

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets

(11) Publication number:

**0 014 142  
B1**

(12)

**EUROPEAN PATENT SPECIFICATION**(45) Date of publication of patent specification: **21.09.83**(51) Int. Cl.<sup>3</sup>: **F 02 M 59/36,  
F 02 M 59/20**(21) Application number: **80400086.7**(22) Date of filing: **21.01.80**(54) **Fuel injector and method of electronically operating a fuel injector.**(30) Priority: **25.01.79 US 6948  
25.01.79 US 6949**(43) Date of publication of application:  
**06.08.80 Bulletin 80/16**(45) Publication of the grant of the patent:  
**21.09.83 Bulletin 83/38**(84) Designated Contracting States:  
**AT DE FR GB IT SE**(56) References cited:  
**AT - B - 195 685  
DE - A - 854 921  
DE - B - 2 131 841  
DE - C - 231 352  
DE - C - 459 676  
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## Fuel injector and method of electronically operating a fuel injector

The invention relates to a fuel injector and to a method of electronically operating a fuel injector.

Fuel injection systems are known which employ hydraulic adjustment means to alter the timing of the injection phase of the cycle of operation of a set of injectors mechanically driven from the crankshaft of an internal combustion engine, and the hydraulic means may be responsive to the speed of the engine and/or the load imposed hereon. While the prior art systems functioned satisfactorily in most instances, several operational deficiencies were noted. For example, the hydraulic adjustment means functioned effectively over a relatively narrow range of speeds, and responded rather slowly to changes in the operating parameters of the engine. Also, problems were encountered in sealing the hydraulic adjustment means, for a rotor-distributor pump was utilized to deliver hydraulic fluid to each of the fuel injectors in the set employed within the fuel injection system. In order to provide a hydraulic adjustment means responsive to both speed and/or the load factor such as suggested in US Patent 3,951,117 granted April 20, 1976 to Julius Perr, an intricate, multicomponent assembly is required, thus leading to high production costs, difficulty in installation and maintenance, and reduced reliability in performance.

US—A—3,951,117, and 4,134,549 to Julius Perr, disclose a fuel supply system including hydraulic means for automatically adjusting the timing of fuel injection to optimize engine performance. The system comprises an injection pump including a body having a charge chamber and a timing chamber formed therein. The charge chamber is connected to receive fuel from a first variable pressure fuel supply, and the timing chamber is connected to receive fuel from a second variable pressure fuel supply, while being influenced by pressure modifying devices. The body further includes a passage that leads through a distributor which delivers the fuel sequentially to each injector within a set of injectors.

A timing piston is reciprocally mounted in the body of the injection pump in Perr between the charge and timing chambers, and a plunger is reciprocally mounted in the body for exerting pressure on the fuel in the timing chamber. The fuel in the timing chamber forms a hydraulic link between the plunger and the timing piston, and the length of the link may be varied by controlling the quantity of fuel metered into the timing chamber. The quantity of fuel is a function of the pressure of the fuel supplied thereto, the pressure, in turn, being responsive to certain engine parameters, such as speed load. Movement of the plunger in an injection stroke results in movement of the hydraulic link and the timing piston, thereby forcing fuel into the selected

combustion chamber. The fuel in the timing chamber is spilled, or vented, at the end of each injection stroke into spill port and spill passage.

Thus, with the deficiencies of the known fuel injection systems utilizing hydraulic adjustment means to control the timing of fuel injection clearly in mind, it is an object of the present invention to provide a fuel injector wherein the timing phase, and the subsequent injection phase, of the cycle of operation can be easily altered in dependence upon any of one or more parameters of engine operation, utilizing existing control units, which respond rapidly to several engine parameters in addition to engine speed and load, and generate appropriate signals for an electronically controlled valve associated with the fuel injector.

To this end, the invention proposes a fuel injector for an internal combustion engine comprising a body having an axially extending bore, a primary pumping plunger and a secondary plunger positioned within said bore for axial movement therein in response to the movement of said primary pumping plunger, a nozzle situated at the end of said bore remote from said primary pumping plunger, a timing chamber defined in said body between said primary plunger and said secondary plunger, a metering chamber defined in said bore between said secondary plunger and said nozzle, passages in said body of said injector for receiving pressurized fuel and transmitting said fuel into said timing chamber and said metering chamber, characterized in that it comprises an electronically operated control element situated intermediate said passages and said timing chamber and adapted to be selectively energized to regulate the timing of the discharge of fuel from the metering chamber through the nozzle and to regulate the quantity of fuel discharged through the nozzle, and to control the quantity of fuel stored in said metering chamber subsequent to said discharge of fuel wherein said electromagnetic control element controls the admission of fuel into said timing chamber for creating a hydraulic link between said primary pumping plunger and said secondary element to selectively hydraulically connect said primary pumping plunger and said secondary plunger wherein said control element is at one of a closed or opened state to create a pressure condition in said timing chamber to permit independent movement of said primary pumping plunger relative to said secondary plunger during a portion of the operation of the injector.

It is also an object of the present invention to provide a method of electronically operating such a fuel injector to regulate both the timing and the metering functions of said fuel injector and to respond more quickly to changes in the engine parameters, the inertial effects attribut-

able to the numerous components of the known hydraulic adjustment means being eliminated.

To this end, the invention proposes a method of operating the above fuel injector which comprises the steps of:

a) introducing fuel at supply pressure into said passages and said chambers;

b) applying a force to the primary pumping plunger to move same axially in relation to the operating cycle of the internal combustion engine; characterized in that it further comprises the steps of:

c) supplying an electrical signal to the control valve means to seal the timing chamber and form a hydraulic link between the primary plunger and secondary plunger and moving them in concert;

d) discharging the fuel in the metering chamber through the nozzle in response to the electrical signal; and

e) filling the metering chamber to a desired level prior to terminating the electrical signal;

f) terminating the electrical signal to the control valve means to open the timing chamber and break the hydraulic link between the plunger and element and moving said primary pumping plunger independently of said secondary element.

The invention will now be described with reference to the accompanying drawing wherein:

— Figure 1 is a schematic diagram of a fuel injection system configured in accordance with the principles of the invention;

— Figure 2 is a vertical cross-sectional view, on an enlarged scale, of a fuel injector utilized within the system of Figure 1;

— Figures 3 to 7 schematically show the sequence of operational steps for the fuel injector of Figure 2;

— Figure 8 is a graphical representation of the cam surface utilized to control the movement of certain portions of the injector of the present invention, depicting cam lift relative to degrees of crank angle rotation; and

— Figure 9 is a composite schematic representation of the cycle of operation of an injector in the instant fuel injection system; the upper graph traces the movement of the primary plunger versus the rotational movement of the crankshaft, while the lower chart notes the sequence of events versus the rotational movement of the crankshaft.

Turning now to the drawings, Figure 1 schematically depicts the major components of a fuel injection system employing an electronically operated control valve for regulating the timing and metering functions of each injector within the system. The system includes a fuel injector 10 that is supported by a support block 12 and is controlled to deliver fuel through a nozzle 14 directly into the combustion chamber (not shown) of an internal combustion engine 16. Although only one injector is shown, it should be noted that a set of identical

injectors is employed within the fuel injection system, one injector being provided for each cylinder in the engine. The injector 10 is operated in synchronism with the operation of the engine through the reciprocal actuation of a follower 20, the follower 20 being biased upwardly by a heavy duty spring 18.

A cam 22 is secured to the camshaft 24 of the internal combustion engine 16. Cam 22 rotates at a speed which is a function of engine speed, for the camshaft is driven via meshing gears 23, 25 from the crankshaft 26. The gear ratio of gears 23, 25 may vary from engine to engine depending on various factors, including, inter alia, whether the engine is a two-cycle or four-cycle engine. The crankshaft drives the piston (not shown) within the combustion chambers of the engine 16 in the usual manner. A roller 27 rides along the profile of the cam, and a push rod 28 and rocker arm 30 translate the movement of the roller into the application of axially directed forces upon the follower 20 and the primary piston; the forces act in opposition to main spring 18 and vary in magnitude with the speed of the engine and the profile of the cam. The cam profile is of particular importance to the operation of the injector and will be discussed more fully in the discussion of Figures 8 and 9.

