

[54] **ELECTRICALLY CONTROLLED FUEL PUMP**[75] Inventors: **Ralph H. Johnston; Leroy E. Lakey,**
both of Anderson, Ind.[73] Assignee: **General Motors Corporation,**
Detroit, Mich.[22] Filed: **Nov. 28, 1973**[21] Appl. No.: **419,481**[44] Published under the Trial Voluntary Protest
Program on January 28, 1975 as document no.
B 419,481.[52] U.S. Cl. **417/220**[51] Int. Cl.² **F04B 49/00**[58] Field of Search 417/212, 218, 220, 219,
417/222, 221; 91/459

[56]

References Cited**UNITED STATES PATENTS**

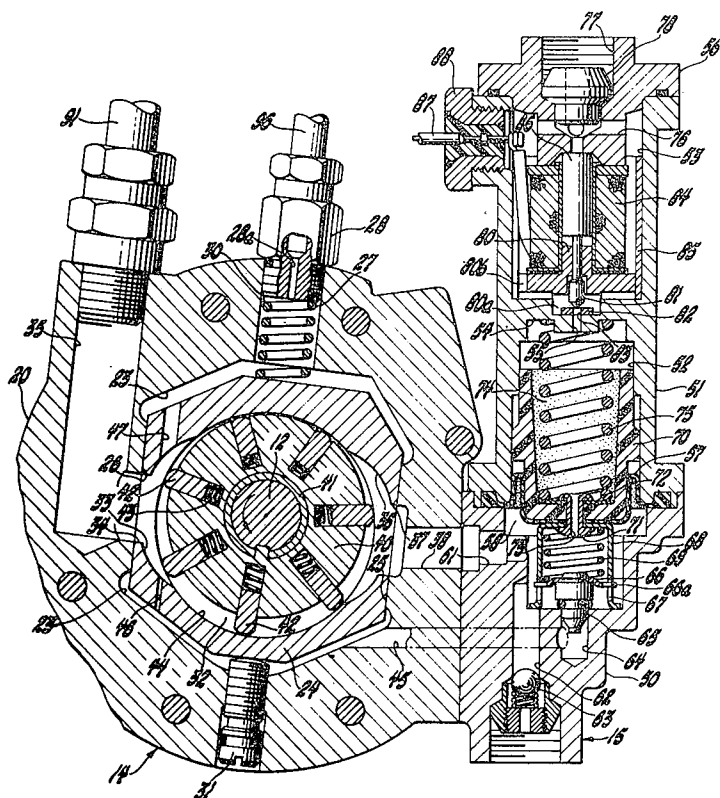
2,588,522	3/1952	Harris	417/222
3,067,693	12/1962	Lambeck	417/300
3,165,068	1/1965	Burnham et al.	91/492
3,252,419	5/1966	Tyler	417/222
3,724,972	4/1973	Guetersloh	417/220
3,732,041	5/1973	Beai et al.	417/222

Primary Examiner—William L. Freeh
Assistant Examiner—Gregory Paul LaPointe
Attorney, Agent, or Firm—Arthur N. Krein

[57]

ABSTRACT

An electrically controlled fuel pump assembly for use in the fuel system of an internal combustion engine which is adapted to deliver fuel at a regulated high pressure, the assembly including a variable displacement vane pump, located in a distributor housing, which also contains ignition components for the engine, the vane pump being driven by the engine and has its discharge outlet connected to a diaphragm type pressure regulator, control pressure on one side of the diaphragm being regulated by electric current which biases a solenoid operated pilot valve, whereby the pressure regulator can modulate fluid pressure used to vary the pump output volume and discharge pressure over the operating speed and work load range of the engine in accordance with an electrical control signal, indicative of engine operating conditions, supplied to the solenoid. This is accomplished by having the displacement of the vane pump hydraulically varied by means of fuel, the flow of which is modulated by the pressure regulator.

