

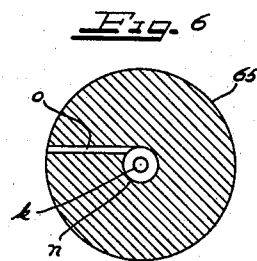
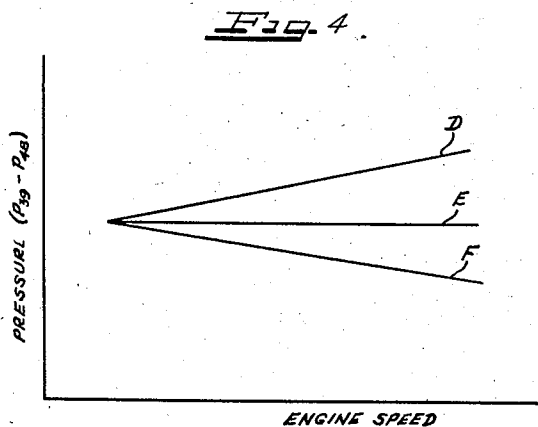
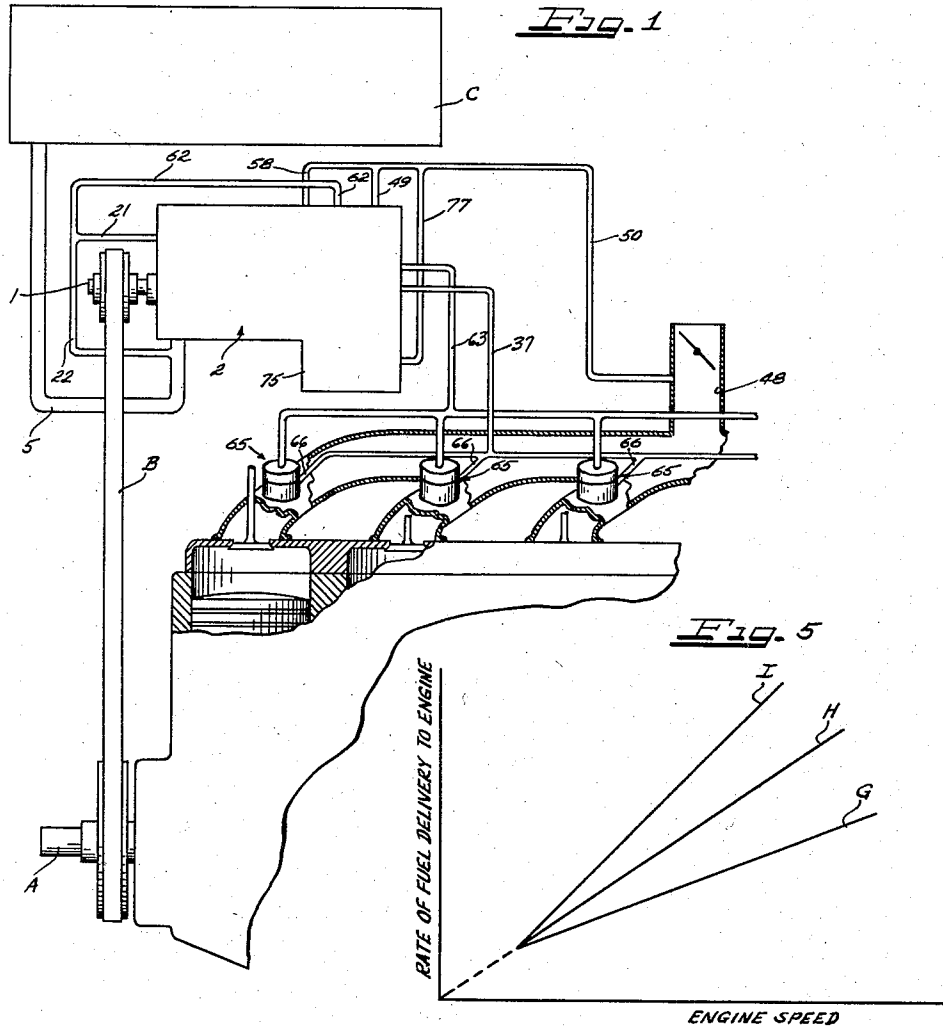
March 10, 1959

