

July 5, 1960

W. F. BOYER ET AL
FUEL INJECTION SYSTEM

2,943,616

Filed Dec. 9, 1957

5 Sheets-Sheet 1

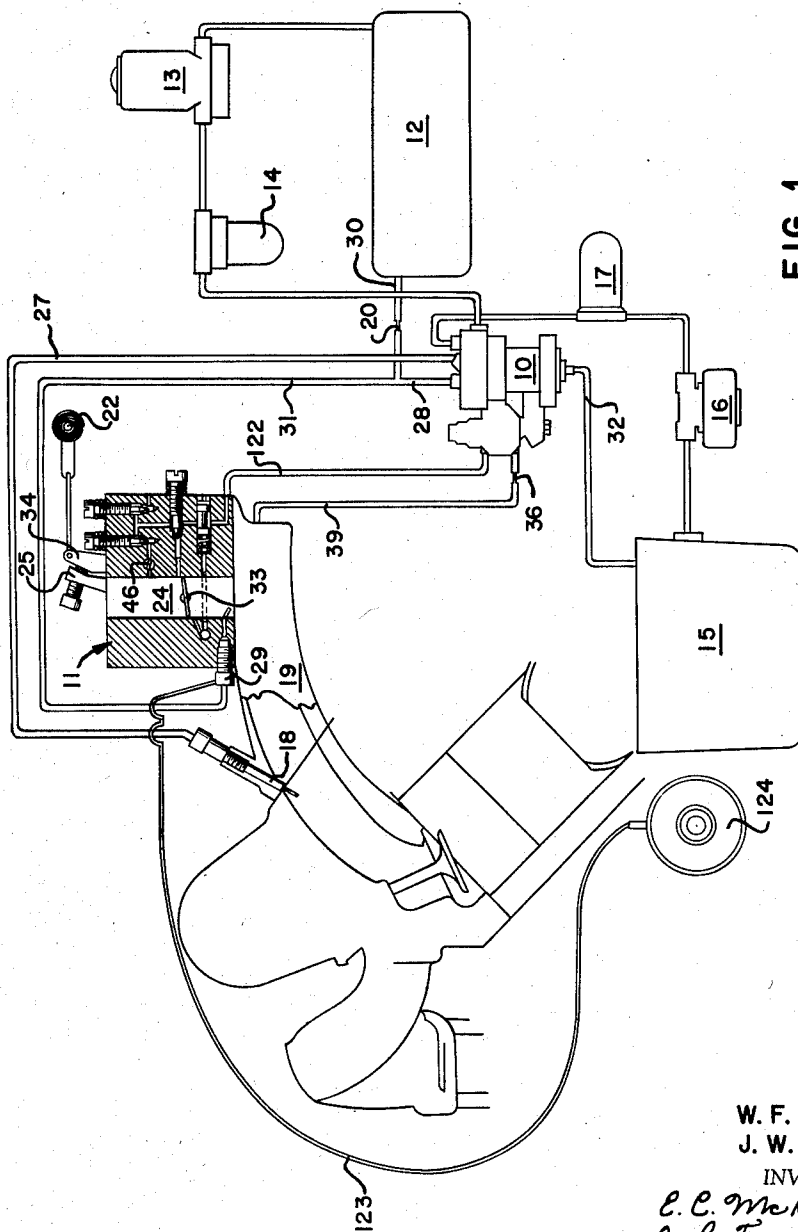


FIG. 1

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5 Sheets-Sheet 3