4 Claims, 3 Drawing Figures

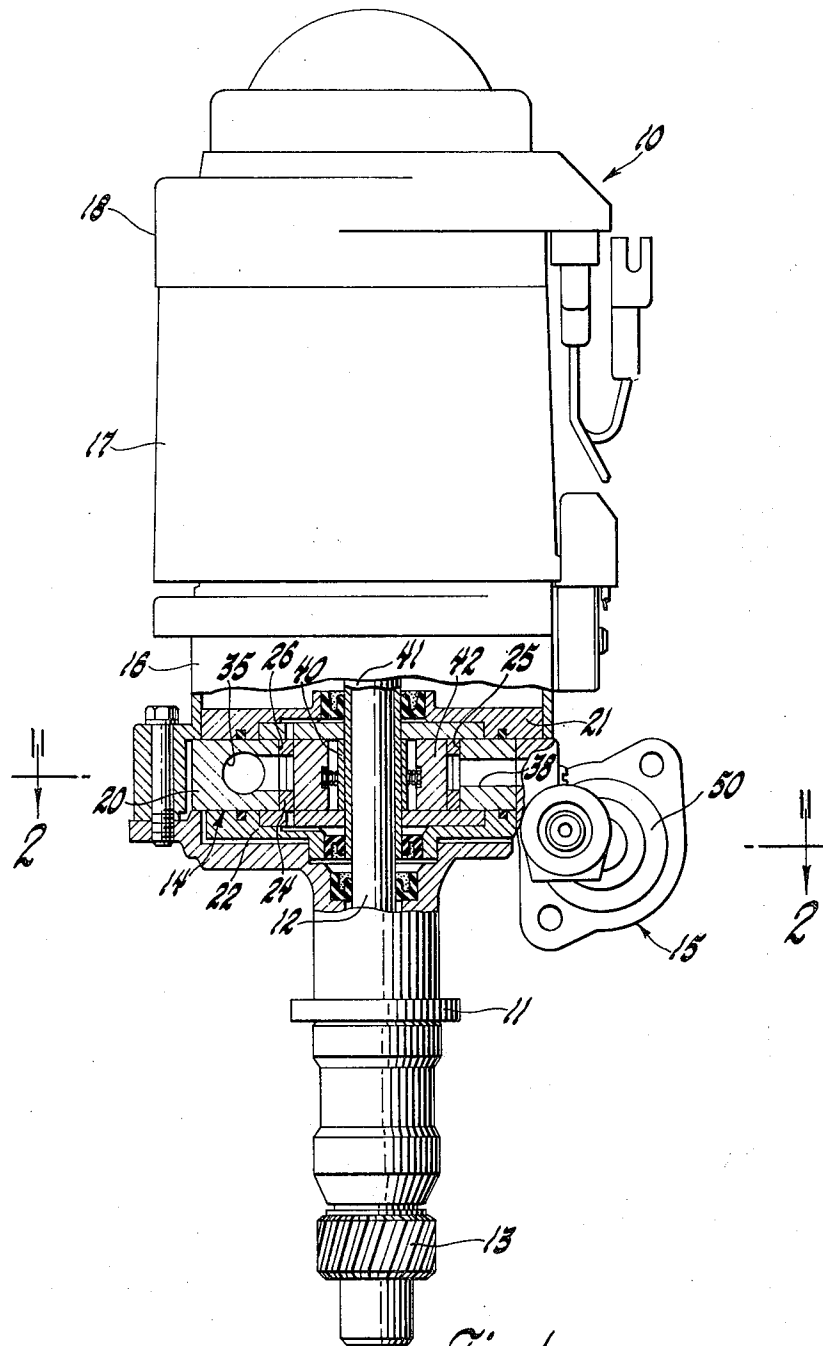