H. GOLD ET AL
FUEL INJECTION SYSTEM

2,876,756

Filed June 28, 1956

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 2

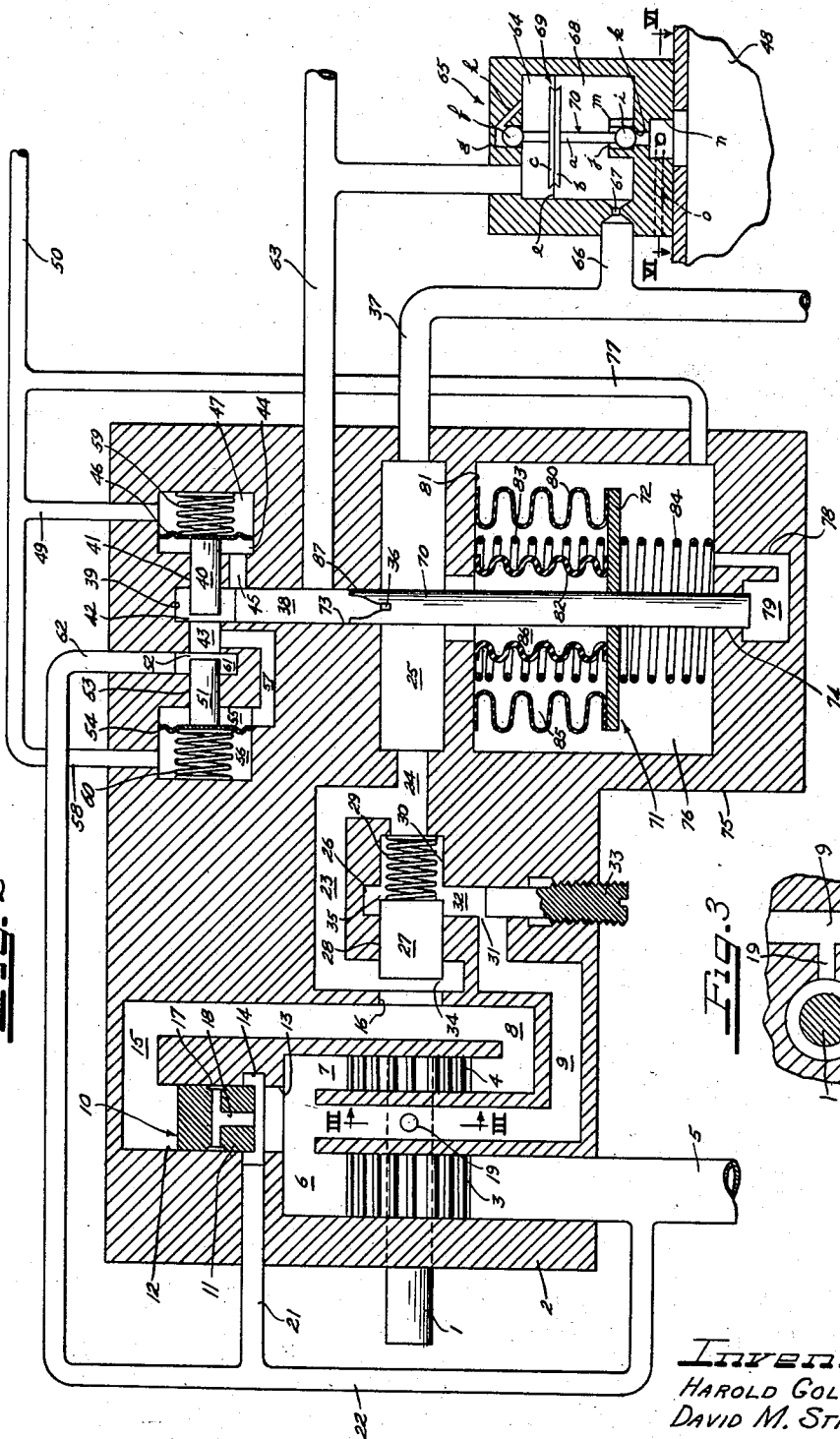
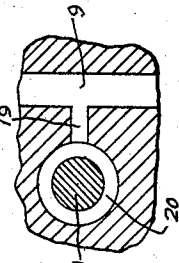


Fig. 3



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2,876,756

FUEL INJECTION SYSTEM

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Application June 28, 1956, Serial No. 594,532

23 Claims. (Cl. 123—119)

This invention relates to a device for automatically controlling the volumetric rate of flow of fluid to an engine, and to a fuel injection system for injecting fuel under pressure into the engine. The present application is directed to certain improvements over our copending application entitled "Fuel Injection System" Serial No. 450,428, filed August 17, 1954.

It is an important object of the present invention to provide an improved method and means for regulating the rate of flow of fuel to an engine.

It is a further object of the present invention to provide a flow control system achieving improved metering accuracy by eliminating the effects of pump slippage and leakage.

It is another object of the present invention to provide an improved fuel injection system having an idle control device providing idle enrichment flow which is entirely cut off at speeds above idle.

It is still another object of the present invention to provide a flow control system capable of a wide range of flow characteristics as a function of engine conditions for more precise matching of fuel flow to engine requirements.

Yet another object of the present invention is to provide an improved injector valve assembly for a fuel injection system whereby greater distribution accuracy at low variable flow rates is obtained.

Other and further important objects, features and advantages of the present invention will be more fully apparent from the following detailed description taken in conjunction with the accompanying drawings, in which:

Figure 1 is a diagrammatic illustration of a fuel injection system in accordance with the present invention;

Figure 2 is an enlarged diagrammatic cross-sectional view illustrating the charge forming mechanism of the present invention;

Figure 3 is a fragmentary cross-sectional view taken generally along the line III—III of Figure 2;

Figure 4 is a graphical representation of certain characteristics of the present invention;

Figure 5 is a graphical representation of certain other characteristics of the present invention; and

Figure 6 is a cross-sectional view taken generally along the line VI—VI of Figure 2.