A reservoir 32 serves as a source of supply for the fuel to be dispensed by each injector 10, and fuel is withdrawn from the reservoir by transfer pump 34. Filters 36, 38 remove impurities in the fuel, and distribution conduit 40 introduces the fuel, at supply pressure, to each of the injectors 10. A branch conduit 42 extends between distribution conduit 40 and block 12 and makes fuel, at supply pressure, available for circulation through injector 10. The fuel that is not dispensed into a combustion chamber in the engine is returned to the reservoir 32 via branch return conduit 44 and return conduit 46. A fixed orifice 48 is disposed in return conduit 46 to control rate of return flow into the reservoir. Directional arrows and legends adjacent to the conduits indicate the direction of fuel flow.

The fuel injection system of Figure 1 responds to several parameters of engine performance. In addition to engine speed, which is reflected in the rate of rotation of the cam 22 secured upon camshaft 24, several sensors 50 are operatively associated with engine 16 to determine, inter alia, engine speed, temperature, manifold absolute pressure, load on the engine, altitude, and air-fuel ratio. The sensors 50 generate electrical signals representative of the measured parameters, and deliver the electrical signals to an electronic control unit, or ECU, 52. The electronic control unit then compares the measured parameters with reference values which may be stored within a memory in the unit, takes into account the rotational speed and angular position of cam 22, and generates a signal to be delivered to each

injector. The signal, in turn, governs the timing and metering functions of each injector. Leads 54, 56 and a connector 58 interconnect the electronic control unit 52 and the control valve 146 for the representative injector shown in Figure 1.

Figure 2 depicts the components of a representative injector 10. The segment at the left hand side of Figure 2 fits atop the segment at the right hand side of Figure 2.

Referring to the upper end of the injector 10, a fragment of the rocker arm 30 is visible bearing against the enlarged upper end of follower 20, and main spring 18 rests on support block 12 and urges the follower 20 upwardly. A primary pumping plunger 62 is joined to the lower end of follower 20, the follower 20 and primary pumping plunger 62 moving as a unitary member. A cylindrical guide 64 insures the axial movement of follower 20, while a seal guide 66 provides a seal and insures the axial movement of primary pumping plunger 62. It is to be understood that block 12 and guides 64, 66 may be formed as an integral unit. A slot 68 in the follower 20 cooperates with stop 60 to prevent the follower 20 and spring 18 from becoming disassembled from the remainder of the injector prior to association with the rocker arm 30 and to limit the downward travel of follower 20.

An internally threaded jacket 70 is screwed into engagement with the mounting block 12, and the interior of the jacket surrounds the distinct segments that comprise the body of the fuel injector 10. Each segment of the body is generally cylindrical in shape, is generally executed in metal, has a central bore and has passages drilled, or otherwise formed there-through, in alignment with the central bore and the passages of the adjacent segment. Thus, in Figure 2, fuel injector 10 includes an elongated sleeve 72, a disc-like segment 74, and a spring cage 76 that communicates with nozzle 14. A seal 78 seals the juncture between the block 12 and the threaded jacket 70. Supply passages 80, 82, of which there are two pairs of each, only one each of which are shown, extend through the various segments, and an annular cavity 84 is defined beneath the seal guide 66 and the upper end of the axial passages. The lowermost ends of passages 80, 82 extend radially inwardly to terminate in annulus 83. The passages 80, 82 (a total of four passages arranged around piston 62) also extend radially inwardly to terminate in annulus 85, spaced above annulus 83 in the sleeve of the injector.

A cylindrical recess 86 is located in the lower end of the primary pumping plunger 62, and a stud 88 is located within the recess to form a spring retaining member. A secondary plunger 90 is axially movable within the central bore of the sleeve 72, and a valve seat insert 92, with a recess 94 in its upper surface, is situated at the upper end of the secondary plunger. A spring 96 extends between stud 88 and the insert 92 and

constantly maintains a downwardly directed biasing force upon the secondary plunger. A variable volume timing chamber 98 is defined between the lower end of plunger 62 and the upper end of secondary plunger 90. Secondary plunger 90 slides freely within the bore of sleeve 72 and primary plunger 62 travels within the bore 97 of support block 12.

A passage 99 extends axially through the valve seat insert 92 to communicate with cross-hole passage 100 which opens into annulus 102 formed on the surface of secondary plunger 90. A first check valve 104, preferably in the form of a poppet valve, is normally biased by spring 106 against a valve seat 108 formed in passage 100 to control fluid communication between chamber 98 and passage 100. The spring 106 is seated in a guide cavity 110 in the secondary plunger 90.

An annulus 112 is formed in the outer surface of secondary plunger 90 at approximately the mid-section thereof, annulus 112 communicating with a cross-hole passage 114 and an axial passage 116. A second check valve 118 in the secondary plunger is biased against its valve seat 120 by a spring 121 disposed in a cavity 122 formed in the plunger 90. Valve 118 thus controls communication between passage 116 and inverted L-shaped passages 124, 126, of which there are two each, which extend axially through the lower end of the secondary plunger. The passages open into an annulus 125 formed in the exterior surface of plunger 90. A variable volume metering chamber 128 is defined between the lower end of secondary plunger 90 and the disc-like segment 74.

A disc 130 fits within a recess 132 at the upper end of segment 74, and the disc is of sufficient area to seal off one end of metering chamber 128 to prevent gases in the cylinders in the engine from blowing back into the injector in the event the nozzle 14 fails to seal. The recess 132 opens downwardly into a plurality of passages 134, 136, sets of which are arranged circumferentially around the central axis of injector 10, passage 136 communicating with nozzle 14. The upper end of a needle valve 144 is secured to a spring retaining member 142, and a spring 138 is disposed between element 74 and member 142 to bias valve 144 downwardly against a valve seat 145 to prevent fuel from being dispensed from the nozzle 14. Only when the pressure in passage 136 significantly exceeds the combined forces of the spring biasing pressure and the supply pressure is the needle valve unseated to permit a fine atomized spray of fuel to be issued from nozzle 14.

Branch conduit 42 introduces fuel, at supply pressures of 3.5 to 14 kg/cm<sup>2</sup>, into support block 12 through conduit 43 and thence into injector 10. An electronically operated control valve 146 is disposed between conduit 42 and conduit 43 to control both the timing and the

metering functions for injector 10 as will be more fully explained hereafter. Branch conduit 43, as suggested by the diagonally extending dotted lines, communicates fuel at supply pressure with timing chamber 98 when the control valve 146 is open.

The functioning of the several components of the fuel injector of Figure 2 will best be appreciated by reviewing the sequence of operation shown in Figures 3 to 7. However, in order to better portray the sequence of operational events, license has been taken in depicting the various elements of the injector 10. For example, the segments housed within jacket 70 are shown as a unitary member, the guides 64, 66 and disc 130 have been omitted, the follower 20 and the primary pumping piston 62 have been shown as a unitary member, etc.

Turning now to Figure 3, which shows a convenient but arbitrarily selected starting point for the cycle of operation, control valve 146 is shown in its normally opened condition to allow fuel at supply pressure in the branch conduit 42 access to supply passage 43 and the timing chamber 98. Actually, an equilibrium pressure condition exists (supply pressure) as the primary plunger 62 has ceased its upward motion and is prepared to start its downward motion due to the action of camshaft 24 and cam 22 on plunger 62 as will be seen from a description of Figures 8 and 9. The timing chamber 98 and metering chamber 128 previously have been filled with fuel as will be seen from a description of Figures 6 and 7. With the control valve 146 open, fuel is free to flow into and out of timing chamber 98. As shown in Figure 3, check valve 104 is biased against its seat by spring 106 and check valve 118 is biased against its seat by spring 121.