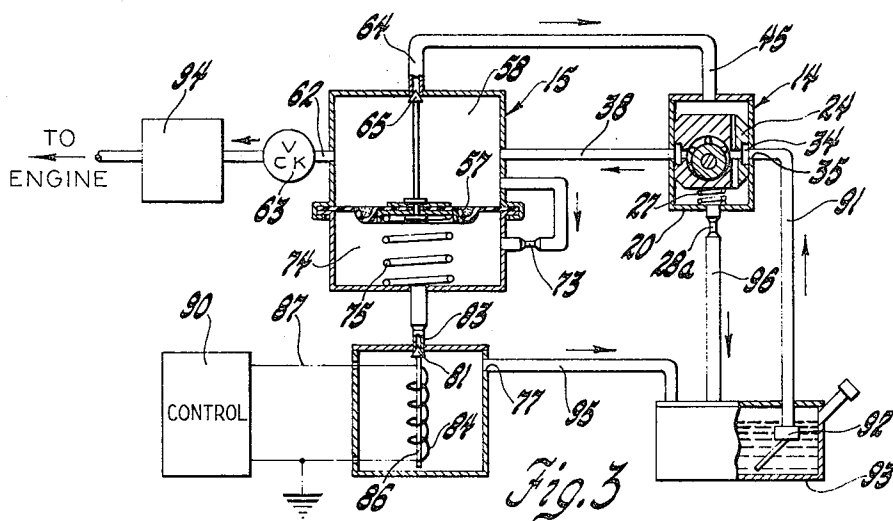
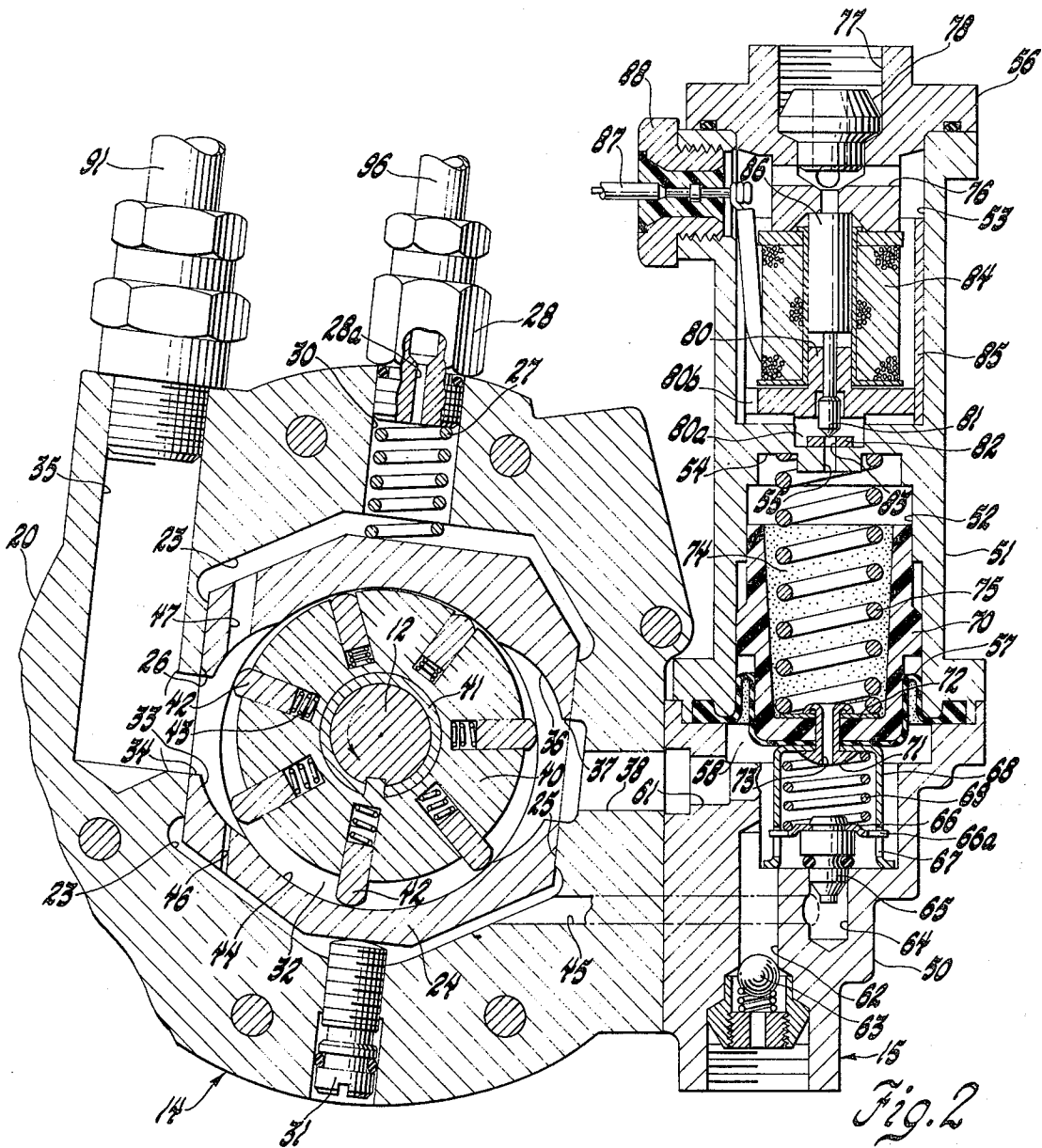