As shown on the drawings:

In the illustrated embodiment, pump shaft 1 is coupled to an engine shaft A. While a pulley belt B has been shown for illustrative purposes, it will be understood that the drive is preferably of a positive nature so that there will be no slippage between the engine shaft A and the pump shaft 1. Thus, the pump shaft 1 will be rotated in exact fixed proportion to engine speed. Shaft 1 passes through a suitable seal and enters housing 2. Shaft 1 is coupled to positive displacement pumps 3 and 4. Pump 3 is of larger displacement than pump 4. Fuel enters at inlet line 5 from fuel tank C and is pumped by pump 3. Pump 3 discharges into passage 6.

Passage 6 communicates with the inlet side 7 of pump

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4. Pump 4 discharges into conduit 8. Because the volumetric output of pump 3 is larger than the rate of intake of pump 4 an excess flow exists which is by-passed through conduit 9 and control valve 10. Control valve 10 consists of piston 11 which operates freely in bore 12. Piston 11 forms a flow controlling element by virtue of its position relative to orifice 13 and annulus 14. The face of piston 11 close to orifice 13 is exposed to the pressure existing in passage 6 and hence the piston 11 will respond to variations of pressure at the inlet of pump 4. The opposite face of piston 11 communicates with the pressure existing at the discharge of pump 4 through conduit 15. Piston 11 thereby is caused to move whenever a difference of pressure exists across pump 4. Movement of piston 11 varies the flow through orifice 13 and thereby automatically maintains a zero gradient across pump 4. Because of the zero gradient the fluid transported through pump 4 is proportional to the pump speed and is independent of the pressure in conduit 8.

In spite of the zero gradient the volumetric flow rate into orifice 16 will vary with the pressure in conduit 8 if external leakage paths exist. Two possible leakage paths exist: across piston 11 from conduit 15 to annulus 14 and across shaft 1 from the housing of pump 4 to the inlet of pump 3. In this invention provisions are made to block both leakage paths. In the first instance the leakage path is blocked by virtue of annulus 17 in piston 11. Annulus 17 is substantially midway between the piston ends or is arranged so that equal length leakage paths from the annulus to the passages 14 and 15, are provided. The annulus 17 communicates with passage 6 through conduit 18. By virtue of this arrangement the pressure in annulus 17 is the same as the pressure at the inlet of pump 4 and leakage from the annulus to 14 or to 15 is along equal leakage paths. Since the pressure difference between annulus 17 and passage 15 is zero, fluid will not flow from conduit 15 into annulus 17. The fluid path that exists from annulus 17 to annulus 14 is obviously a path parallel to the valve path between piston 11 and orifice 13. Hence an increased leakage rate from annulus 17 to annulus 14 is automatically compensated for by adjustment of the valve passage between piston 11 and orifice 13.

Leakage across shaft 1 is prevented by passage 19 and annulus 20, Fig. 3. Passage 19 communicates with conduit 9 which is at the inlet pressure for pump 4. Since piston valve 10 holds the pump outlet pressure in conduit 8 the same as in conduit 9, the fluid pressure in annulus 20 is at substantially the pressure existing in pump 4. Therefore, fluid will not flow from pump 4 across shaft 1. Fluid leakage from annulus 20 to the inlet side of pump 3 is automatically compensated for by adjustment of valve 10.

By virtue of the arrangement described the volumetric flow rate into orifice 16 is proportional only to engine speed and is independent of the pressure in conduit 8. As the pressure level in passage 8 is raised at a given pump speed the slippage rate of pump 3 will increase. This increased slippage is compensated for by the automatic closing of valve 10. Obviously a pressure limit exists which occurs when valve 10 is completely closed. This pressure limit is kept beyond the operating limits of the fuel injector by proper design of the components of the pump. Valve 10 discharges into passage 21. Passage 21 opens into conduit 22. The flow from valve 10 is thereby returned to inlet 5.

The metered flow from pump 4 flows through orifice 16 into conduit 23. Conduit 23 joins conduit 24 and conduit 24 discharges into chamber 25. Conduit 24 also communicates with annulus 26. Annulus 26 communicates with conduit 9. Piston 27 operates freely in bore 28. Piston 27 is biased toward closed against orifice 16