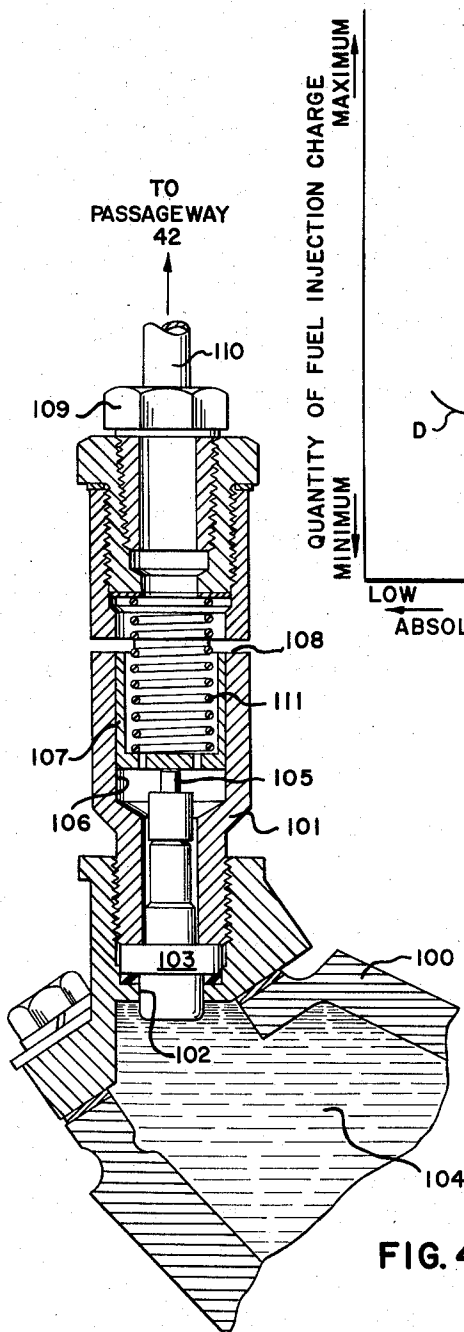


FIG. 4

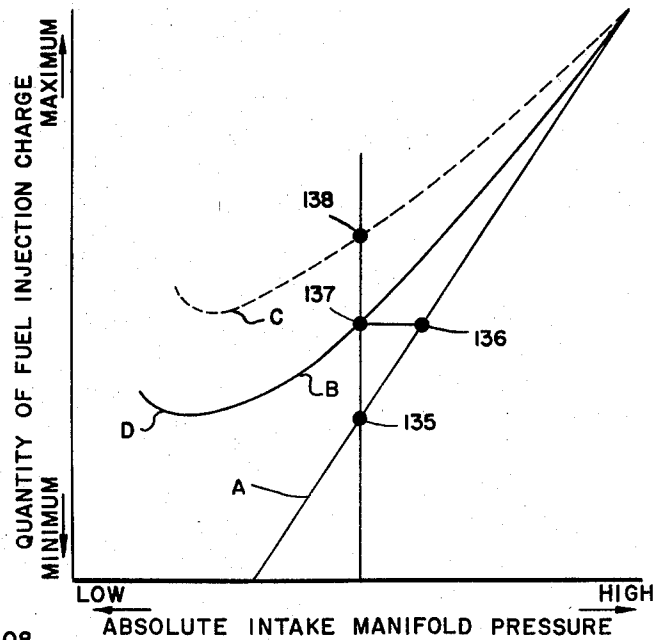


FIG. 3

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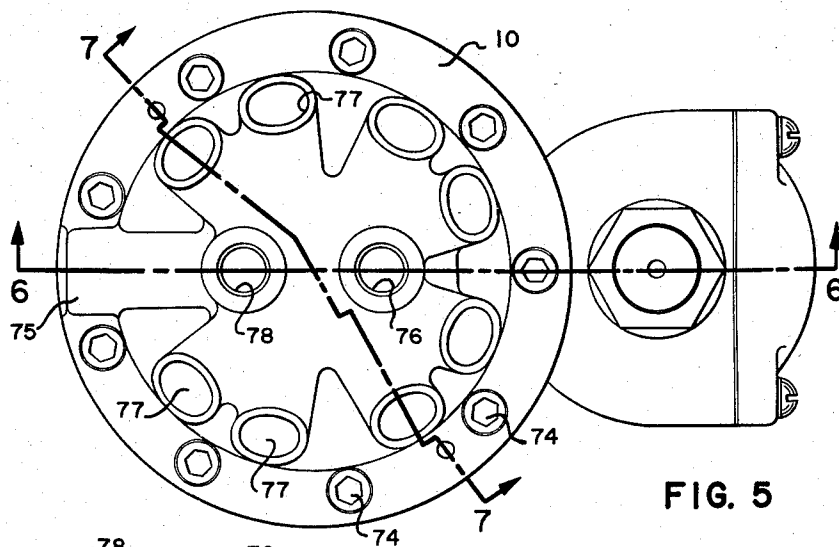