Fig. 1



ELECTRICALLY CONTROLLED FUEL PUMP

This invention relates to a fuel control system and, in particular, to an electrically controlled fuel pump for controlling the delivery rate of the fuel to an internal combustion engine as a function of the magnitude of an electric control current.

In order to properly meter the amount of fuel delivered to an internal combustion engine to effect optimum operation of the engine at various speed and load conditions, it is necessary to accurately control the delivery of fuel to the fuel metering system for the engine. In U.S. Pat. No. 3,724,972, entitled "Fuel Injection Pump," issued Apr. 3, 1973 to Donald G. Guetersloh, there is disclosed a fuel injection pump that is located in a distributor housing which also contains various ignition components for the internal combustion engine with which this pump is associated. As disclosed in this patent, the fuel injection pump is a variable displacement vane pump and has an accumulator and pressure regulator unit which maintains the fuel supplied to, for example, fuel injection nozzles at a constant pressure. Although this fuel injection pump is suitable for use in the application disclosed in the patent, the output volume and pressure from such a unit is not adequately controllable as a function of engine operating conditions, a necessary requirement for certain types of air metering-fuel metering systems.

Accordingly, it is a primary object of this invention to provide an electrically controlled fuel pump adapted to provide fuel discharge controlled by the magnitude of an electric current indicative of engine operating conditions.

Another object of this invention is to provide a variable displacement pump mechanism and a regulator therefor whereby a rather small current flowing through a solenoid biases a pilot valve which thus variably regulates a control pressure on one side of the regulator, this control pressure, relative to the discharge pressure from the pump mechanism, in turn controlling the delivery of fuel used to hydraulically vary the displacement of the pump to thereby regulate the flow and pressure of fuel discharged therefrom.

These and other objects of the invention are attained by means of a variable displacement fuel pump, the displacement of which is hydraulically varied by discharged fuel at a pressure modulated by a pressure regulator of the diaphragm type having fuel on one side thereof at pump outlet pressure and fuel on the other side thereof at a control pressure determined by fuel flowing through an inlet orifice from a fuel supply at outlet pressure and fuel flow through a discharge orifice, the flow from the discharge orifice being regulated by a control signal to a solenoid which in turn controls the position of a pilot valve in relation to the discharge orifice.

For a better understanding of the invention, as well as other objects and further features thereof, reference is had to the following detailed description of the invention to be read in conjunction with the accompanying drawings, wherein:

FIG. 1 is an elevational view, partly in section, of a distributor assembly incorporating the electrically controlled fuel pump of the invention;

FIG. 2 is a sectionial view taken along line 2-2 of FIG. 1 showing the variable displacement fuel pump and pressure regulator for controlling fuel delivery; and,

FIG. 3 is a schematic diagram of a fuel feed system for an internal combustion engine and showing schematically the functional components of the electrically controlled fuel pump, including the pump and pressure regulator associated therewith.

Referring now to FIG. 1, there is shown a distributor, generally designated 10, having a base 11 adapted for mounting on an internal combustion engine, not shown, and having a distributor drive shaft 12 suitably journaled therein with one end of the distributor drive shaft extending from the base 11 with a gear 13 fixed thereto to be driven by the engine at a speed directly related to the engine speed in a well-known manner. A variable displacement fuel pump assembly 14 is mounted on the base 11 and a pressure regulator unit 15 is secured to the pump assembly 14.

A housing 16, also mounted on base 11, supports an ignition distributor shell 17 which contains an ignition distributor rotor, a centrifugal advance mechanism, a vacuum advance mechanism and a magnetic pick-up assembly, not shown, all of which are of the type as shown and described in detail in U.S. Pat. No. 3,254,247, entitled "Breakerless Distributor," issued May 31, 1966 to John H. Falge. In addition, a distributor cap 18, mounted on the distributor shell 17, contains an ignition coil, not shown, which may be of the type as shown and described in detail in U.S. Pat. No. 3,638,630, entitled "Internal Combustion Engine Ignition Distributor Cap and Coil Assembly," issued Feb. 1, 1972 to Lewis R. Hetzler et al.