by spring 29. Spring 29 is contained in chamber 30. Piston 27 forms a flow sensing variable orifice with orifice 16 and also with the opening to chamber 30. The flow in passage 9 is further controlled by orifice 31 which is formed between passage 32 and adjustable plug 33. Let us consider first the condition in which the adjustable plug 33 is completely withdrawn and the principal flow restriction that exists from passage 9 to chamber 30 exists in the orifice formed between piston 27 and the walls of chamber 30. Assume further that all the associated fluid passages are of sufficient size that no appreciable fluid friction pressure drop exists. It may then be seen that by virtue of the action of valve 10 that the pressure drop across the variable orifice 34 formed between orifice 16 and piston 27 and variable orifice 35 formed between piston 27 and chamber 30 are equal, and hence the ratio of the flow into chamber 25 contributed by orifice 34 to the flow into chamber 25 contributed by orifice 35 is equal to the ratio of the open area of orifice 34 to the open area of orifice 35. The flow through variable orifice 34 is the output of pump 4, hence is independent of the open area of orifice 34 and is linearly proportional to the speed of shaft 1. Therefore the flow through variable orifice 35 is determined by the speed of shaft 1 and the aforementioned area ratio. The total flow into passage 24 and chamber 25 is thereby controlled by the speed of shaft 1 and the aforementioned area ratio. At the lowest engine speed the ratio of the open area of adjustable orifice 35 to the open area of orifice 34 is at the maximum value and hence the ratio of the flow contributed by orifice 35 to the total flow into chamber 25 is at the maximum value. When the engine speed is increased, the increased flow through orifice 34 from pump 4 forces piston 27 backward against spring 29 to increase the open area of orifice 34 and decrease the open area of orifice 35. The ratio of the open area of orifice 35 to that of orifice 34 is thereby caused to reduce as the speed is raised. The ratio of the flow contributed by orifice 35 to the total flow into chamber 25 is thereby caused to reduce as the engine speed is increased. At a predetermined speed the open area of orifice 35 is reduced to zero. Above this speed the flow into chamber 25 is the output of pump 4 only, and hence is directly proportional to the speed of shaft 1. At any point of operation in which variable orifice 35 is open, manually adjustable orifice 31 can be adjusted to cause a significant pressure drop and hence reduce the flow in passage 32. This effect provides a means of manual adjustment whereby the best engine idle may be obtained.

As now described, the flow into chamber 25 is directly and positively proportional to engine speed and is in fixed proportion at speeds above a predetermined value. Below this engine speed the proportion may be varied in the rich direction for improved engine idle.

The flow into chamber 25 divides between variable orifice 36 and passage 37. The flow from variable orifice 36 enters passage 38 which in turn opens into annulus 39. Piston 40 operates freely in bore 41 and forms a variable orifice 42 with bore 43. Annulus 39 communicates with chamber 44 through passage 45. Movable wall 46 is fastened to piston 40 and forms a fluid tight wall between chamber 44 and chamber 47. Chamber 47 communicates with the engine intake manifold 48 through conduits 49 and 50. Bore 43 and piston 51 form variable orifice 52 which is directly downstream of variable orifice 42. Piston 51 operates freely in bore 53 and is fastened to movable wall 54. Movable wall 54 forms a fluid tight seal between chamber 55 and chamber 56. Chamber 55 communicates with bore 43 through conduit 57. Chamber 56 communicates with the engine intake manifold 48 through conduits 58 and 50. Spring 59 biases piston 40 toward closed relation with bore 43 and spring 60 biases piston 51 toward closed relation with bore 43. Orifice 52 discharges into

annulus 61. Annulus 61 communicates with conduit 22 through conduit 62. When flow is established through variable orifice 42 and variable orifice 52 pistons 40 and 51 are caused to adjust the associated variable orifices 42 and 52 to establish the fluid pressure such that a force equilibrium exists between the spring forces and the pressure forces that act in the direction of axial movement of pistons 40 and 51. In accordance with the arrangement described the fluid pressure in annulus 39 acts on the annular area contained between the periphery of movable wall 46 and the periphery of piston 40. The fluid pressure in bore 43 acts on the end area of piston 40. Engine intake manifold pressure acts on the full area of movable wall 46. By virtue of this arrangement piston 40 adjusts variable orifice 42 until the closing forces resulting from spring 59 and engine intake manifold pressure are balanced by the opening forces that result from the pressure in annulus 39 and bore 43. By virtue of the arrangement described the fluid pressure in bore 43 acts on the end area of piston 51 and also on the annular area formed between the periphery of movable wall 54 and the periphery of piston 51. The fluid pressure in annulus 61 acts on the side of piston 51 and hence acts perpendicular to the axis of movement of piston 51. Therefore the pressure in annulus 61 does not directly influence the axial movement of piston 51. As now described, piston 51 adjusts variable orifice 52 until the closing forces that result from spring 60 and engine intake manifold pressure are balanced by the opening force that results from the pressure in bore 43. Under a condition of constant intake manifold pressure but increasing engine speed, the flow by-passed through variable orifices 42 and 52 increases by the same magnitude. The increased flow rate causes pistons 40 and 51 to increase the areas of orifice 42 and 52. This increase in orifice area results from pistons 40 and 51 moving in the direction which compresses springs 59 and 60 respectively. Because of these spring compressions the axial forces that result from the fuel pressures increase to maintain the axial force balance. The pressure in bore 43 increases to balance the increased force from spring 60. The increased pressure in bore 43 also acts to balance the increased force from spring 59. If the increased pressure in bore 43 exactly balances the increased force from spring 59, the pressure in annulus 39 remains unchanged. By this action the pressure in annulus 39 can be made to remain constant over very wide ranges of flow rate into annulus 39. It is also possible to proportion the various piston and movable wall areas and the rates of the springs to obtain either increasing, decreasing or constant pressure-flow characteristics for annulus 39.