FIG. 5

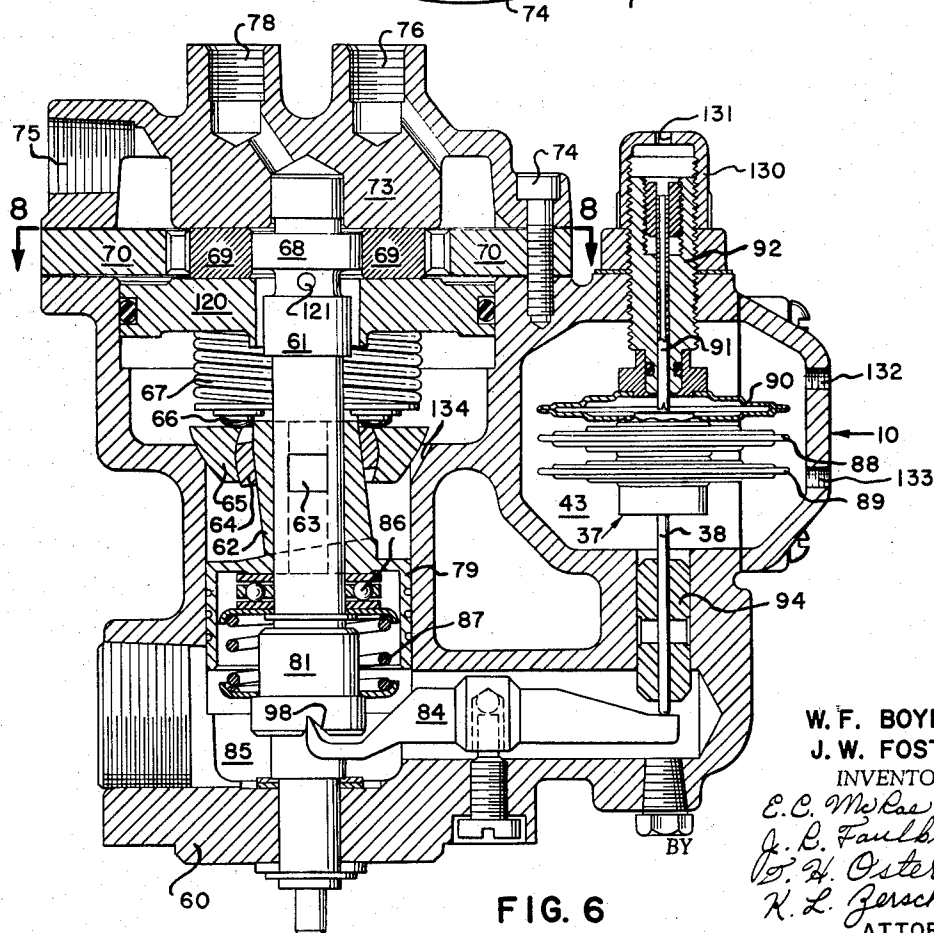


FIG. 6

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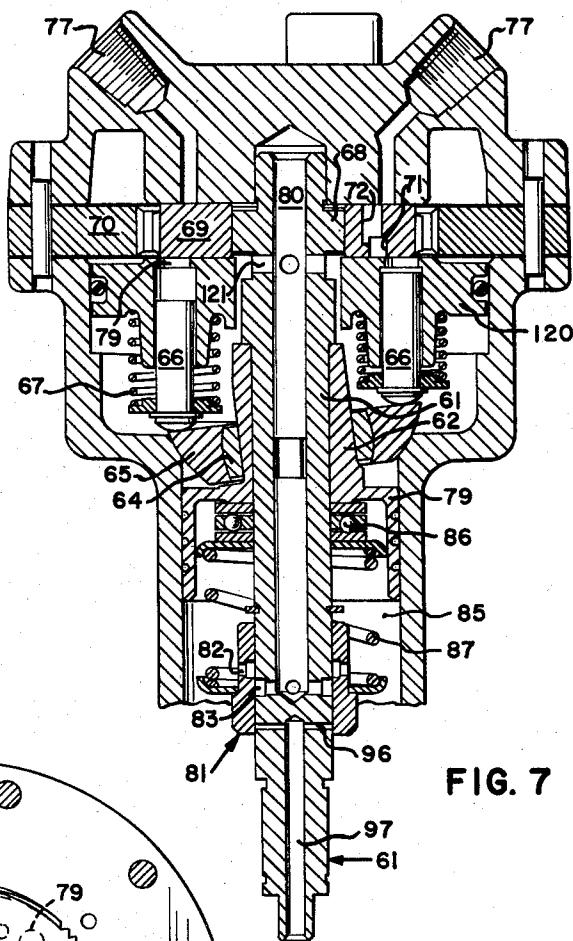


FIG. 7

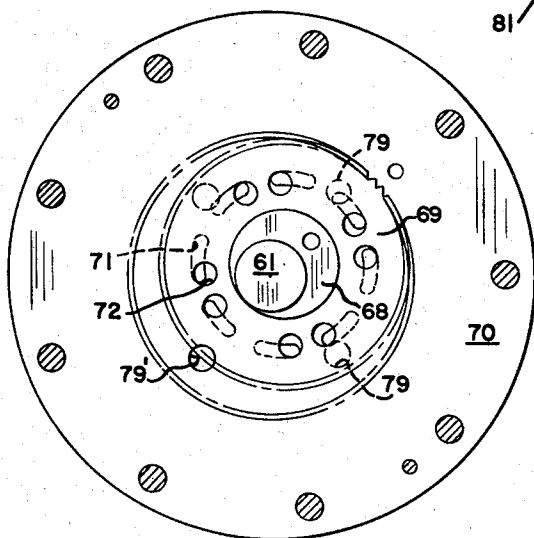


FIG. 8

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2,943,616

FUEL INJECTION SYSTEM

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Filed Dec. 9, 1957, Ser. No. 701,542

7 Claims. (Cl. 123—140)

This invention pertains to a fuel injection system and more particularly to a means and method of controlling fuel injection mechanisms in accordance with engine operating conditions. This application is a continuation-in-part of our copending application, Serial No. 615,370, filed October 11, 1956, now abandoned.

In gasoline burning engines it is common practice to control fuel injection pumps directly by engine manifold vacuum to provide an injected quantity of fuel responsive to engine load. In such injection systems the metering mechanism is operated by a pressure responsive device to provide a fuel-to-air mixture in accordance with the engine's fuel requirements for a fixed engine temperature, air pressure and air temperature. However, devices of this kind are incapable of modifying the mixture in accordance with altitude, air or engine temperature in such a manner as to give reliable and predictable operation over a variety of operating conditions.

We provide a pressure-controlled injector having a metering curve with a linear slope too steep for direct engine operation, i.e., it would provide too lean a mixture if operated directly from manifold pressure and then we selectively bleed air into the pressure system by predetermined amounts to satisfy such requirements as cold starting and cold running. An advantage of this arrangement is that all injected fuel may be cut off when desired by applying a high manifold vacuum to the injector's pressure control.