Since the construction and operation of the various ignition components in distributor 10 form no part of the subject invention, they are not shown and are not described. However, for a detailed description of these components, reference is had to the above-identified U.S. Pat. Nos. 3,254,247 and 3,638,630 in addition to the previously referenced U.S. Pat. No. 3,724,972, these patents being incorporated herein by reference.

It should be noted that housing 16 may be rotatably adjusted with respect to distributor base 11 without moving the fuel pump 14 or the pressure regulator 15.

Referring now to FIGS. 1 and 2, the fuel pump 14 includes an annular casing or stator housing 20 closed at opposite sides by top plate 21 and bottom plate 22, as seen in FIG. 1, to form a cavity or stator chamber 23 in which a control slide or slider 24 is slidably disposed, the opposed flat outer sides of the slider 24 slidably engaging the inner side walls 25 and 26 of the housing 20. A compression spring 27 is interposed between the top of the slider 24 and a connector 28 threaded in a return passage 30 extending through the housing 20 to normally bias the slider 24 in a direction, toward the bottom as seen in FIG. 2, to increase the pumping capacity of the fuel pump, downward movement of the slider 24 being limited by engagement of the opposite side of the slider against an adjustment screw 31 threaded into a suitable aperture provided for this purpose in the housing 20. Connector 28 is provided with a restricted passage or orifice 28a for a purpose to be described.

The slider 24 is provided with a centrally located cylindrical pumping chamber or cavity 32 which is in communication via an inlet chamber 33 and connecting passage 34 in the control slider to an inlet port 35 in the housing 20 and, via an outlet chamber 36 and connecting passage 37 in the slider 24 with the outlet port 38 in the housing 20.

A cylindrical rotor 40, pressed on a pump shaft sleeve 41 keyed to the distributor drive shaft 12, is ro-

tatably disposed in the pumping chamber. A plurality of vanes 42, disposed in slots of the rotor, are outwardly biased by springs 43 into engagement with the cylindrical wall 44 of the slider forming the pumping cavity 32. The output of the fuel pump per revolution of the rotor, as it is rotated in a counterclockwise direction with reference to FIG. 2, depends on the relative eccentricity of the rotor 40 with respect to the pumping cavity 32 in the slider 24.

The pressure regulator 15 is provided with a three-piece housing including a regulator body 50 with an annular opening at its upper end, with reference to FIG. 2, an intermediate case 51 having a stepped bore 52 at its lower end and a bore 53 at its opposite or upper end with an intervening wall 54 therebetween having a central aperture 55 therethrough and a cover 56 partly closing off the upper bore 53 in the intermediate case. These elements are suitably secured together as by screws, not shown, with a regulator diaphragm in the form of roll diaphragm 57 having its outer periphery sandwiched between the regulator body 50 and intermediate case 51 to form with the opening in the regulator body 50 an accumulator chamber 58. As shown in FIG. 2, the regulator body 50 of the pressure regulator 15 is suitably secured to the pump housing 20 with the inlet 61 therein, in communication with the chamber 58, aligned with the outlet port 38 in the housing 20. A fuel delivery outlet 62 in the regulator body 50 is in communication at one end with the chamber 58 and at its other end is provided with a spring biased ball check valve 63 to limit fuel flow in one direction.

The chamber 58 in regulator body 50 is adapted to be placed in communication via a control pressure outlet 64 and a passage 45 in the pump housing 20 to the stator chamber 23 at one side of the slider 24, the bottom side as seen in FIG. 2, whereby high pressure fluid discharged from the pump can be supplied to this side of the chamber 23 to bias the slider 24 in an upward direction, as seen in this figure, against the biasing action of spring 27 to effect a reduction in the output capacity of the fuel pump, this side of the stator chamber 23 being vented by a properly sized, restricted orifice passage 46 in the slider to the inlet chamber 33 of the slider. To permit rapid upward movement of the slider 24, the opposite side, upper side as seen in FIG. 2, of the stator chamber 23 is vented through passage 47 in the slider to the inlet chamber thereof. Flow of fluid through the control pressure outlet 64 is controlled by a valve member 65 slidably received in one end of the control pressure outlet 64 adjacent to the chamber 58, this valve being suitably fixed at its upper end to a retainer 66 having a pair of opposed radially extending ears or tangs 66a slidably received in suitable slots 67 formed in the walls of a bracket 68, shown in the form of an inverted cup, the valve member 65 being normally biased to its closed position by a spring 69 in abutment at one end against bracket 68 and at its other end against retainer 66.