The primary pumping plunger 62 and the secondary plunger 90 sealingly engage the central bores 97, 69, respectively, of the injector, and the spring 96 continuously imparts a downward bias upon plunger 90. A precise amount of fuel is present in metering chamber 128 due to a prior metering operation, to be described in conjunction with the description of Figures 6 and 7, and the trapped fuel acts against spring 96. With the control valve 146 opened, timing chamber 98 is in its equilibrium condition, so that when rocker arm 30 forces follower 20 and primary pumping plunger 62 downwardly, at the rate suggested by the arrow beneath plunger 62, fuel is forced out of timing chamber 98 through passages 43, 42. The secondary plunger is unaffected by such movement and remains stationary under the bias of spring 96 and trapped fluid in metering chamber 128. The duration of the period during which valve 146 is maintained in its opened condition relative to a fixed reference is a variable quantity determined by the electronic control unit 52 in response to actual engine conditions and independent of the travel of plunger 62. Thus, the instant at which the valve

146 is closed, and the timing chamber 98 isolated from the supply passage 42, can be adjusted relative to the fixed reference, e.g., the top dead center (TDC) position of the crankshaft 26, over fairly broad limits.

Figure 4 shows the various components of the fuel injector 10 at the instant that injection starts through nozzle 14 due to the high pressure (several hundred bar) created by the trapped fluid in timing chamber 98 and metering chamber 128. During the downward travel of plunger 62 from the arbitrarily selected starting position of Figure 3, and a very short period of time before the instant of injection shown in Figure 4, the valve 146 is closed as described above. With the valve closed, timing chamber 98 is sealed, and the continued downward movement of plunger 62 causes the downward movement of secondary plunger 90 to rapidly increase the pressure of the fuel trapped in chamber 128. The downward movement of the secondary plunger 90 pressurizes the fuel in chamber 128 to a level sufficient to unseat needle valve 144 and permits a fine spray of pressurized fuel to be discharged through the pin holes in nozzle 14.

The second check valve 118 remains seated during the injection phase of the cycle of operation due to the fact that the high pressure below check valve 118 created by the pressure in metering chamber 128, as communicated thereto by passages 124, 126, is greater than the supply pressure in passages 80, 82 and cross-hole 114.

Figure 5 shows the various components of the fuel injector immediately after the termination of the injection shown in Figure 4, Figure 5 illustrating the "dumping" or pressure relieving phase of operation. In this phase the control valve 146 is still closed and the primary pumping plunger 62 is approaching its limit of downward travel, as suggested by the small arrow beneath the plunger. In this phase, the annulus 125 is in fluid communication with annulus 83 thereby communicating the high pressure in passages 124, 126, 136 with the supply pressure in passages 80, 82. As the pressure in passages 124, 126, 136 approaches the supply pressure existing in passages 80, 82, the pressure on the needle valve is insufficient to hold valve 144 open and the needle valve 144 is again seated against seat 145. The pressure build-up in passage 136 and metering chamber 128 is rapidly relieved, so that the undesirable dribble of fuel through the nozzle is prevented.

At the same time, the pressure of the fuel in timing chamber 98, which has been intensified by the downward movement of plunger 62, is relieved to permit the primary plunger 62 to complete its downward travel after the termination of injection and precludes excess pressure on the parts of the injector subject to the pressure in timing chamber 98. More specifically, the annulus 102 is in fluid com-

munication with annulus 85 thereby communicating passage 100 below valve 104 with the supply pressure in passages 80, 82. The pressurized fuel in chamber 98, as compared to supply pressure in passage 100, creates a pressure differential across first check valve 104 to unseat check valve 104. Fuel flows from timing chamber 98, through check valve 104, annulus 102, and annulus 85 back into axial passages 80, 82. Check valve 104 has been provided to check the flow of fuel from passage 80 to timing chamber 98, through annuli 85, 102, just prior to the metering phase of operation. If valve 104 did not seat, fuel flow from passage 80 to timing chamber 98 would preclude the metering to be described below.

The direction of flow of pressurized fuel from both the timing chamber chamber 98 and the metering chamber 128 is indicated by directional arrows. After entering the axial passages, the fuel is returned to reservoir 32 via conduits 44, 46 (Figure 1).

Figure 6 shows the various components of the fuel injector after the primary pumping plunger 62 has completed its downward travel and has started its upward travel under the urging of spring 18 to create the "metering" phase of operation. The control valve 146 is retained in its closed condition, and annulus 102 is out of communication with annulus 85, thereby sealing timing chamber 98. The fuel in timing chamber 98 is approximately at supply pressure due to the dumping shown in Figure 5. First check valve 104, which was unseated during the "dumping" phase of the cycle of operation, as shown in Figure 5 is again held against its seat 108 by spring 106 to prevent communication between chamber 98 and passage 100.

As the primary pumping plunger 62 moves upwardly, as suggested by the arrow atop the head of follower 20, the pressure in timing chamber 98 drops to a pressure level below supply pressure as the volume of chamber 98 increases marginally. The pressure of the fuel beneath secondary plunger 90 in metering chamber 128 is greater than the combined forces of the fuel in chamber 98 and the biasing force of spring 96. The secondary piston 90 thus follows the primary pumping piston 62 in its ascent because of the net, upwardly directed pressure differential. During this early movement of secondary plunger 90, while annuli 125, 83 are in alignment, fuel flows from passages 80, 82, through passages 124, 126, to metering chamber 128.

As the secondary plunger moves upwardly, the lower-most annulus 125 defined on the plunger 90 moves out of alignment with annulus 83, thereby sealing metering chamber 128 from the annulus 83. The intermediate annulus 112, which opens into cross-hole passage 114, stays in alignment with the lower portion of annulus 85. Consequently, supply pressure in passages 42, 80, 82 is impressed on

annulus 85, thence into annulus 112, and passage 114, to the upper portion of second check valve 118. This pressure differential across check valve 118 created by the relatively high supply pressure above check valve 118 as compared to the relatively low pressure in metering chamber 128, unseats check valve 118. Thus, fuel flows into metering chamber 128 through check valve 118, through passages 124, 126, as shown by the arrows in Figure 6.

The quantity of fuel that flows into metering chamber 128 is proportional to the volumetric displacement of plunger 90 created by the pressure differential across plunger 90. The plunger 90 can only move in concert with plunger 62 while control valve 146 is closed. In summarizing these relationships, it will be appreciated that the quantity of fuel introduced into the metering chamber 128 is proportionally related to the duration or interval, in crankshaft degrees, during which the control valve 146 is held closed after the start of the upward travel of secondary plunger 90. Obviously, when the valve 146 is held closed by a signal from the electronic control unit 52 for the entire interval in crankshaft degrees allocated for metering, the chamber 128 will be filled with the maximum amount of fuel. When the valve 146 is held closed by a signal from the electronic control unit for only half of the interval, defined in degrees of crankshaft rotation, then the metering chamber will be half filled. Other proportional relationships are available in accordance with the fraction of the crankshaft rotational interval selected to hold valve 146 closed. This proportionality will become more apparent during the discussion of Figures 8 and 9.

Figure 7 shows the various components of the fuel injector at the termination of the metering phase of the cycle of operation. The metering phase is terminated by terminating the electrical signal from electronic control unit 52 to the control valve 146, which then returns to its normally opened condition. With valve 146 opened, the fuel at supply pressure in passages 42, 43 and the fuel in timing chamber 98 quickly establish an equilibrium condition at approximately supply pressure level. The pressure differential across plunger 90 is removed and secondary plunger 90 is, in effect, disconnected and cannot follow primary pumping plunger 62 as plunger 62 continues its upward movement. With valve 146 opened, the combined forces of the fuel in timing chamber 98 and spring 96 are greater than the force of the fuel, at supply pressure, retained in metering chamber 128. Therefore, plunger 90 is "locked" or retained in fixed position. The instant at which the signal to valve 146 is terminated is determined by engine operating parameters sensed by the electronic control unit relative to the number of degrees of angular rotation of the camshaft 24 as measured by the crankshaft

26 rotation from the above-described fixed reference, as determined by conventional sensors. Primary pumping plunger 62 continues upwardly, following the cam surface, under the urging of spring 18 independently of secondary plunger 90, as suggested by the arrow atop follower 20 in Figure 7. When the primary pumping plunger 62 reaches its uppermost position, as shown in Figure 3, then the cycle of operation for the fuel injection can be repeated in the manner shown progressively in Figures 3 to 7.