It is, therefore, an object of this invention to provide a load responsive control signal to a pressure-controlled fuel injector pump.

A further object is to provide a pressure signal which is variable as a function of engine temperature.

A further object is to provide an adjustment which modifies a pressure signal to increase the injected fuel quantity for idle conditions.

A further aim of this invention is to provide means for cutting off all injected fuel during deceleration.

Another object is to provide supplemental priming fuel during engine cranking.

These and other objects will become apparent from the following description in which:

Figure 1 is a schematic diagram of a fuel injection system embodying our invention;

Figure 2 is a section of a throttle body used in this system;

Figure 3 is a graph showing the metering curves computed by this invention;

Figure 4 is a modified form of a temperature controlled air bleed arrangement;

Figure 5 is an outline top view of a fuel injector pump controlled by our invention;

Figure 6 is a sectional view of the pump taken on line 6—6 of Figure 5;

Figure 7 is a partial sectional view of the pump taken on line 7—7 of Figure 5; and

Figure 8 is a plan view of the pump's distributor valve taken along line 8—8 of Figure 6.

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In the accompanying description the term "pressure" as used with reference to control pressure originating in the intake manifold is taken as absolute pressure.

Referring to Figure 1 there is seen a schematic diagram of a fuel injection system. An outline of an injector pump is shown at 10 and it feeds intake manifold 19 through injector nozzle 18 from line 27. There are as many injector lines leading from pump 10 to fuel injection nozzles as there are engine cylinders.

Fuel to the injector pump 10 is stored in tank 12 and is supplied under pressure by electrical fuel pump 13 through filter 14. A fuel return line 28 has two branches. One branch 30 returns to the fuel tank 12 through restriction 20 and the other branch 31 supplies priming fuel to throttle body 11 through electrically operated solenoid valve 29.

As will be subsequently explained, pump 10 is oil-servo operated and oil under pressure for this purpose is supplied from sump 15 by oil pump 16 through filter 17. Oil is returned to the sump through return line 32.

A throttle body 11 mounts on intake manifold 19 in the manner of a carburetor. A butterfly valve 33 controls the quantity of air admitted to the manifold and thereby the absolute manifold pressure. The butterfly valve 33 is accelerator operated in the usual manner.

Rod 25 turns with butterfly valve 33 and coacts with a step-up cam arm 34 to provide increased air during cold engine operation in the well-known manner. Arm 34 is operated from a bimetal thermostat 22 and, in turn, operates an air bleed valve 46.

A pressure signal is provided by throttle body 11 for pump 10 through lead 122. Also, pump 10 is connected to the manifold by line 39 through pressure restriction 36.

Figure 2 is an enlarged section through throttle body 11 with the parts arranged in a different order but identical in function to the arrangement shown in Figure 1. Air is drawn into the manifold through passageway 24 past accelerator pedal-operated butterfly valve 33. To the left of passageway 24 is seen the air bleed arrangement which bleeds air according to operating requirements into the pressure sensitive unit on the pump 10. The pressure sensitive unit is chamber 43 containing sealed capsules 37 and is located within injector pump 10 but is shown on Figure 2 for reference. Push pin 38 is attached to one side of capsules 37 and moves in accordance with the expansion or contraction of the capsules to control the injected fuel quantity as will be more fully explained in connection with the injection pump.

Opening 40 admits filtered air past metering screw 41 into passageway 42. Opening 40 and screw 41 provide a constant orifice air bleed into passageway 42. Similarly, filtered air through opening 44 passes metering screw 45 through a temperature-operated valve 46 into passageway 42. Valve 46 is operated by an exhaust gas heated bimetal thermostat 22 and is open during cold engine operation. Idle bleed orifice 48 admits air past metering screw 49 into passageway 42 when orifice 48 is uncovered by valve 33 in the idle position as shown. In other positions of valve 33 this bleed path is substantially inoperative or may bleed some air from passageway 42 into the manifold due to the decrease in pressure at orifice 48.

Passageway 42 communicates with chamber 43 through normally opened spool valve 50. A slit 51 is cut in cylinder 52 and communicates with passageway 42. Spool valve 50 is reciprocally carried within cylinder 52 and is urged by spring 56 into the open position as shown. Manifold pressure is admitted behind spool 50 through passageway 54 and orifice 55 just below the throttle plate 33. The movement of valve 50 is limited by stop pin 53. The spring bias on valve 50 is adjusted by slug 59. The other

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side of valve 50 is vented to atmospheric pressure through passageway 57.