A piston 70 is reciprocally journaled in the stepped bore 52 of intermediate case 51 and this piston and bracket 68 are secured together on opposite sides of the roll diaphragm 57 by means of a hollow rivet 71 extending through central apertures in the bracket 68, diaphragm 57, the bottom wall of the piston 70 and a washer 72 in abutment against the bottom wall of the piston. The tubular rivet provides an axially extending restricted orifice passage 73 therethrough to effect communication between the accumulator chamber 58

and a bias pressure chamber 74 defined by the piston 70 in the stepped bore 52. A spring 75, of predetermined force, positioned in the stepped bore 52 and piston 70 abuts at one end against the wall 54 of intermediate case 51 and at its other end against the washer 72 to normally bias the piston 70 and diaphragm 57 in a downward direction, with reference to FIG. 2, therefore moving barcket 68 also in a corresponding direction to allow seating of the valve member 65 by spring 69 to block fluid flow through the control pressure outlet 64.

Except for the restricted passage 73 through the tubular rivet 71, the pump and the portion of the regulator structure thus far described correspond generally to the structure of the fuel injection pump disclosed in the previously referenced U.S. Pat. No. 3,724,972.

Now, in accordance with the invention, a solenoid operated pilot valve assembly is used to control the flow of fuel from the bias pressure chamber 74 whereby to regulate the bias pressure therein, this bias pressure in turn setting, through the operation of the valve member 65, as affected by the differential bias pressure and pump discharge pressure acting on opposite sides of diaphragm 57, the fuel flow used to hydraulically vary the displacement of the fuel pump and therefore, its discharge volume and pressure, as a function of an electrical signal applied to the solenoid, this electrical control signal reflecting the engine operating conditions, including, preferably, a measurement of the desired air-fuel ratio of the combustion fluid to be supplied to the engine.

As shown in FIG. 2, the solenoid operated pilot valve assembly is mounted in the bore 53 in the upper half of the intermediate case 51 and is enclosed and retained by the cover 56. The space within the bore 53 contains fuel at fuel tank pressure, the space being vented to a fuel tank by radial passages 76 in the cap commuting with a stepped and threaded axial fuel return passage 77 having an axially apertured insert 78 positioned therein.

The solenoid operated pilot valve assembly includes a plunger guide 80 for a valve plunger 81 which cooperates with an annular valve seat disk 82 which is clamped by the lower split collet portion 80a of the plunger guide in abutment against the wall 54 of the intermediate casing 51. The valve seat disk 82 has a central circular sized orifice 83 which overlies the aperture 55 in wall 54 in communication with the bias pressure chamber 74, the orifice 83 being of a larger diameter than the orifice 73 which controls the flow rate into chamber 74 from chamber 58.

The solenoid coil assembly 84 of the solenoid is supported concentrically within the bore by means of a split annular coil housing 85 which also centrally aligns the plunger guide 80, the radial flange of the plunger guide engaging the inner peripheral surface of the coil housing 85. The radial flange portion of the plunger guide is provided with circumferentially spaced apart slots 80b at the outer periphery thereof to permit fuel flow through the openings thus provided adjacent to the inner periphery of coil housing 85. The armature 86 of the solenoid is slidably positioned within the armature core of coil assembly 84 and is magnetically attracted by energization of the coil assembly 84 to bias the plunger 81, by abutment therewith, into engagement with the valve seat 82. Although the armature 86 and plunger 81 are shown as separate elements, it is to be realized that they can be formed integral with each

other.

The orifice passage 83 in the valve seat 82 is of relatively small diameter so that the pressure exerted by fuel in the bias pressure chamber 74 on the plunger 81 is relatively small. The magnetic force on armature 86 tends to close the plunger 81 relative to orifice 83 and opposes the pressure of fuel tending to escape from the bias pressure chamber 74, fuel being supplied to this chamber through the orifice passage 73 from the discharge side of the fuel pump, whereby the static pressure of the fuel between the orifice 73 and orifice 83 is regulated as a function of current flow to the solenoid.