Referring to Figures 8 and 9, Figure 8 illustrates, in graphic form, the profile, or lift, of the cam surface of cam 22 (Fig. 1) relative to the number of degrees of crankshaft rotation, and Figure 9 illustrates, in graphic form, the vertical motion of primary pumping plunger 62 relative to the same number of degrees of crankshaft rotation and the relationship thereto of the single electronic control unit pulse which initiates injection and terminates metering. Both figures, Figure 9 particularly, correlate the various phases of injector operation described in conjunction with the description of Figures 3 to 7 with degrees of crankshaft rotation. From Figures 8 and 9, a very graphic illustration of the proportionality of the metering phase may be seen. Thus the termination of the electronic control unit pulse to control valve 146 will be seen to be linearly related to the number of degrees of crankshaft rotation after a pre-selected reference point (for example, top dead center).

Specifically describing Figure 8, there is illustrated the lift of the cam, or cam profile surface plotted against the number of degrees of crankshaft rotation, and includes various points (A, B, C, D) along the curve. The curve approaches point A, which is the lowest point of the curve, and will be seen to correspond to the arbitrarily selected starting position described in conjunction with the description of Figure 3. The curve progresses through the injection phase, between points B and C; the dumping phase, between points C and D; and the metering phase, between points D and E. Point E corresponds to the end of the metering phase and a point F corresponds for the next sequence to point A for the previous sequence.

Figure 9 is a composite graphic representation of the operation of one injector 10 in the set of injectors employed in the instant fuel injection system. The upper graph plots the movement, or stroke, of primary pumping plunger 62 along the vertical axis against the degrees of rotational movement of the crankshaft 26; the rotational movement being measured by sensors that provide a signal representative of crankshaft rotation in degrees. The trace of the plunger 62 shows that the plunger instantaneously peaks, then moves downwardly until it reaches a nadir position, and then linearly returns upwardly to the peak position. For a two cycle engine, a complete

cycle occurs within 360° of rotational movement of the crankshaft; for a four cycle engine, a complete cycle occurs within 720° of rotational movement of the crankshaft.

The lower graph in Figure 9 plots the opening and closing of control valve 146 by the electronic control unit, and other events, against the degrees of rotational movement of the crankshaft 26. The leading edge of the signal to control valve 146 causes the valve to change state from its normally opened state to its closed state, and the trailing edge of the signal causes the valve to change state again and return to its normally opened position. It will be noted that a single pulse from the electronic control unit initiates the injection phase and terminates the metering phase, while the internal configuration of the injector (annuli, check valves, etc.) terminates the injection phase and initiates the metering phase.

The upper and lower graphs of Figure 9 may be correlated by following the progression of steps indicated by reference characters A, B, C, D, E and F. It is to be understood that the duration of the period A to D, in degrees, is determined by the sum of injection timing variation and injection duration plus the duration of the damping operation. It is believed that the determination of the duration of the period A to D is well within the scope of one skilled in the art. The plunger 62 assumes its peak upward position under the bias of main spring 18 at the start of the cycle of operation (Fig. 3). This is point A on the curve and, with the control valve 146 still in its normally opened state, as seen at the bottom of Figure 9, the plunger 62 starts downwardly under the force of rocker arm 30 pressing against follower 20.

During the course of the downward movement of plunger 62, the electronic control unit 52 delivers a signal to valve 146, and closes the valve as described in conjunction with the description of Figure 4. Point B on the curve designates the instant at which injection occurs during the timing function due to the closing of the valve 146, while point C indicates when the injection ceases due to the communication of annuli 102, 85 as described in conjunction with the description of Figure 5. The electronic control unit can be adjusted, either manually or automatically, in accordance with actual engine operating parameters, to shift the timing of the leading edge of the signal relative to the downward movement of the plunger 62. Point B will then shift along the curve to reflect such adjustments. The ability to adjust the instant at which valve 146 is closed to start the injection function assists in more completely burning the fuel discharged into each combustion chamber in the engine 16. Thus, the closure of valve 146 starts the injection phase of the cycle of operation as shown in Figure 4.

The compression-injection phase of the cycle of operation lasts for the brief interval B—C, the length of which is determined by the quantity of

fuel which has been metered into metering chamber 98. During the period B—C the secondary plunger follows the primary plunger downwardly and forces the fuel out of metering chamber 128 and through nozzle 14. The plungers are coupled through the sealed timing chamber 98 which forms a hydraulic link between the two plungers.

Point C on the curve designates the cessation of the injection phase of the cycle of operation and the period between points C—D represents the overtravel and dumping portion of the cycle. At point C, while the control valve 146 remains closed, the passages 124 and 126 in the secondary plunger 90 are in fluid communication with the annuli 125, 83 to communicate metering chamber 128 and passage 136 with the supply pressure in passages 80, 82 and vent, or dump, the pressurized fuel trapped in the metering chamber 128 and the nozzle 14 back into the low pressure of axial passages 80, 82. The venting of the nozzle enables the needle valve to be re-seated and prevent dribble of fuel through the nozzle into the combustion chamber.

Due to the alignment of annuli 102, 85, the pressure below check valve 104 is reduced to supply pressure (below the pressure in timing chamber 98), and the upper check valve 104 is unseated so that the pressure in the timing chamber 98 is reduced, or dumped, to supply pressure, while the primary plunger is decelerating. The relationships that exist at the instant of dumping the pressurized fuel from chamber 128, the nozzle 14, and chamber 98 are shown in Figure 5.

The downward travel of the primary pumping plunger 62 continues for the interval C—D, or until the plunger 62 reaches its maximum travel. The overtravel of the plunger 62 beyond the termination of injection (point C) and end of dumping (point D) provides sufficient time to equalize the pressures in the injector at supply pressure and to provide the necessary range of timing and injection. When plunger 62 reaches point D, the nadir of travel, and then starts to travel upwardly under the urging of main spring 18, its return trip to its peak upward position occurs over a major portion of the cycle of operation which corresponds to the metering phase (Figures 6 and 7).

The curve from point D through points E and F is substantially a linear curve having a constant slope. The linear slope is achieved by a unique profile on the cam 22, which slope is important to the proportional operation of the metering phase of operation. Point E represents the instant that the metering function ceases and corresponds to the termination of the signal from the electronic control unit. The termination of the signal to control valve 146 causes the control valve to return to its normally opened condition, which allows the timing chamber 98 to reach an equilibrium condition with the fuel at supply pressure in passage 42.

Spring 96 locks secondary plunger 90 in fixed position in metering chamber 128, and plunger 62 can move independently in response to the application of forces by rocker arm 30 and spring 18. This termination is described in conjunction with the description of Figure 7.

The metering function can be terminated at any point along the slope D—F; if the metering function is terminated shortly after the primary plunger starts its return trip, then the interval D—E will be shorter than the interval from E—F. The greater the interval D—E, the greater the volume of fuel admitted into metering chamber 128. It is to be noted that the linearity of the portion of the curve between points D and F permits a direct, proportional relationship between the amount of fuel metered and the number of degrees of camshaft rotation. The interval, in degrees of rotation, between points D and F represents the maximum volume of fuel which can be metered, any lesser amount is a direct function (proportional) to the number of degrees of rotation the control valve remains closed after point D. Thus, if point E occurs one-half the number of degrees between D and F, one-half the quantity of fuel is metered.