On the opposite side of body 11 is seen a priming nozzle 26 supplied by fuel through a normally closed electrical solenoid valve 29 from priming line 31. Positive fuel pressure is maintained in line 31 by fuel pump 13 which supplies fuel to injector pump 10 and hence to fuel tank 12 through return line 30 and pressure restriction 20. The actuating lead 123 (Figure 1) of solenoid valve 29 is connected to the starter 124 of the engine and is, therefore, actuated coterminously with the operation of the starter. In this manner priming fuel is added directly to the intake manifold through passageway 24 to supplement the fuel which may be supplied through the injection nozzle 18 during engine cranking. Since we employ an air pressure controlled metering system which utilizes intake manifold pressures as its source of pressure, we cannot accurately predict or control the quantity of fuel which may be injected during cranking due to the fluctuation of manifold pressure. Also, we have discovered that an engine whether warm or cold requires additional priming fuel during cranking over and above that which can be supplied by the injectors even when they are caused to deliver an amount equivalent to wide open throttle operation. Therefore, we have found this relatively simple priming system adequate to supplement the injectors during cranking to provide dependable engine starts. A metering screw 58 is interposed in a flow stoppable position before priming nozzle 26 to provide adjustment for the rate of priming.

For assistance in understanding the operation of this invention, reference may be had to Figure 3 on which is seen a graph wherein quantity of injected fuel is plotted on the ordinate and absolute intake manifold pressure on the abscissa. Curve A represents the metering curve which would be followed by the fuel injection pump 10 if chamber 43 of the pump were connected directly to the intake manifold. The slope of this curve is purposely made so that the fuel quantity required by the engine is satisfied at the full load conditions of high manifold pressure but becomes increasingly lean with decreasing manifold pressure. Curve B represents the actual injected fuel quantity which is obtained by bleeding down the manifold vacuum within chamber 43. This fixed bleed down is accomplished through opening 40 on Figure 2. Curve B is provided with a knee portion D which provides increased fuel at engine idle. The slope of portion D is controlled by idle adjustment screw 49. This increased fuel compensates for the exhaust gas dilution in the cylinders at low r.p.m. due to valve overlap. Metering curve C is caused by bleeding even more air into capsule 43 during cold engine operation by the operation of temperature-controlled valve 46. It is, therefore, seen from Figure 3 that the greater the quantity of air bled into capsule 43, the greater will be the injected fuel quantity.

In this manner the requirements of the engine can be approximated by regulating the quantity of air bled into chamber 43 from cold to warm engine operation. As shown in Figure 2, the pressure difference between chamber 43 and the manifold tube 39 is developed across restriction 36. As an example, a $\frac{1}{8}$ inch opening in restriction 36 has provided a satisfactory pressure differential for a given installation.

Spool valve 50 forms an overrun cutoff, the function of which is to prevent the air bled in passageway 42 from entering chamber 43. This valve is moved by the exceedingly low pressures which occur during deceleration as picked up by orifice 55 and tube 54 which cause valve 50 to move against spring 56 to close slit 51. Chamber 43 is then acted upon only by manifold pressure, and, as shown in Figure 3, the injector pump will be cut off at such low pressures. Slug 59 may be adjusted against spring 56 so that upon further deceleration of the engine and the subsequent rise in manifold pressure, the spool

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valve 50 will be returned by spring 56 in time to re-establish the air bleed to chamber 43 and fuel to the injectors thereby preventing engine stalling.

One advantage in having two pressure communicating lines between the control body and the pump capsule chamber, with pressure restriction 36, is to assure a flow of intake air through the capsule chamber 43 so that the sealed capsules 37 are subjected to a continuous flow of air at ambient temperature and in this manner compensate for air temperature by the expansion or contraction of the bellows thereby affecting the injected fuel quantity in a manner which will be subsequently explained.

An alternative air bleed arrangement responsive to engine temperature is shown in Figure 4. This arrangement may be used to bleed air into passageway 42 in lieu of valve 46 and screw 45. The use of exhaust gases as an indication of engine temperature to operate a bimetal thermostat may suffer a deficiency due to the fact that these gases cool at a rate which exceeds the rate of change of the engine's fuel requirements, and, as a result, the throttle body may provide additional fuel through the injectors at a time when the engine is still too warm to require it. Therefore, a modified engine temperature air bleed is shown which uses a temperature-operated capsule partly submerged in the engine's coolant.

Cylinder block 100 receives threaded body 101 and further provides opening 102 through which temperature capsule 103 projects into the coolant 104. Capsule 103 may be of the positive displacement type where a push pin 105 is actuated by the change in physical state of matter as fully described in U.S. Patent Numbers 2,259,846, 2,265,586, and 2,769,597. Body 101 defines a cylinder 106 within which sleeve valve 107 is reciprocally received. Valve 107 rests against push pin 105. An air inlet slit 108 is cut through cylinder 106 just above sleeve valve 107 in the cold position shown. Connector 109 is threadably received in body 101 and provides air outlet 110. Spring 111 is interposed between connector 109 and valve 107 to provide valve contact with push pin 105.

Air outlet 110 may be connected to passageway 42 in throttle body 11. When the engine is cold, the full quantity of bleed air is drawn into passageway 42 through slit 108. Upon warming of coolant 104, thermostat 103 drives push pin 105 upward to cause cylinder 107 to cut off slit 108 from the outside air.