Under a condition of constant engine speed but increasing intake manifold pressure the flow into annulus 39 decreases as a result of the accompanying reduction of area of variable orifice 36. (The variation of variable orifice 36 with intake manifold pressure is described in subsequent paragraphs.) By virtue of the valve action previously described, the change in flow through annulus 39 may not, in itself, cause a change in pressure in annulus 39. However, variations in intake manifold pressure are communicated to chambers 56 and 47. An increase in intake manifold pressure contributes forces along the axes of both piston 51 and 40 in the direction of closure of orifices 52 and 42, thereby causing an increase in pressure in conduit 43 and annulus 39. As previously described, the pressure in conduit 43 effectively acts on the full area of movable wall 54. Intake manifold pressure also acts on the full area of movable wall 54. Therefore the pressure in conduit 43 must vary in equal increments with intake manifold pressure. Intake manifold pressure acts on the full area of movable wall 46. The pressure in conduit 43 acts on the end of piston 40. The pressure in annulus 39 acts on an area of

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movable wall 46 equal to the full area of movable wall 46 minus the end area of piston 40. Because the end area of piston 40 is acted upon by changes in pressure equal to changes in intake manifold pressure the force balance on piston 40 requires that the pressure in annulus 39 also vary in equal increments with intake manifold pressure.

Figure 4 shows the characteristic variations of pressure in annulus 39, this pressure being designated P_{39} , with changes in engine speed and intake manifold pressure, intake manifold pressure being designated P_{48} , that may be obtained with the system described above. As shown in Fig. 4 and as already described, the difference between the pressure in the annulus 39 and intake manifold pressure may be made to increase with engine speed as illustrated in curve D of Figure 4, remain constant with speed as illustrated by the curve E, or decrease with speed as illustrated by the curve F. If in a given design, characteristic D exists and it is desired to alter the characteristic to that of E or F, one or all of the following steps may be used: decrease the rate of spring 59; increase the ratio of the end area of piston 40 to the area of movable wall 46; increase the rate of spring 60; or decrease the area of movable wall 54 which is exposed to the pressure in chamber 55.

By means of the arrangement herein described, a constant value of pressure in annulus 39 at constant intake manifold pressure and varying engine speed as illustrated in characteristic E can be maintained with substantially greater accuracy than is obtainable with a single spring loaded valve as is described in our copending application Serial No. 450,428. It will be appreciated that upper and lower limits may be imposed on the open area of variable orifice 42 in order to further modify the pressure-speed characteristic of annulus 39 and hence modify the fuel delivery-speed characteristic of the overall device in a manner described in our copending application Serial No. 450,428.

The pressure in conduit 38 is substantially the same as the pressure in annulus 39. Conduit 63 communicates the pressure in conduit 38 to chamber 64 of the various discharge nozzle-regulator assemblies 65. Branch conduits 66 carry fuel from conduit 37 to the metering orifices 67 of the various assemblies 65. The conduits 37 and 66 are of sufficient size to deliver the fuel to the upstream sides of orifices 67 at substantially the fluid pressure existing in chamber 25. Fuel flows through orifices 67 into chamber 68 of each assembly 65. Each assembly 65 comprises a movable wall 69 which is coupled to a valve assembly 70. Movable wall 69 forms a fluid tight wall between chambers 64 and 68. Fuel from chamber 68 is discharged through valve assembly 70 into engine intake manifold 48. Movable wall 69 adjusts valve assembly 70 to maintain the fluid pressure in chamber 68 substantially equal to the fluid pressure in chamber 64. By virtue of this action the pressure drop across orifices 67 of the various assemblies 65 is made equal to the pressure drop that exists across variable orifice 36. The volumetric flow rate discharged into the engine intake manifold is therefore proportional to the flow rate through variable orifice 36. The flow rate through variable orifice 36 is proportional to the flow rate entering chamber 25 from conduit 24 and to the open area of orifice 36. The flow rate delivered to the engine is therefore proportional to engine speed and to the position of metering rod 70. Metering rod 70 is positioned by bellows 71 in accordance with pressure and temperature existing in the engine intake manifold. The overall device thereby functions to deliver fuel to the engine at a rate proportional to the product of engine speed and intake manifold air density.

Bellows assembly 71 is identical with that described in our application Serial No. 450,428, except that simplifications suitable for automotive use have been made. For automotive use the bellows element used to correct for engine back pressure may be eliminated. Also in 75

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the case of non-supercharged automotive use the temperature bulb may be eliminated but temperature corrections can still be obtained by placing the bellows in the air stream. Based on these simplifications the bellows assembly functions as follows: Metering rod 70 is fastened in fluid tight and rigid relation to bellows head 72 and is guided in bore 73 and guide bearing 74. Housing 75 encloses assembly 71 forming a chamber 76. Chamber 76 communicates with the engine intake manifold through conduit 77. Passage 78 causes the pressure in chamber 79 to be equal to the pressure in chamber 76 and on bellows 80 is fastened to end 81 of chamber 76 and on the opposite end to head 72. Inner bellows 82 is similarly fastened. All bellows connections are fluid tight. Auxiliary springs 83 and 84 are employed to obtain the desired combined spring rate of the assembly. Chamber 85 formed between bellows 80 and 82 is sealed with an inert gas at a predetermined pressure. This trapped gas expands and contracts with changes in temperature and thereby adjusts the assembly for changes in intake manifold temperature. In most automotive use the intake manifold temperature is equal to the outside air temperature, hence the temperature of the housing 75 and consequently the temperature of the air in chamber 76 will be substantially the same as the intake manifold temperature, for this reason the auxiliary temperature sensing bulb is not shown in this description.

