuel in accordance with engine speed, means in said conduit controlling the flow therethrough in response to changes in engine charging pressure, means connected to said conduit for by-passing a quantity of fuel from said passage to the conduit anterior said pumping means, fluid pressurizing means in said passage downstream of said restriction for delivering separate charges of fuel to the engine in timed relation thereto, means for varying the quantity of fuel in said charges, and common actuating means for said last mentioned means and said pumping and fluid pressurizing means.

2. In a fuel supply system for a multi-cylinder combustion engine having an air intake manifold with throttle and supercharger therein; a conduit for supplying fuel to the engine, a positive displacement pump in said conduit having an inlet and an outlet and adapted to be driven by said engine, metering means in said conduit posterior to said pump, a passage connected to said conduit anterior to said metering means and communicating with the inlet of said pump, a valve in said passage responsive to manifold pressure anterior said supercharger for controlling the flow in said passage, a restricted passageway communicating with said conduit posterior said metering means for returning a quantity of fuel to the inlet of said pump, means for maintaining the pressure head across said valve substantially equal to the head across said metering means, means responsive to pump discharge pressure for increasing the quantity of metered fuel, a fuel injection pump connected to said conduit having a plurality of circularly disposed plungers for delivering separate charges of fuel to the engine in timed relation thereto, a rotary valve concentric with said plungers for varying the quantity of fuel in said charges, and resilient means for urging said rotary valve in a direction to reduce said charges, said pumps and rotary valve being in axial alignment and adapted to be driven by said engine through a common shaft.

3. A fuel feeding system for an internal combustion engine comprising a source of fuel, a conduit adapted to connect said source with the engine, a metering restriction in said conduit, a passage connected to said conduit on either side of said restriction, a valve in said passage responsive to the pressure differential between metered and unmetered fuel for regulating the flow therethrough, fluid pressurizing means in said conduit for supplying fuel to the metering restriction at a pressure varying in accordance with engine speed, means for subjecting the valve to metered fuel pressure for urging said valve in a direction to increase fuel flow to the engine, and means for returning a quantity of metered fuel to said source.

4. A fuel feeding system for an internal combustion engine having a source of fuel and an induction passage with a throttle and air pressurizing device therein: comprising a pump, an inlet for said pump adapted for connection with said source, an outlet for said pump, means for varying the discharge of said pump as a function of engine speed, a by-pass connected to said inlet and outlet, means responsive to induction passage pressure between the throttle and pressurizing device for controlling the flow through said by-pass and fuel divider means connected to said outlet and formed to deliver separate charges of fuel to the engine in timed relation thereto.

5. A fuel injection system for an internal combustion engine having an induction passage, a conduit for supplying fuel to the engine, a pump connected to said conduit, means for varying the discharge of said pump as a function of engine speed, a metering restriction in said conduit downstream of said pump, means connected to said conduit between said pump and restriction and responsive to pressure in said induction passage for controlling the flow in said conduit, means for equalizing the pressure differential across said restriction and said second mentioned means, means connected to said conduit for returning a quantity of fuel downstream of said restriction to said conduit upstream of said pump, and means connected to said conduit for delivering separate charges of metered fuel to the engine in timed relation thereto.

6. A fuel feeding system for an internal combustion engine, a conduit for supplying fuel to the engine, means connected to said conduit for pressurizing said fuel as a function of engine speed, metering means in said conduit, and means connected to said conduit for returning a substantially constant quantity of metered fuel to the conduit anterior said metering means irrespective of engine speed.

7. In a fuel supplying system for an internal combustion engine, a conduit for supplying fuel to the engine, metering means in said conduit, pressure creating means in said conduit upstream of said metering means for supplying fuel to the metering means at a pressure varying in accordance with engine speed, means connected to said conduit between said pressure creating means and said metering means and responsive to engine charging pressure for controlling the flow in said conduit, means connected to said conduit for by-passing a quantity of

metered fuel to the conduit anterior said pressure creating means.

8. In a fuel feeding system for an internal combustion engine having a source of fuel, a conduit adapted to connect said source with the engine, a metering restriction in said conduit, a pump in said conduit for delivering fuel to said restriction at a pressure varying in response to variations in engine speed, a passage connected to said conduit on either side of said pump, a valve in said passage, means responsive to engine charging pressure for actuating said valve, a by-pass adapted to connect said conduit anterior said restriction with said source and a valve in said by-pass responsive to pump discharge pressure for controlling the flow therethrough.