The injector pump 10 is now described:

Shaft 61 is carried within body 60 and is driven by the engine at crankshaft speed. Shaft 61 carries Z-shaft 62 keyed thereon by key 63. A spherical segment bearing 64, known also as a wedding ring bearing, is carried on Z-shaft 62 and imparts a harmonic wobble motion to wobble plate 65. Reciprocally mounted in plunger block 120 are fuel plungers 66 biased against wobble plate 65 by springs 67 and move in synchrony therewith. Z-shaft 62 can be axially displaced to various positions along the center line of shaft 61, while the phase relationship of the two shafts is retained by key 63. The axial displacement of Z-shaft 62 governs the magnitude of harmonious displacement of the wobble plate 65, thus making it possible to vary the stroke of plunger 66 in accordance with the fuel charge quantity required.

Shaft 61 at its upper extremity carries eccentric crank bearing 68. Received on bearing 68 is distributor valve 69, also known as a ported pinion gear. Valve 69 has a circular periphery with gear teeth cut therein which contact with the geared annular ring 70 fixed to body 60. Any point on valve 69, such as kidney lobe 71 or communicating port 72, is caused to move in a hypotrochoid motion as the distributor valve 69 is driven by the eccentric bearing 68. This valve arrangement is well-known in the art as shown in U.S. Patents Numbers 2,143,052 and 2,329,912.

A distributor block 73 is fixed to body 60 by bolts 74. Block 73 defines gasoline inlet port 75, gasoline outlet port 76, pump high pressure outlet ports 77 and

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oil inlet port 78. Communication is made between the plunger ports 79 (Figure 7) and the outlet ports 77 through kidney groove 71 and communicating port 72 cut in valve 69 as the valve 69 is driven by bearing 68. Plunger filling through ports 79 occurs when the valve 69 uncovers a cylinder port such as shown in the case of port 79' in Figure 8.

Oil at servo pressure of approximately 65 p.s.i. enters oil inlet port 78 from pump 16. As shown best in Figure 7, shaft 61 has a drilled passageway 80 axially of its length and this passageway is in communication with oil inlet 78, and upper oil outlet is provided by radial drillings 121 which permit the oil to enter the area surrounding the plunger body 120 and the wobble plate 65 thereby providing lubrication to these moving parts. A diagonal cut 134 in body 60 (shown in Figure 6) admits oil at servo supply pressure below wobble plate 65 where it acts upon the top side of servo piston 79 formed integrally with Z-shaft 62. A control valve 81 admits servo oil at a controlled pressure below piston 79 for the purpose of positioning Z-shaft 62 and controlling the displacement of wobble plate 65.

Passageway 80 in shaft 61 conducts oil at servo pressure down to servo control valve 81. Valve 81 is in the form of a sleeve rotatably carried on shaft 61 and defines a variable pressure relief orifice between the metering lips of the annuli 82 of valve 81 and annuli 83 of shaft 61. Valve 81 is positioned by rocker arm 84 axially along shaft 61 and admits oil under pressure to chamber 85 where it acts on the underside of piston 79 in opposition to the pressure on the top of the piston.

A spring 87 is interposed between valve 81 and a ball race 86 which adds to the force of oil in chamber 85. Z-shaft 62 will, therefore, find a point of equilibrium in accordance with the oil pressure in chamber 85 as determined by valve 81.

Chamber 43 holds sealed capsules 88 and 89 containing dry nitrogen at sub-atmospheric pressure. Capsule 90 is vented to atmosphere through hollow pin 91 and vent 131 in cap 130. Rod 91 is threadably received within capsule supporting stud 92, the latter being threaded into body 60. Stud 92 provides a pre-load adjustment for the bellows and the position of push pin 38. Hollow pin 91 may also be adjusted to limit the upward excursion of capsules 88 and 89. Openings 132 and 133 are provided for communication with pressure signal line 122 and manifold line 39 respectively as shown in Figure 1. The expansion or contraction of the capsules (or more accurately the force caused by such expansion or contraction) is transmitted to servo valve 81 through the axial movement of push pin 38 as translated by the movement of lever 84. Seal 94 prevents oil from being drawn into chamber 43.

Oil is returned to sump 15 through oil pick up holes 96 (Figure 7) in drive shaft 61 and passageway 97 drilled axially through the end of drive shaft 61. Pick up holes 96 are uncovered only when they pass V slot 98 (Figure 6) in valve 81, providing thereby the necessary pressure differential between chamber 85 and the sump.

The manner in which the foregoing described structure renders a fuel injection system sufficiently versatile for all driving conditions, including the requirements for cold engine starting, warm up and idling, may be summarized, in general, as follows: In the fuel injection system embodying the present invention, fuel mixture requirements are established by the throttle body 11, butterfly valve 33 and the speed-density function of the injector. As was explained above, the butterfly valve 33 controls the flow of the air into the engine and is itself controlled by the throttle or accelerator pedal in the driver's compartment. The fuel injector is controlled by engine speed and intake manifold absolute pressure.

The chamber 43 containing the gas-filled sealed bellows or capsules 37 has been described as being connected by the two tubes 122 and 39 to the engine intake

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manifold so that air flowing through the chamber 43 at manifold pressures and temperatures acts directly upon the bellows 37. As was stated above, the bellows is a sealed unit, filled with dry nitrogen at sub-atmospheric pressure (approximately 4 p.s.i.a.), which furnishes the injector with a base line against which it measures any change in intake manifold pressure and temperature (air density). As the density in the manifold changes, the bellows either expands (low pressure or part load operation) or contracts (high pressure or wide open throttle operation) in order to balance its internal forces with external forces.