It should be noted that the metering function can occur, potentially, over more than half the cycle of operation. This "stretching out" of the metering function increases the opportunity to accurately fill the metering chamber 128 to the desired level. As described above, the slope of the curve D—F through the metering function is linearly proportional to the degrees of angular rotation of the crankshaft 26. Thus, if the metering function is assumed to occur, potentially, over 300° of angular rotation for the crankshaft for a two cycle engine, then the termination of the signal from electronic control unit 52 to control valve 146 after 150° of angular rotation, would allow the metering chamber 128 to be half-filled. Alternatively, if the termination of the signal from electronic control unit 52 to control valve 146 occurred after 75° of rotation, metering chamber 128 would be a quarter-filled. Obviously, the metering chamber can be filled to an infinite variety of fractional levels.

It will be readily apparent to the skilled artisan that the foregoing embodiment of this fuel injection system is susceptible of numerous changes without departing from the basic inventive concepts. For example, the primary pumping plunger 62 and follower 20 could be formed as a unitary plunger, and the check valves 104, 112, which are preferably shown as poppet valves, could be disc valves, ball valves, etc. The control valve 146, which is shown as a gate valve responsive to electromagnetic forces, could assume diverse other forms. The profile of cam 22 can also be altered to adjust the duration of the metering function and the rate of return of the primary plunger 62. Also, the spring 96 could be joined to the central bore of the injector, and need not have one end seated

in a cavity in the primary pumping plunger; the key consideration is the ability of the spring 96 to always exert a downward force on the secondary plunger and, when necessary, at the end of the metering operation, lock plunger 90 in fixed position.

### Claims

1. A fuel injector (10), for an internal combustion engine comprising a body having an axially extending bore (97), a primary pumping plunger (62) and a secondary plunger (90) positioned within said bore for axial movement therein in response to the movement of said primary pumping plunger (62), a nozzle (14) situated at the end of said bore (97) remote from said primary pumping plunger (62), a timing chamber (98) defined in said body between said primary plunger (62) and said secondary plunger (90), a metering chamber (128) defined in said bore between said secondary plunger (90) and said nozzle (14), passages (42, 43, 80, 82) in said body of said injector (10) for receiving pressurized fuel and transmitting said fuel into said timing chamber (98) and said metering chamber (128), characterized in that it comprises an electronically operated control element (146) situated intermediate said passages (42, 43, 80, 82) and said timing chamber (98) and adapted to be selectively energized to regulate the timing of the discharge of fuel from the metering chamber (128) through the nozzle (14), and to regulate the quantity of fuel discharged through the nozzle, and to control the quantity of fuel stored in said metering chamber (128) subsequent to said discharge of fuel wherein said electromagnetic control element (146) controls the admission of fuel into said timing chamber (98) for creating a hydraulic link between said primary pumping plunger (62) and said secondary plunger (90) to selectively hydraulically connect said primary pumping plunger (62) and said secondary plunger (90) wherein said control element (146) is at one of a closed or opened state the latter to create a pressure condition in said timing chamber (98) to permit independent movement of said primary pumping plunger (62) relative to said secondary plunger (90) during a portion of the operation of the injector.

2. A fuel injector according to Claim 1, characterized in that said pressure condition is an equilibrium pressure condition.

3. A fuel injector according to Claims 1 or 2, characterized in that said secondary plunger (90) is biased in a normal position.

4. A fuel injector according to Claim 3, characterized in that the lower end of said primary pumping plunger (62) has a cavity (86) defined therein and the upper end of said secondary plunger (90) has a recess (94) defined therein, the injector further including spring means (96), the opposite ends of said spring

means being seated in said cavity (86) and said recess (94).

5. A fuel injector according to Claim 2, characterized in that it comprises a first check valve (104) interconnected to control fuel flow between said timing chamber (92) and said passages for periodically eliminating said hydraulic link between said primary pumping and said secondary plungers (62, 90).

6. A fuel injector according to Claim 5, characterized in that said first check valve (104) is unseated to release fuel from said timing chamber (92) into said passages when the secondary plunger (90) approaches its most downward position.

7. A fuel injector according to Claim 2, characterized in that said secondary element (90) has elongated axially extending passages (124, 126) defined in its lower end, said axially extending passages (124, 126) opening at one end into said metering chamber (128), and said passages (124, 126) momentarily dumping fuel at high pressures back into said passages (80, 82) in the injector body when the injection phase of the cycle of operation is terminated.

8. A fuel injector according to Claim 6, characterized in that said secondary plunger (90) has an annulus (112) defined near its mid-section, said annulus (112) leading into a cross-hole (114) which communicates with a short axial passage (116), said short axial passage (116) communicates with said elongated axially extending passages (124, 126) that open into said metering chamber (128), a second check valve (118), and a spring (121) to normally bias said second check valve (118) against its seat (120) to prevent communication between said annulus (112) and said metering chamber (128), said second check valve being unseated only during the metering phase of the cycle of operation to allow fuel at supply pressure from the passages (80, 82) in the injector body to enter the annulus (112) and proceed downwardly into the metering chamber (128) through said axially extending passages (124, 126).

9. A fuel injector according to Claim 1, characterized in that the volumes of said timing chamber (98) and said metering chamber (128) are varied during each cycle of operation of said fuel injector in accordance with engine operating conditions.

10. A fuel injector according to Claims 1, 2 or 8, characterized in that a portion of said operation is metering and said metering chamber volume is varied linearly during said metering portion.

11. A fuel injector according to Claim 3, characterized in that it comprises spring means (96) situated in said central bore (97) for biasing the secondary plunger (90) toward said nozzle (14).

12. The fuel injector according to Claim 1 characterized in that one of said passages (82) communicates said timing chamber (98) or said

metering chamber (128) to a reservoir (32) or to a return conduit (44).

13. The fuel injector according to Claim 1 characterized in that one of said passages (82) communicates both said timing chamber (98) and said metering chamber (128) to a reservoir or to a return conduit (44).

14. A method of operating a fuel injector (10) of Claim 1, said method comprising the steps of:

a) introducing fuel at supply pressure into said passages (42, 43, 80, 82) and said chambers (98, 128);

b) applying a force to the primary pumping plunger (62) to move same axially in relation to the operating cycle of the internal combustion engine;

characterized in that it further comprises the steps of:

c) supplying an electrical signal to the control valve means (146) to seal the timing chamber (98) and form a hydraulic link between the primary plunger (62) and secondary plunger (90) and moving them in concert;

d) discharging the fuel in the metering chamber (128) through the nozzle (14) in response to the electrical signal; and

e) filling the metering chamber (128) to a desired level prior to terminating the electrical signals;

f) terminating the electrical signal to the control valve means (146) to open the timing chamber and break the hydraulic link between the primary pumping plunger (62) and the secondary plunger (90) and moving said primary pumping plunger independently of said secondary plunger.

15. A method according to Claim 14, characterized in that it further comprises the step of aligning passages formed in the secondary plunger with the passages (42, 43, 80, 82) in the body of the injector (10) after discharging the fuel so that excess fuel trapped in the nozzle (14), metering chamber (128) and timing chamber (98) can be readily vented.