Whenever the pressure exerted on the plunger 81 by the fuel in chamber 74 exceeds the force exerted by the solenoid, this valve arrangement opens to bleed fluid out of the bias pressure chamber 74 at a value which is proportional to the closing force exerted by the solenoid. Fuel flow from accumulator chamber 58 into chamber 74 being regulated by the predetermined size of orifice passage 73. The magnetic structure of the solenoid is such that the displacement of the armature and therefore of plunger 81 is very slight and the force applied to the plunger 81 is substantially directly proportional to current flowing into the coil assembly 84. Thus, control of this current by a control device applying a control signal to the coil assembly determines the bias pressure in the bias pressure chamber 74.

As shown in FIG. 2, the coil assembly 84 of the solenoid is energized by a lead 87 which is connected to a terminal assembly 88 threaded into a corresponding threaded recess in the intermediate case 51. As shown in FIG. 3, the solenoid valve is supplied with an electrical control signal mechanism 90. This control signal mechanism may be of any suitable type. Ordinarily, it will include means for transmitting a current to the solenoid which is determinative of the pressure of fuel to be supplied to the engine to run the engine at a predetermined air-fuel ratio at the desired power level. The details of the control signal mechanism 90 are immaterial to the subject invention, may take any desired form and, therefore, need not be described in detail.

A clearer understanding of the operation of the subject electrically controlled fuel pump can best be obtained by reference to the internal combustion engine fuel feed system illustrated schematically in FIG. 3. As shown, a fuel line 91 delivers fuel to the pump 14 at a predetermined relatively low pressure from a supply pump 92 located in a fuel tank 93, the fuel line being connected to the pump inlet 35. Upon rotation of the pump shaft, fuel is delivered from the pump through the outlet port 38 and inlet passage 61 of the pressure regulator unit 15 to the chamber 58 thereof at a pressure corresponding to the outlet pressure of the pump for discharge at a regulated high pressure through the one-way flow ball check valve 63 in the fuel delivery outlet 62 via a fuel metering valve 94 to the engine, not shown. Valve 94 may be any suitable type metering valve, not described since it forms no part of the subject invention and, if desired, it may take the form of a suitable fuel injector discharging into a common induction manifold or it may be in the form of a plurality of unit fuel injectors.

As fuel flows into the chamber 58, fuel will flow from this chamber through the orifice passage into the chamber 74, the fuel in this chamber being at a biased control pressure, a pressure less than the discharge pump pressure in chamber 58. With no current control signal applied to the coil assembly 84 of the solenoid, the fuel

in the chamber 74 can flow through the orifice 83 for recirculation back to the fuel tank 93 through the fuel return passage 77 and bleed line 95, the pressure in this bleed line and therefore in bore 53 of casing 51 being substantially that of the pressure in fuel tank 93.

During pump operation, as the pressure of fuel in chamber 58 increases, it will effect upward movement of the diaphragm 57 to permit accumulation of fuel in the chamber 58. Fuel is accumulated in chamber 58 until the pressure differential on opposite sides of the diaphragm 57 is sufficiently unbalanced to permit movement of the bracket 68 sufficiently, in an upward direction with respect to FIG. 2, so that the tangs 66a of retainer 66 are engaged by the bottom ends of the bracket adjacent slots 67, to effect disengagement of the valve member 65 from the pressure control outlet 64, permitting fuel at a thus modulated regulating pressure to be discharged through the outlet 64 and passage 45 into the stator chamber 23 to move the slider 24 upward, with respect to FIG. 2, against the biasing action of spring 27 to effect a reduction in the output capacity of the pump 14 and, thus, reducing the pressure of fuel discharged therefrom. As seen in FIG. 2, rapid upward movement of the slider 24 can be effected since the spring 27 side of the stator cavity contains fuel at pump inlet pressure via the relatively large passage 47 in the slider 24 and, in addition, this portion of the stator cavity is connected by the orifice passage 28a in connector 28 for the bleeding of fuel via conduit 96 back to the fuel tank 93.