Chamber 86 formed inside bellows 82 communicates directly with chamber 25. The forked end 87 of metering rod 70 flairs outward so that the area of orifice 36 increases as rod 70 is withdrawn from bore 73. It may therefore be seen that at a fixed engine speed an increase in intake manifold pressure causes an increase in fuel delivered to the engine; an increase in manifold temperature causes a decrease; and an increase in fuel pressure in chamber 25 causes a decrease.

As was described in Serial Number 450,428 the effect of the pressure in chamber 25 may be used to modify the delivery characteristics of the overall device to match non-linear engine requirements. In the present device the variation of the pressure in annulus 39 with engine speed may also be employed to modify the delivery characteristics. In addition to the modifications of delivery characteristics described in Serial No. 450,428, all of which may be achieved with the present device, a new and significant modification may be achieved with the present device. This modification is shown in Figure 5. Figure 5 shows three delivery characteristics under varying engine speed and constant manifold pressure (intake manifold temperature and exhaust pressure also being considered constant). Characteristic G is obtained when characteristic D of Fig. 4 is employed. When characteristic D of Figure 4 is employed, the pressure in chamber 39 increases as engine speed is increased thereby causing rod 70 to be withdrawn as the speed is increased (at constant manifold pressure). This effect causes the flow delivered to the engine to continuously drop below the linear proportionality with speed as speed is increased as shown in characteristic G of Fig. 5. When characteristic E of Figure 4 is employed, the pressure in chamber 25 remains constant over a substantial speed range and hence rod 70 remains in a fixed position as speed is varied over the speed range; consequently the flow delivered to the engine remains linearly proportional to engine speed. The characteristic is shown in Figure 5 and is designated characteristic H. When characteristic F of Figure 4 is employed, the pressure in chamber 25 reduces as speed is increased (over a substantial speed range). As a result of the reduction in pressure, rod 70 moves inwardly as the speed is increased thereby causing the flow delivered to the engine to continuously rise above the linear proportionality with engine speed as the speed is increased over a substantial speed range. This characteristic is indicated at I in Figure 5.

Valve assembly 70 in Figures 2 and 6 illustrates the

significant features of a very desirable construction. The assembly consists of a rod *a* extending through and fastened to circular plates *b* and *c*. Plates *b* and *c* clamp between them limp diaphragm *e*. Diaphragm *e* is fastened along a circular periphery to housing 65. Rod *a* is fastened to a sphere on each end. On the end in chamber 64 the sphere *f* is guided in bearing *g*. Passage *h* communicates the end of the sphere to chamber 64. The opposite end of rod *a* is fastened to sphere *i*, and sphere *i* is guided in bearing *j* and forms a variable orifice with orifice *k*. A slot *m* in guide *j* brings fuel to orifice *k*. Orifice *k* opens into cylindrical chamber *n*. Tangential passage *o* brings air at high velocity into chamber *n*. This causes the air to rotate in chamber *n*. The rotating air hastens the evaporation of the fuel discharged from orifice *k*.

It will be apparent that many modifications and variations may be effected without departing from the scope of the novel concepts of the present invention.

We claim as our invention:

1. A fuel supply system comprising a conduit for delivering fuel to an engine, fuel delivery means for creating a flow of fuel in said conduit, and means controlled by the output flow of said fuel delivery means for providing an idle enrichment fuel flow to said conduit which is restricted at engine speeds above idle.

2. A fuel supply system comprising a fuel supply conduit, fuel delivery means for creating a flow of fuel in said conduit, means for diverting fuel from said conduit downstream of said fuel delivery means, and series related pressure control valves controlling pressure downstream of said fuel diverting means, pressure responsive means controlling discharge of fuel from said conduit, and means for controlling said pressure responsive means in accordance with pressure downstream of said fuel diverting means.

3. A fuel supply system comprising a fuel supply conduit, first pump means developing an output pressure, second pump means having its intake connected with the output of said first pump means and its output connected to said fuel supply conduit, means driving said second pump means to provide a volumetric flow rate to said conduit proportional to engine speed, and means downstream of said second pump means for regulating delivery of fuel to said engine in accordance with the rate of air intake to said engine in each revolution of said engine.

4. A fuel supply system comprising a fuel supply conduit, first pump means developing an output pressure, second pump means having its intake connected with the output of said first pump means and its output connected to said fuel supply conduit, means driving said second pump means to provide a volumetric flow rate to said conduit proportional to engine speed, means downstream of said second pump means for regulating delivery of fuel to said engine in accordance with the rate of air intake to said engine in each revolution of said engine, and means for rendering the output pressure of said second pump means substantially equal to the input pressure of said second pump means over a given range of speeds of said engine.

5. A fuel supply system comprising a fuel supply conduit, positive displacement pump means creating a flow of fuel in said conduit proportional to engine speed, flow responsive means movable in response to flow at the output of said pump means, idle enrichment passage means, an orifice means in said idle enrichment passage means and controlled by said pressure responsive means to restrict said orifice means in response to a predetermined output pressure of said pump means.