## Revendications

1. Un injecteur (10) de carburant pour un moteur à combustion interne, comprenant un corps ayant un alésage (97) s'étendant axialement, un plongeur de pompage primaire (62) et un plongeur secondaire (90) positionné à l'intérieur dudit alésage de façon à pouvoir s'y déplacer axialement en réponse au déplacement dudit plongeur de pompage primaire (62), une buse (14) située à l'extrémité dudit alésage (97) éloignée dudit plongeur de pompage primaire (62), une chambre (98) de fixation du point d'injection formée dans ledit corps entre ledit plongeur primaire (62) et ledit plongeur secondaire (90), une chambre de dosage (128) formée dans ledit alésage entre ledit plongeur secondaire (90) et ladite buse (14), des passages (42, 43, 80, 82) formés dans ledit corps dudit injecteur (10) pour recevoir du

carburant sous pression et transmettre ledit carburant à ladite chambre (98) de fixation du point d'injection et à ladite chambre de dosage (128), caractérisé en ce qu'il comprend un élément de commande (146) actionné électriquement situé entre lesdits passages (42, 43, 80, 82) et ladite chambre (98) de fixation du point d'injection et agencé de manière à pouvoir être sélectivement excité pour régler le moment de l'éjection du carburant hors de la chambre de dosage (128) par la buse (14) et pour régler la quantité de carburant éjectée par la buse et pour commander la quantité de carburant emmagasinée dans ladite chambre de dosage (128) à la suite de ladite éjection de carburant, en ce que ledit élément de commande (146) électromagnétique commande l'admission de carburant dans ladite chambre (98) de fixation du point d'injection pour créer une liaison hydraulique entre ledit plongeur de pompage primaire (62) et ledit plongeur secondaire (90) pour relier sélectivement hydrauliquement ledit plongeur de pompage primaire et ledit plongeur secondaire, et en ce que ledit élément de commande (146) est dans l'un de deux états, fermé ou ouvert, ce dernier état servant à créer une condition de pression dans ladite chambre (98) de fixation du point d'injection permettant un déplacement indépendant dudit plongeur de pompage primaire (62) par rapport audit plongeur secondaire (90) pendant une partie du fonctionnement de l'injecteur.

2. Un injecteur de carburant selon la revendication 1, caractérisé en ce que ladite condition de pression est une condition de pression en équilibre.

3. Un injecteur de carburant selon la revendication 1 ou 2, caractérisé en ce que ledit plongeur secondaire (90) est sollicité à une position normale.

4. Un injecteur de carburant selon la revendication 3, caractérisé en ce qu'une cavité (86) est formée dans l'extrémité inférieure dudit plongeur de pompage primaire (62) et un évidement (94) est formé dans l'extrémité supérieure dudit plongeur secondaire (90), l'injecteur comprenant, en outre, des moyens élastiques (96), les extrémités opposées desdits moyens élastiques étant en appui dans ladite cavité (86) et dans ledit évidement (94).

5. Un injecteur de carburant selon la revendication 2, caractérisé en ce qu'il comprend une première soupape de retenue (104) montée de manière à commander l'écoulement du carburant entre ladite chambre (98) de fixation du point d'injection et lesdits passages pour supprimer périodiquement ladite liaison hydraulique entre lesdits plongeurs de pompage primaire et secondaire (62, 90).

6. Un injecteur de carburant selon la revendication 5, caractérisé en ce que ladite soupape de retenue (104) est écartée de son siège pour décharger le carburant depuis ladite chambre (98) de fixation du point d'injection

dans lesdits passages lorsque le plongeur secondaire (90) s'approche de sa position basse extrême.

7. Un injecteur de carburant selon la revendication 2, caractérisé en ce que des passages allongés (124, 126) s'étendant axialement sont formés dans l'extrémité inférieure dudit plongeur secondaire (90), lesdits passages (124, 126) s'étendant axialement débouchant, à une extrémité, dans ladite chambre de dosage (128) et lesdits passages (124, 126) déchargeant momentanément le carburant à haute pression en retour dans lesdits passages (80, 82) formés dans le corps de l'injecteur lorsque la phase d'injection du cycle de fonctionnement est terminée.

8. Un injecteur de carburant selon la revendication 7, caractérisé en ce que ledit plongeur secondaire (90) comporte un espace annulaire (112) formé au voisinage de son milieu, ledit espace annulaire (112) débouchant dans un passage transversal (114) qui communique avec un court passage axial (116), ledit court passage axial (116) communiquant avec lesdits passages allongés (124, 126) qui débouchent dans ladite chambre de dosage (128), une seconde soupape de retenue (118) et un ressort (121) pour solliciter normalement ladite seconde soupape de retenue (118) en appui contre son siège (120) afin d'empêcher la communication entre ledit espace annulaire (112) et ladite chambre de dosage (128), ladite seconde soupape de retenue n'étant écartée de son siège que pendant la phase de dosage du cycle de fonctionnement, pour permettre au carburant à la pression d'alimentation des passages (80, 82) formés dans le corps de l'injecteur de pénétrer dans l'espace annulaire (112) et de s'écouler vers le bas jusque dans la chambre de dosage (128) par lesdits passages (124, 126) s'étendant axialement.

9. Un injecteur de carburant selon la revendication 1, caractérisé en ce que les volumes de ladite chambre (98) de fixation du point d'injection et de ladite chambre de dosage (128) sont modifiés au cours de chaque cycle de fonctionnement dudit injecteur de carburant en conformité avec les conditions de fonctionnement du moteur.

10. Un injecteur de carburant selon la revendication 1, 2 ou 8, caractérisé en ce qu'une partie du fonctionnement est une opération de dosage et ledit volume de la chambre de dosage varie linéairement pendant ladite partie de dosage.

11. Un injecteur de carburant selon la revendication 3, caractérisé en ce qu'il comprend des moyens élastiques (96) situés dans ledit alésage central (97) pour solliciter ledit plongeur secondaire (90) en direction de ladite buse (14).

12. L'injecteur de carburant selon la revendication 1, caractérisé en ce que l'un desdits passages (82) fait communiquer ladite chambre (98) de fixation du point d'injection ou ladite

chambre de dosage (128) avec un réservoir (32) ou avec un conduit de retour (44).

13. L'injecteur de carburant selon la revendication 1, caractérisé en ce que l'un desdits passages (82) fait communiquer à la fois ladite chambre (98) de fixation du point d'injection et ladite chambre de dosage (128) avec un réservoir ou avec un conduit de retour (44).

14. Un procédé d'utilisation d'un injecteur de carburant (10) de la revendication 1, ce procédé comportant les étapes qui consistent:

a) à introduire du carburant à la pression d'alimentation dans lesdits passages (42, 43; 80, 82) et lesdites chambres (98, 128);

b) à appliquer une force au plongeur de pompage primaire (62) pour le déplacer axialement en rapport avec le cycle de fonctionnement du moteur à combustion interne;

caractérisé en ce qu'il comprend, en outre, les étapes qui consistent:

c) à appliquer un signal électrique aux moyens formant valve de commande (146) pour obturer la chambre (98) de fixation du point d'injection et établir une liaison hydraulique entre le plongeur primaire (62) et le plongeur secondaire (90) et de façon que ceux-ci se déplacent à l'unisson;

d) à éjecter le carburant contenu dans la chambre de dosage (128) par la buse (14) en réponse au signal électrique; et

e) à remplir la chambre de dosage (128) à un niveau désiré avant la fin du signal électrique;

f) à terminer l'application du signal électrique aux moyens formant valve de commande (146) pour ouvrir la chambre de fixation du point d'injection et rompre la liaison hydraulique entre le plongeur de pompage primaire (62) et le plongeur secondaire (90) et à déplacer ledit plongeur de pompage primaire indépendamment dudit plongeur secondaire.

15. Une procédé selon la revendication 14, caractérisé en ce qu'il comporte, en outre, l'étape qui consiste à aligner des passages formés dans le plongeur secondaire avec les passages (42, 43, 80, 82) formés dans le corps de l'injecteur après éjection du carburant de sorte que le carburant en excès emprisonné dans la buse (14), la chambre de dosage (128) et la chambre (98) de fixation du point d'injection peut être facilement évacué.