The movement of the bellows upsets the balance of forces acting in the main part of the injector by means of the rocking lever 84. The rocking lever moves the servo-oil valve 81, the latter controlling the flow of oil into the servo-oil chamber 85 by means of the set of orifices 82-83 located between it and the shaft 61. A stream of constant-pressure oil flows down the passageway 80 in the shaft 61 from above the piston 79. As the oil flows through the orifices between the servo-oil valve 81 and the shaft 61, it undergoes a pressure drop, and the oil located in the servo-oil chamber 85 is then at a lower pressure than oil located above the piston 79. As long as steady-state conditions prevail, the forces below the piston 79, i.e., the pressure of the oil in chamber 85 plus the force of the metering spring 87 will balance the hydraulic force above the piston 79.

With any change in manifold air density, the servo-oil valve 81 will move, changing the orifice areas and the oil pressure in the servo-oil chamber 85. The piston 79 immediately will move axially to set up new equilibrium conditions above and below it. As the piston 79 moves along the driveshaft, it causes the angle of the wobble plate 65 to be changed and the pumping stroke of the plungers 66 to be varied.

It might be assumed that a fuel injection system operating as described to this point, that is, with the two controls described above, might give satisfactory engine performance. However, the engine is not supplied by such controls with the necessary fuel for the following conditions: (1) Cold engine warm up: Extra fuel is required because fuel does not vaporize readily at low temperatures. (2) Idle: Additional amounts of fuel are required because of the exhaust dilution in the cylinders due to valve overlap. (3) Cranking: Extra fuel is required during the slow speed cranking operation to insure some of the fuel vaporizing and forming a combustible mixture. (4) Decelerating fuel cutoff: Fuel cutoff during deceleration is required because the injector is sensitive to speed and delivers more fuel to the engine during deceleration than is normally required for idle. Figure 3, described above, represents the fuel output curves of the injector if it is to satisfy the demands of the engine for all the above-enumerated operating conditions.

Figure 3 may be explained further to assist in an understanding of the general principle of operation of the present invention. Since the bellows 37 directly controls the output of the injector by sensing manifold air densities, it is readily apparent that it is possible to vary the injector output by varying the pressure in the bellows chamber 43. This may be done by introducing air into the bellows chamber 43 in amounts large enough to change the pressure in the chamber yet small enough to have no effect on the pressure inside the intake manifold.

Curve A of Figure 3 has been described as representing the metering curve which would be followed by the fuel injection pump 10 if chamber 43 of the pump were connected directly to the intake manifold. For example, the point 135 on the curve would indicate the quantity of fuel delivered to the engine at the absolute intake manifold pressure represented by the point 135. In carrying out the present invention, the quantity of fuel delivered relative to absolute intake manifold pressure is set so as to be deliberately below the quantity required

to satisfy the engine demands. To compensate for this deficiency, air is introduced into the bellows chamber 43 through the opening 40 (see Fig. 2). The chamber pressure is thus slightly higher than manifold pressure which means that the injector output with reference to curve A would be at a point 136 above the original reference point 135. However, the engine is still operating at an absolute intake manifold pressure corresponding to the point 135 pressure. The result is that the fuel supplied is actually represented by the point 137 on the curve B. By projecting a series of points equivalent to the point 137, the curve B, which is the air control curve (warmed up engine) may be developed.

The same principle is utilized to furnish the additional fuel required under the various transient engine operating conditions, i.e., idling and warm up. When the engine is cold, air is introduced into the bellows chamber 43 from a second source, i.e., through opening 44 (see Fig. 2) which is controlled by temperature controlled valve 46. This second air supply further increases the fuel output for the relatively large quantities of fuel required during cold engine operations. This is illustrated by point 138 on curve C of Fig. 3, which is the cold engine fuel requirements curve. A third source of air is additive to either one or both of the other air circuits and supplies extra fuel to the engine only when it is idling, i.e., when the butterfly valve is closed, as has been explained. This third source is the opening 48 controlled by the idle adjustment screw 49.

Thus, the above principles satisfy the two major transient engine conditions, i.e., idle and warm up. The problem of additional fuel for starting is handled by the present invention in another manner because of the large amounts of fuel required. The junction of the three curves A, B and C, Fig. 3, represents the wide open throttle condition. The fuel required during cranking is above this point. That is, the quantity of fuel required for starting the engine is greater than the maximum amount the injector is set to pump, and the injector cannot be set for a higher flow rate because its maximum delivery must match the engine fuel requirements for wide open throttle or full load operation. Therefore, it is readily apparent that no controls added to the injector would suffice. As was explained, a priming line 31 is provided which is maintained under positive pressure from fuel pump 13. Fuel from priming line 31 can only be fed into the manifold air intake when solenoid valve 29 is opened and this valve is opened only when the starter is operated.