6. A fuel supply system comprising a fuel supply conduit, positive displacement pump means for creating fuel flow in said conduit in accordance with engine speed, and means for equalizing the intake and output pressures of said pump means to prevent slippage.

7. A fuel supply system comprising fuel discharge

means, pressure responsive means controlling the pressure upstream of said discharge means, means for delivering fuel to said discharge means, first pressure responsive valve means for creating a pressure at the upstream side thereof, means for supplying fuel to said first valve means, means for controlling the upstream pressure of said discharge means in accordance with said first valve upstream pressure, and second valve means downstream of said first valve means for creating a pressure acting on said first valve means.

8. A fuel supply system comprising fuel discharge means, means controlling the pressure upstream of said discharge means, means for delivering fuel to said discharge means, first valve means for creating a pressure at the upstream side thereof, means for supplying fuel to said first valve means, means for controlling the upstream pressure of said discharge means in accordance with said first valve upstream pressure, second valve means for creating pressure acting on said first valve means, and means for controlling said valve means in accordance with engine air intake pressure.

9. A fuel supply system comprising a fuel supply conduit, means for creating a flow of fuel in said conduit proportional to engine speed, a fuel diverting passage communicating with said fuel supply conduit for diverting fuel from the engine, means for controlling diversion of fuel from said fuel supply conduit through said fuel diversion passage in accordance with the rate of air intake to the engine in each revolution thereof, pressure responsive discharge valve means controlling discharge of fuel from said fuel supply conduit and referenced to pressure downstream in said fuel diverting passage, first valve means controlling pressure in said fuel diversion passage, and second valve means controlling the discharge of fuel from said first valve means and controlling pressure downstream of said first valve means, said first valve means being responsive to pressure downstream thereof to tend to reduce the pressure in said fuel diversion passage, and means for controlling said discharge valve means in accordance with a predetermined schedule in respect to engine operative conditions.

10. A fuel supply system comprising a fuel supply conduit, fuel delivery means for creating a flow of fuel along said fuel supply conduit, a fuel enrichment passage communicating with said fuel supply conduit downstream of said fuel delivery means, means for producing a flow of fuel in said fuel enrichment passage, and valve means responsive to flow in said fuel supply conduit and operative to progressively restrict said flow in said fuel enrichment passage in response to the discharge pressure of said fuel delivery means to progressively cut off the supply of fuel from said fuel enrichment passage.

11. A fuel supply system comprising a fuel supply conduit, fuel delivery means for creating a flow of fuel along said fuel supply conduit, a fuel enrichment passage communicating with said fuel supply conduit downstream of said fuel delivery means, means for producing a flow of fuel in said fuel enrichment passage, valve means responsive to flow in said fuel supply conduit and operative to progressively restrict said flow in said fuel enrichment passage in response to the discharge pressure of said fuel delivery means to progressively cut off the supply of fuel from said fuel enrichment passage, and adjustable valve means in said fuel enrichment passage in series with said first mentioned valve means and operable to control flow in said fuel enrichment passage over a predetermined range of output pressures of said fuel delivery means.

12. A fuel supply system comprising a fuel supply passage, first positive displacement pump means driven in accordance with engine speed and creating a pressure in said fuel supply passage, second positive displacement pump means having its intake connected with the output of said first pump and having its output delivering fuel

to said fuel supply passage, a fuel enrichment passage communicating with said fuel supply conduit between said first pump means and said second pump means and delivering fuel to said fuel supply conduit downstream of said second pump means, reciprocating valve means having a control orifice in said fuel supply conduit downstream of said second pump means and responsive to flow downstream of said second pump means to move toward open position, said valve having means restricting flow in said fuel enrichment passage and operative to respond to increasing pressure downstream of said second pump means to progressively restrict flow in said fuel enrichment passage.

13. In a fuel supply system, a fuel supply conduit, first positive displacement pump means driven in accordance with engine speed for creating a flow of fuel in said fuel supply conduit, second positive displacement pump means having its input connected with the output of said first pump means for creating a flow of fuel in said fuel conduit in accordance with engine speed, a fixed orifice downstream of said second pump means in said fuel supply conduit, and means for controlling the pressure differential across said fixed orifice in accordance with the air intake rate to the engine in each revolution thereof, and means for equalizing the pressure upstream and downstream of said second pump means to prevent leakage.

14. In a fuel supply system, a fuel supply conduit, first positive displacement pump means driven in accordance with engine speed for creating a flow of fuel in said fuel supply conduit, second positive displacement pump means having its input connected with the output of said first pump means for creating a flow of fuel in said fuel conduit in accordance with engine speed, a fixed orifice downstream of said second pump means in said fuel supply conduit, and means for controlling the pressure differential across said fixed orifice in accordance with the air intake rate to the engine in each revolution thereof, and means for equalizing the pressure upstream and downstream of said second pump means to prevent leakage, said pressure equalizing means comprising a valve means controlling pressure upstream of said second pump means and responsive to an increase in pressure downstream of said second pump means to increase the pressure upstream of said second pump means, and means for preventing leakage across said valve means.