## Patentansprüche

1. Kraftstoff-Einspritzventil (10) für eine Brennkraftmaschine, mit einem Gehäuse, das eine axial verlaufende Bohrung (97) aufweist, einem primären Pumpkolben (62) und einem sekundären Kolben (90), der in der Bohrung angeordnet ist und in Abhängigkeit von der Bewegung des primären Pumpkolbens (62) axial bewegbar ist, einer Düse (14), die an dem vom primären Pumpkolben (62) abgewandten Ende der Bohrung (97) angeordnet ist, einer Zeitgeberkammer (98), die in dem Gehäuse zwischen dem primären Pumpkolben (62) und

dem sekundären Kolben (90) gebildet ist, einer Zumeßkammer (128), die in der Bohrung zwischen dem sekundären Kolben (90) und der Düse (14) gebildet ist, im Gehäuse des Einspritzventils (10) gebildeten Kanälen (42, 43, 80, 82), die unter Druck stehenden Kraftstoff empfangen und diesen Kraftstoff an die Zeitgeberkammer (98) und die Zumeßkammer (128) weiterleiten, dadurch gekennzeichnet, daß es ein elektronisch betätigtes Steuerelement (146) aufweist, das zwischen den Kanälen (42, 43, 80, 82) und der Zeitgeberkammer (98) angeordnet ist und wahlweise erregbar ist, um die Zeitsteuerung der Kraftstoffabgabe aus der Zumeßkammer (128) durch die Düse (14) zu regeln und um die Menge des durch die Düse abgegebenen Kraftstoffes zu regeln und um die Menge des Kraftstoffes, die in der Zumeßkammer (128) im Anschluß an die Kraftstoffabgabe gespeichert wird, zu steuern, daß das elektromagnetische Steuerelement (146) die Kraftstoffzufuhr in die Zeitgeberkammer (98) steuert, um eine hydraulische Verbindung zwischen dem primären Pumpkolben (62) und dem sekundären Kolben (90) zu erzeugen und dadurch den primären Pumpkolben (62) und den sekundären Kolben (90) wahlweise hydraulisch zu verbinden, und daß sich das Steuerelement (146) in geschlossenem oder offenem Zustand befindet, um in letzterem Zustand eine Bedingung in der Zeitgeberkammer (98) zu erzeugen, die während eines Teiles des Betriebes des Einspritzventils eine unabhängige Bewegung des primären Pumpkolbens (62) relativ zum sekundären Kolben (90) zuläßt.

2. Kraftstoff-Einspritzventil nach Anspruch 1, dadurch gekennzeichnet, daß die besagte Druckbedingung ein Druckgleichgewicht ist.

3. Kraftstoff-Einspritzventil nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß der sekundäre Kolben (90) in eine Normalstellung vorgespannt ist.

4. Kraftstoff-Einspritzventil nach Anspruch 3, dadurch gekennzeichnet, daß das untere Ende des primären Pumpkolbens (62) einen darin gebildeten Hohlraum (86) aufweist und das obere Ende des sekundären Kolbens (90) eine darin gebildete Ausnehmung (94) aufweist, wobei das Einspritzventil außerdem Federmittel (96) umfaßt, deren entgegengesetzte Enden in dem Hohlraum (86) und der Ausnehmung (94) sitzen.

5. Kraftstoff-Einspritzventil nach Anspruch 2, gekennzeichnet durch ein erstes Rückschlagventil (104), das den Kraftstofffluß zwischen der Zeitgeberkammer (92) und den Kanälen so steuert, daß die hydraulische Verbindung zwischen dem primären Pumpkolben (62) und dem sekundären Kolben (90) periodisch aufgehoben wird.

6. Kraftstoff-Einspritzventil nach Anspruch 5, dadurch gekennzeichnet, daß das erste Rückschlagventil (104) zur Freigabe von Kraftstoff aus der Zeitgeberkammer (92) an die Kanäle abgehoben wird, wenn der sekundäre Kolben

(90) sich seiner untersten Stellung nähert.

7. Kraftstoff-Einspritzventil nach Anspruch 2, dadurch gekennzeichnet, daß der sekundäre Kolben (90) langgestreckte, axial verlaufende Kanäle (124, 126) aufweist, die in seinem unteren Ende gebildet sind, wobei die axial verlaufenden Kanäle (124, 126) an einem Ende in die Zumeßkammer (128) münden, und daß diese Kanäle (124, 126) unter hohem Druck stehenden Kraftstoff kurzzeitig an die im Gehäuse gebildeten Kanäle (80, 82) zurückführen, wenn die Einspritzphase des Betriebszyklus beendet ist.

8. Kraftstoff-Einspritzventil nach Anspruch 6, dadurch gekennzeichnet, daß der sekundäre Kolben (90) einen Ringraum (112) aufweist, der nahe seines Mittelabschnittes gebildet ist, wobei der Ringraum (112) in eine Querbohrung (114) mündet, die mit einem kurzen axialen Kanal (116) in Verbindung steht, wobei der kurze axial Kanal (116) mit den langgestreckten axial verlaufenden Kanälen (124, 126) verbunden ist, die in die Zumeßkammer (128) münden, und daß ein zweites Rückschlagventil (118) vorgesehen ist, das von einer Feder (121) normalerweise gegen seinen Sitz (120) gedrückt wird, um eine Verbindung zwischen dem Ringraum (112) und der Zumeßkammer (128) zu unterbrechen, wobei das zweite Rückschlagventil nur während der Zumeßphase des Betriebszyklus vom Sitz abgehoben wird, damit Kraftstoff unter Zufuhrdruck aus den im Gehäuse gebildeten Kanälen (80, 82) in den Ringraum (112) eintreten und nach unten durch die axial verlaufenden Kanäle (124, 126) in die Zumeßkammer (128) fortschreiten kann.

9. Kraftstoff-Einspritzventil nach Anspruch 1, dadurch gekennzeichnet, daß die Volumina der Zeitgeberkammer (98) und der Zumeßkammer (128) während jedes Betriebszyklus des Kraftstoff-Einspritzventils in Abhängigkeit von Betriebsbedingungen der Brennkraftmaschine veränderbar sind.

10. Kraftstoff-Einspritzventil nach Anspruch 1, 2 oder 8, dadurch gekennzeichnet, daß ein Teil des Betriebes ein Zumessen ist und daß das Volumen der Zumeßkammer während des Zumeßvorganges linear verändert wird.

11. Kraftstoff-Einspritzventil nach Anspruch 3, dadurch gekennzeichnet, daß in der zentralen Bohrung (97) Federmittel (96) angeordnet sind, die den sekundären Kolben (90) in Richtung auf die Düse (14) vorspannen.

12. Kraftstoff-Einspritzventil nach Anspruch 1, dadurch gekennzeichnet, daß einer der Kanäle (82) die Zeitgeberkammer (98) oder die Zumeßkammer (128) mit einem Reservoir (32) oder einer Rückführleitung (44) verbindet.

13. Kraftstoff-Einspritzventil nach Anspruch 1, dadurch gekennzeichnet, daß einer der Kanäle (82) sowohl die Zeitgeberkammer (98) wie auch die Zumeßkammer (128) mit einem Reservoir oder einer Rückführleitung (44) verbindet.

14. Verfahren zur Betätigung eines Kraft-

stoff-Einspritzventils (10) nach Anspruch 1 mit folgenden Schritten:

a) Einführen von Kraftstoff unter Zufuhrdruck in die Kanäle (42, 43, 80, 82) und die Kammern (98, 128);

b) Ausüben einer Kraft auf den primären Pumpkolben (62), um diesen in Abhängigkeit vom Betriebszyklus der Brennkraftmaschine axial zu bewegen;

gekennzeichnet durch folgende weiteren Schritte:

c) Abgabe eines elektrischen Signals an die Steuerventilmittel (146), um die Zeitgeberkammer (98) abzudichten und eine hydraulische Verbindung zwischen dem primären Pumpkolben (62) und dem sekundären Kolben (90) herzustellen und sie gemeinsam zu bewegen;

d) Abgabe von Kraftstoff an die Zumeßkammer (128) durch die Düse (14) in Abhängigkeit von dem elektrischen Signal;

e) Auffüllen der Zumeßkammer (128) auf ein vorgegebenes Niveau vor Beendigung der elektrischen Signale;

f) Beendigung der Abgabe des elektrischen Signals an die Steuerventilmittel (146), um die Zeitgeberkammer zu öffnen und die hydraulische Verbindung zwischen dem primären Pumpkolben (62) und dem sekundären Kolben (90) zu unterbrechen und den primären Pumpkolben unabhängig vom sekundären Kolben zu bewegen.