9. In a fuel supplying system for an internal combustion engine having an air intake manifold with a throttle and supercharger therein, a conduit for supplying fuel to the engine, a pump in said conduit for pressurizing fuel as a function of engine speed, metering means in said conduit, a by-pass around said pump, means responsive to manifold pressure between said throttle and supercharger for controlling the flow in said by-pass.

10. In a fuel supply system for an internal combustion engine, a conduit for supplying fuel to the engine, a pump in said conduit adapted to discharge fuel as a function of engine speed, metering means in said conduit downstream of said pump, a by-pass around said pump upstream of said metering means, a valve in said by-pass responsive to a predetermined pump discharge pressure to close said by-pass.

11. In a fuel supply system for an internal combustion engine having an induction passage and a source of fuel, a conduit adapted to connect said source with the engine, an engine driven pump in said conduit, metering means in said conduit, means connected to said conduit and responsive to induction passage pressure for regulating the flow in said conduit, a by-pass around said pump upstream of said metering means, and a valve in said by-pass responsive to engine speed and metered fuel pressure for controlling the flow through said by-pass.

12. In a fuel supply system for an internal combustion engine, a conduit adapted for supplying fuel to said engine, an engine driven positive displacement pump in said conduit, an inlet for said pump, a metering restriction in said conduit, a passage connected to said conduit on either side of said pump, a valve in said passage, means responsive to engine charging pressure for actuating said valve, a valve in said conduit responsive to engine speed and metered fuel pressure, and means for by-passing a quantity of metered fuel to the inlet of said pump.

13. A fuel feeding system for a multi-cylinder internal combustion engine comprising: a conduit for supplying fuel to the engine, a pump connected to said conduit for pressurizing fuel as a function of engine speed, metering means in said conduit, means connected to said conduit downstream of said metering means for delivering a substantially constant quantity of metered fuel to said conduit upstream of said metering means, and means connected to said conduit for delivering all of the metered fuel in said conduit except said substantially constant quantity to said engine in separate and distinct charges for each cylinder.

14. A fuel feeding system for a multi-cylinder internal combustion engine having an induction passage comprising: a conduit for supplying fuel to the engine, a pump connected to said conduit for pressurizing fuel as a function of engine speed, metering means in said conduit, means responsive to induction passage pressure and connected to said conduit between said pump and metering means for by-passing fuel to said conduit upstream of said pump, means connected to said conduit downstream of said metering means for by-passing a substantially constant quantity of metered fuel to said conduit upstream of said pump and means connected to said conduit for delivering all of the metered fuel in said conduit except said substantially constant quantity to said engine in separate and distinct charges for each cylinder.

15. In a fuel supply system for a multi-cylinder internal combustion engine having an induction passage; a conduit for supplying fuel to the engine, a positive displacement pump in said conduit adapted to be driven by said engine, an inlet and an outlet for said pump, a metering restriction in said conduit downstream of said pump, a passage connected to said conduit around said pump and upstream of said restriction, a valve in said passage responsive to induction passage pressure for controlling the flow through said passage, means for maintaining the pressure drop across said valve substantially equal to the pressure drop across said restriction, a passageway connected to said conduit downstream of said restriction and upstream of said pump, and a rotary valve in said conduit rotatable as a function of engine speed to divide the fuel in said conduit into separate charges for each cylinder.

16. In a fuel supply system for an internal combustion engine having an induction passage, a conduit adapted to supply fuel to said engine, an engine driven positive displacement pump in said conduit, a metering restriction in said conduit downstream of said pump, a valve in said conduit downstream of said pump, means responsive to ambient air temperature for regulating said valve, a passage connected to said conduit on either side of said pump and upstream of said restriction, a valve in said passage, means responsive to induction passage pressure for actuating said last mentioned valve, and means for equalizing the pressures in said passage and conduit.

References Cited in the file of this patent

UNITED STATES PATENTS

2,093,477	Parsons	Sept. 21, 1937
2,136,959	Winfield	Nov. 15, 1938
2,142,086	Alden	Jan. 3, 1939
2,384,282	Chandler	Sept. 4, 1945
2,419,171	Simpson et al.	Apr. 15, 1947
2,438,663	Greenland	Mar. 30, 1948
2,673,556	Reggio	Mar. 30, 1954