15. A fuel supply system comprising a fuel supply conduit, fuel delivery means for delivering fuel to said conduit, a fuel diversion passage communicating with said fuel supply conduit for diverting fuel from said engine, fixed orifice means downstream of said fuel diversion passage in said fuel supply conduit, valve means controlling diversion of fuel from said fuel supply conduit to said fuel diversion passage to control the pressure upstream of said fixed orifice means, first valve means controlling pressure in said fuel diversion passage, means controlling pressure downstream in said fixed orifice means and responsive to pressure upstream of said first valve means, and second valve means controlling pressure downstream of said first valve means, said first valve means being responsive to pressure upstream of said second valve means, means biasing said first and second valve means in accordance with air intake pressure, and means referencing said first valve means to pressure upstream of said first valve means to tend to open said first valve means in response to increase in pressure upstream thereof, and means referencing said second valve means to pressure upstream of said second valve means to tend to open said second valve means in response to increasing pressure upstream of said second valve means, said air intake pressure acting to tend to restrict said first and second valve means.

16. In a fuel supply system, a fuel supply conduit, fixed orifice means in said conduit, discharge valve means in said conduit downstream of said fixed orifice means,

means for controlling the pressure differential across said fixed orifice means in conjunction with said discharge valve means in accordance with the rate of air intake to the engine, and means defining a tangential air intake duct leading into said fuel supply conduit immediately downstream of said discharge valve means to bring air into the fuel supply conduit at high velocity for rotation therein to hasten evaporation of the fuel discharged from said discharge valve means.

17. In combination in a fuel supply system, a fuel supply conduit, positive displacement pump means driven in proportion to engine speed for delivering fuel along said conduit, fixed orifice means downstream of said pump means in said conduit, fuel diversion passage means communicating with said fuel supply conduit intermediate said pump means and said fixed orifice means for diverting fuel from the fuel supply conduit, valve means controlling the diversion of fuel from said fuel conduit to said fuel diversion passage means, means defining a temperature sensing chamber having a gas sealed therein and in substantial heat transfer relation to outside air to thereby substantially reflect intake manifold temperature, and means controlled by the pressure of said gas to vary the position of said diversion valve means.

18. An engine fuel supply system comprising a conduit, speed responsive means in said conduit for establishing a flow of fuel proportional to engine speed, a bypass around said speed responsive means, valve means controlling said bypass to increase flow in said conduit in the idle speed range of the engine, a fuel return conduit downstream from said speed responsive means, pilot valve means controlling flow in said return conduit and responsive to parameters reflecting engine fuel flow per revolution of the engine, pressure regulating means in said return conduit including a spring biased valve and a flow restriction downstream from said valve, said spring biased valve being responsive to the pressure in said return conduit and to the pressure upstream of said flow restriction whereby pressure upstream of said spring biased valve is regulated by coaction of the flow restriction and the spring biased valve, metering orifice means in said conduit downstream of said pilot valve means and fuel discharge means biased by pressure in said return conduit upstream of said pressure regulating means for controlling pressure downstream of said metering orifice means to deliver fuel to said engine.

19. In a metering system including a conduit, a pump in said conduit, a drive shaft for the pump, a journal for said shaft exposed to pressure downstream from the pump, pressure control means in said conduit maintaining a zero pressure gradient across said pump, means defining an annular chamber between the shaft and journal, and means venting said chamber to the upstream side of the pump to prevent flow of fluid through the journal from the pump.

20. A metering system comprising a conduit for fluid, a pump in said conduit, a bore in said conduit joining the upstream and downstream sides of the pump, a piston slidable in said bore having its opposite ends exposed respectively to the upstream and downstream sides of the pump, orifice means on the upstream side of the pump controlled by said piston to maintain a zero pressure gradient across the pump, said piston having a groove therearound surrounded by said bore and providing an annulus between said opposite ends of the piston, and a passage joining the upstream end of the piston with said annulus whereby flow between the downstream side of the pump and said annulus is prevented.

21. In a flow control system, a conduit, positive displacement pump means in said conduit for establishing flow proportional to speed, valve means in said conduit for regulating the pressure upstream of said pump in proportion to the pressure downstream of said pump, flow restriction means in said conduit downstream of the pump, a branch conduit diverting flow from said conduit

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upstream from said pump, second flow restriction means in said branch conduit, and means for equalizing the pressure downstream of the first mentioned flow restriction means and the second flow restriction means whereby the flow of fluid in said branch conduit is proportional to the speed of the pump, and means for varying said flow restriction.

22. In a fluid flow conduit, a valve for regulating the pressure upstream thereof, a spring urging said valve to closed position, a first valve area and a second valve area associated with said valve and operative to position the valve in accordance with pressure to which said areas are exposed, said first valve area being exposed to upstream pressure in said conduit, said second valve area being exposed to downstream pressure in said conduit, and a variable flow restriction in said conduit downstream from said valve having a pressure characteristic to cause the pressure upstream of the valve to vary as desired over a range of flows in said conduit.

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23. A system for regulating fluid pressure comprising a spring biased pressure responsive valve and a flow restriction in series relation with said valve, said valve being responsive to said spring bias, the regulated pressure of said system and the pressure variation across said flow restriction whereby changes in spring bias associated with flow changes are modified by the simultaneous pressure variation across said flow restriction.

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