There is one other transient operating condition for which provision is made in the fuel injection system embodying the present invention. With a fuel injector driven at engine speed, the problem arises of fuel being delivered to the engine when the engine is operating at high speed and yet does not require any fuel. Such a condition exists during long decelerations. Therefore, as was described, the present system includes a deceleration fuel cutoff device, or overrun cutoff. It will be noted in Fig. 3 that the fuel metering curve A crosses the zero-fuel output line of the injector at an absolute manifold pressure point. This point corresponds to the pressure existing in the manifold during overrun conditions. With the injector set to meet this curve and with the air controls described above, it is necessary only to cut off all sources of air supply to the injector bellows and subject the bellows to true manifold pressure for the flow of fuel to be cut off. This overrun cutoff was described as the spool valve 50 which moves in response to the decrease in manifold pressure during deceleration. The valve 50 moves against the spring 56 and closes slit 51 (see Fig. 2). Chamber 43 is then acted upon only by manifold pressure and, as shown in Fig. 3, the quantity of fuel injected is zero for any absolute intake manifold pressure between the intersection of the abscissa and

ordinate and the intersection of the curve A and the abscissa.

We claim:

1. In a pressure controlled fuel injection system for internal combustion engines that improvement comprising a pressure responsive chamber operable to control the quantity of the injected fuel, a pressure restriction, said chamber connected to a source of intake manifold pressure through said pressure restriction, a fixed bleed path connecting said chamber to a source of atmospheric pressure, and an engine temperature variable bleed path connecting said chamber to a source of atmospheric pressure by an amount which increases with decreasing temperature.

2. In a pressure controlled fuel injection system for internal combustion engines that improvement comprising a pressure responsive chamber operable to control the quantity of injected fuel, a pressure restriction, said chamber connected to a source of intake manifold pressure through said restriction, parallel bleed paths connecting said chamber to a source of atmospheric pressure, said paths including a first path having a constant bleed orifice, a second path having a temperature-controlled orifice, and a third path having a constant orifice being subjected to said source only at engine idle.

3. In a pressure controlled fuel injection system for internal combustion engines that improvement comprising a pressure responsive chamber operable to control the quantity of the injected fuel, a pressure restriction, said chamber connected to a source of intake manifold pressure through said pressure restriction, said chamber connected to a source of atmospheric pressure through parallel bleed paths consisting of a first path with a constant diameter bleed, a second path with a variable diameter temperature controlled bleed increasing with decreased engine temperature, and a third path operable only at engine idle.

4. In a pressure controlled fuel injection system for an internal combustion engine, a unit having a chamber therein, pressure responsive means in said chamber operable to control the quantity of injected fuel, means connecting said chamber to a source of intake manifold pressure, means connecting said chamber to a source of atmospheric pressure, and means responsive to a decrease in manifold pressure below a predetermined absolute pressure effective to shut off the communication of said chamber to said source of atmospheric pressure, said pressure responsive means then becoming effective to reduce the quantity of injected fuel to a predetermined minimum.

5. In a pressure controlled fuel injection system for an internal combustion engine, a unit having a chamber therein, pressure responsive means in said chamber operable to control the quantity of injected fuel, means connecting said chamber to a source of intake manifold pressure, parallel bleed paths connecting said chamber to a source of atmospheric pressure, at least one of said bleed paths being in communication with said chamber when said intake manifold pressure is above a predetermined absolute pressure, whereby the absolute pressure in said chamber is higher than the absolute intake manifold pressure, and means responsive to a decrease in manifold pressure below a predetermined absolute pressure effective to shut off the communication of said chamber to said source of atmospheric pressure, said pressure responsive means then becoming effective to reduce the quantity of injected fuel to a predetermined minimum.

6. In a pressure controlled fuel injection system for an internal combustion engine, a unit having a chamber therein, pressure responsive means housed in said chamber effective to control the quantity of injected fuel, means connecting said chamber to a source of intake manifold pressure, parallel bleed paths connecting said chamber to a source of atmospheric pressure, said paths including a first path having a constant bleed orifice, a second path having a temperature-controlled orifice, and a third path having a constant orifice subjected to atmospheric pres-

sure only at engine idle, at least said first path normally being in communication with said chamber when said intake manifold pressure is above a predetermined absolute pressure, whereby the absolute pressure in said chamber is normally higher than the absolute intake manifold pressure when said engine is operating at other than a rapidly decelerating condition.

7. In a pressure controlled fuel injection system for an internal combustion engine, a unit having a chamber therein, pressure responsive means housed in said chamber effective to control the quantity of injected fuel, means connecting said chamber to a source of intake manifold pressure, parallel bleed paths connecting said chamber to a source of atmospheric pressure, said paths including a first path having a constant bleed orifice, a second path having a temperature-controlled orifice, and a third path having a constant orifice subjected to atmospheric pressure only at engine idle, at least said first path normally being in communication with said chamber when said intake manifold pressure is above a predetermined abso-

lute pressure, whereby the absolute pressure in said chamber is normally higher than the absolute intake manifold pressure when said engine is operating at other than a rapidly decelerating condition, and means responsive to a decrease in manifold pressure below a predetermined absolute pressure, such as caused by a rapid deceleration of the engine, effective to cut off the communication of all bleed paths with the chamber, said pressure responsive means then becoming effective to reduce the quantity of injected fuel to a predetermined minimum.

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