As current is applied to the coil assembly 84 of the solenoid, the fuel flow becomes more restricted through the orifice 83 of the solenoid control pilot valve to cause pressure to build up in the chamber 74 to modify the forces applied on opposite sides of the regulating diaphragm 57 so that diaphragm 57 can be moved downward, as seen in FIG. 2, by fluid pressure in chamber 74 and by spring 75 to permit spring 69 to effect closure of the valve member 65, thus closing off the regulating pressure flow of fuel to the stator chamber of the pump, fuel pressure in this portion of the stator chamber being dissipated by bleeding through the sized orifice 46 to the inlet side of the pump thereby allowing the spring 27 to move the slider 24 downward, with respect to FIG. 2, to increase the output capacity and therefore the output pressure of the fuel pump to a new regulated output pressure. This regulated output pressure will continue to increase as more control current is applied to the solenoid to permit the pump to deliver fuel at an output pressure and flow which is proportional to control current applied to the solenoid.

As previously disclosed in the above-referenced U.S. Pat. No. 3,724,972, the chamber 58 is in effect an accumulator chamber having an accumulating volume dependent on the upper movement of the diaphragm 57, without unseating of the valve member 65, which movement is determined by the lost motion distance provided by the slots 67 in bracket 68. Thus, if there is increased flow of fuel through the fuel metering valve 94 to the engine, the pressure of fuel discharged from chamber 58 will tend to decrease and in response to such a drop in pressure, the diaphragm 57 is moved downward, with reference to FIG. 2, by the spring 75 and the control pressure of fuel in the control pressure chamber 74 and, the accumulated fuel in chamber 58 is delivered through the outlet 62 to the fuel metering valve 94.

What is claimed is:

1. In a fuel pump mechanism having a variable displacement pump for delivering fuel, said pump including a spring biased slider with a pump cavity therein slidable in a stator chamber of the pump housing for varying the displacement of the pump, a pressure regulator for controlling delivery of fuel from said pump comprising a housing defining a cavity divided by a diaphragm to provide a first chamber for receiving fuel discharged from said pump and a second chamber in communication with said first chamber by a sized orifice, said housing further defining a fuel delivery outlet extending from said first chamber for discharge of fuel and a regulating pressure outlet extending from said first chamber in communication with said stator chamber on the opposite side of said slider from said spring, said diaphragm being movable away from said regulating pressure outlet in response to an increase in fuel pressure within said first chamber, spring means biasing said diaphragm toward said regulating pressure outlet, a bracket secured to said diaphragm within said first chamber, a valve member disposed in said first chamber and engageable with said regulating pressure outlet for controlling flow therethrough, means biasing said valve member away from said diaphragm toward engagement with said regulating pressure outlet, said valve member including means engageable with said bracket after said diaphragm and said bracket move a selected distance away from said regulating pressure outlet to thereby disengage said valve member from said regulating pressure outlet, a discharge orifice from said second chamber, and a solenoid operated pilot valve positioned to control the flow through said discharge orifice from said second chamber.

2. In a fuel pump mechanism according to claim 1 wherein said sized orifice is of a smaller size than said discharge orifice.

3. An electrically controlled fuel pump for use in the fuel system of an internal combustion engine compris-

ing, in combination, a variable displacement pump having an inlet and an outlet, said pump including a housing having a stator chamber, a slider with a pump cavity therein slidable in said stator chamber, engine driven pump rotor means operative in said pump cavity, spring means in said stator chamber on one side of said slider to normally bias said slider in a first direction relative to said pump rotor means, a regulator housing having a fuel inlet connected to said outlet, a fuel discharge outlet, a regulating pressure outlet operatively connected to said stator chamber on the opposite side of said slider from said spring means, and a fuel return passage, a diaphragm positioned in said regulator housing to provide with the interior thereof a first chamber in communication with said fuel inlet, said discharge outlet and said regulating pressure outlet and a second chamber in communication with said fuel return passage, conduit means including an orifice and a variably controllable pressure regulating pilot valve in communication with said second chamber connecting said first chamber to said fuel return passage, electric current responsive means controlling said pilot valve, spring biased valve means positioned in said first chamber to control flow through said regulating pressure outlet, a lost motion means connecting said spring biased valve means to one side of said diaphragm, a spring positioned in said second chamber in engagement with the other side of said diaphragm to bias said diaphragm toward said regulating pressure outlet.

4. An electrically controlled fuel pump according to claim 3 wherein said lost motion means is a bracket secured to said diaphragm and wherein said spring biased valve means includes a valve member engageable with said bracket upon a predetermined movement of said bracket to effect opening movement of said valve member relative to said regulating pressure outlet.

* * * * *

40

45

50

55

60

65