15. Verfahren nach Anspruch 14, gekennzeichnet durch den folgenden weiteren Schritt, daß in sekundären Kolben gebildete Kanäle zu den Kanälen (42, 43, 80, 82) im Gehäuse des Einspritzventils (10) nach Abgabe des Kraftstoffes ausgerichtet werden, sodaß in der Düse (14), der Zumeßkammer (128) und der Zeitgeberkammer (98) gefangener überschüssiger Kraftstoff rasch abgeführt werden kann.

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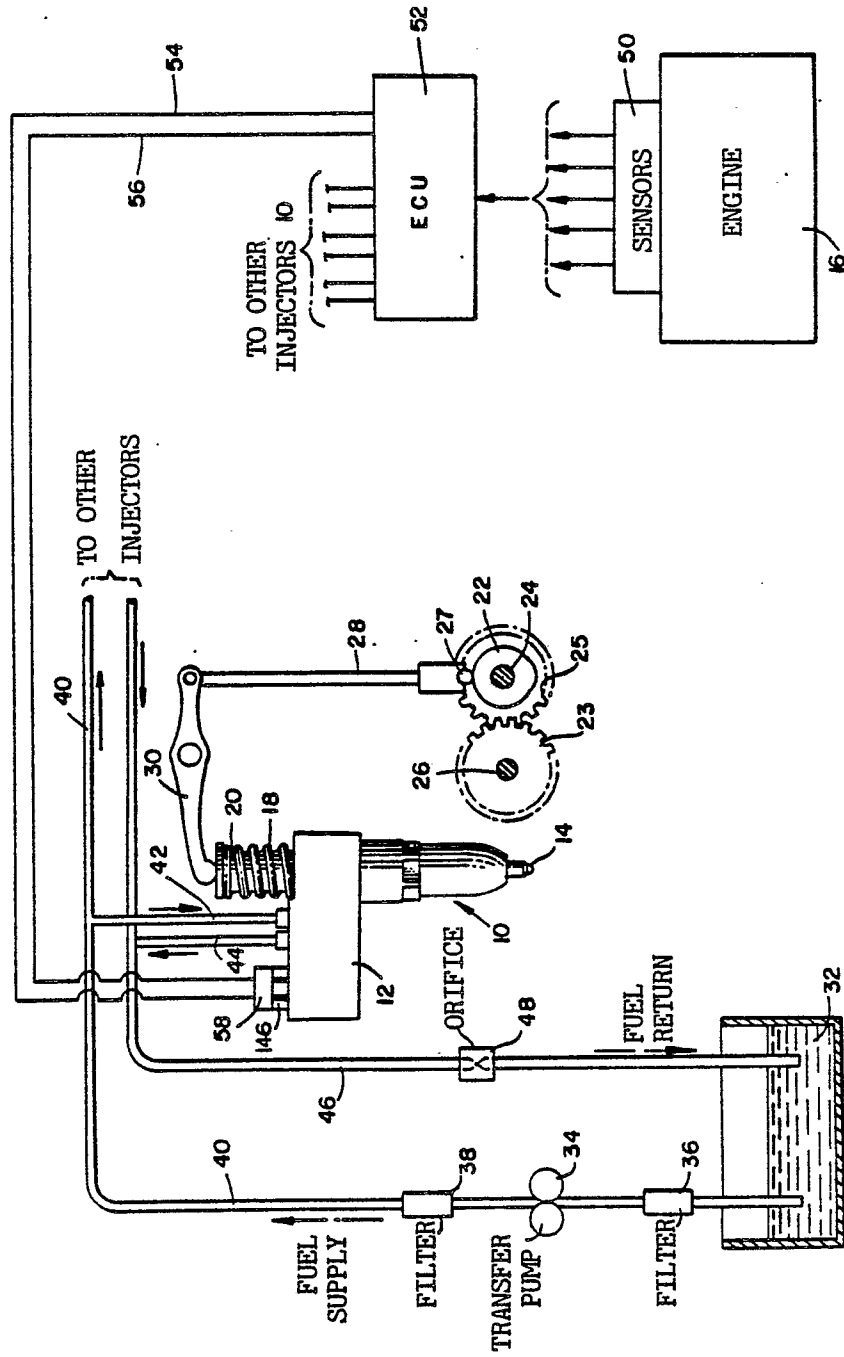
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FIG. 1.



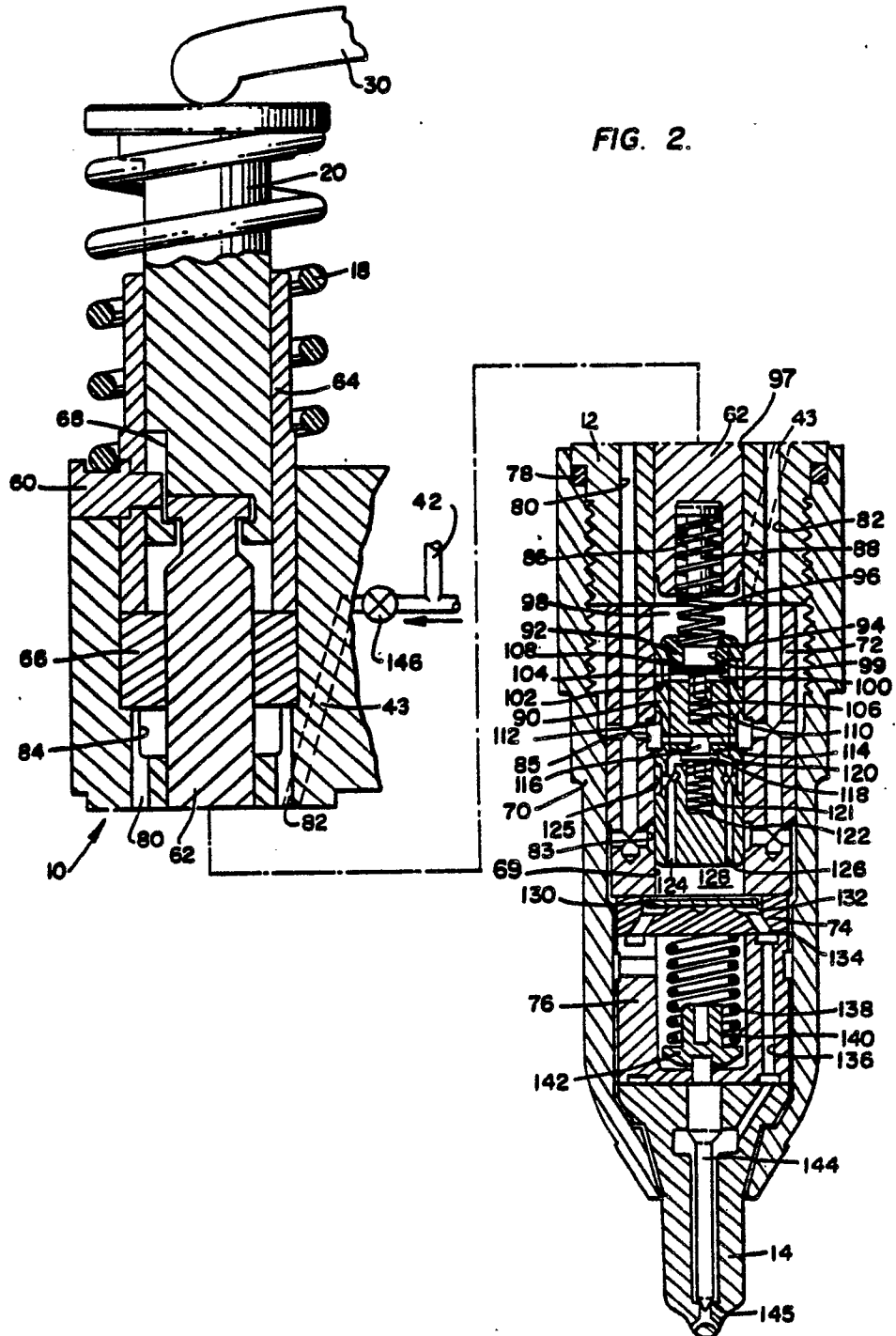


FIG. 3.

STARTING POSITION

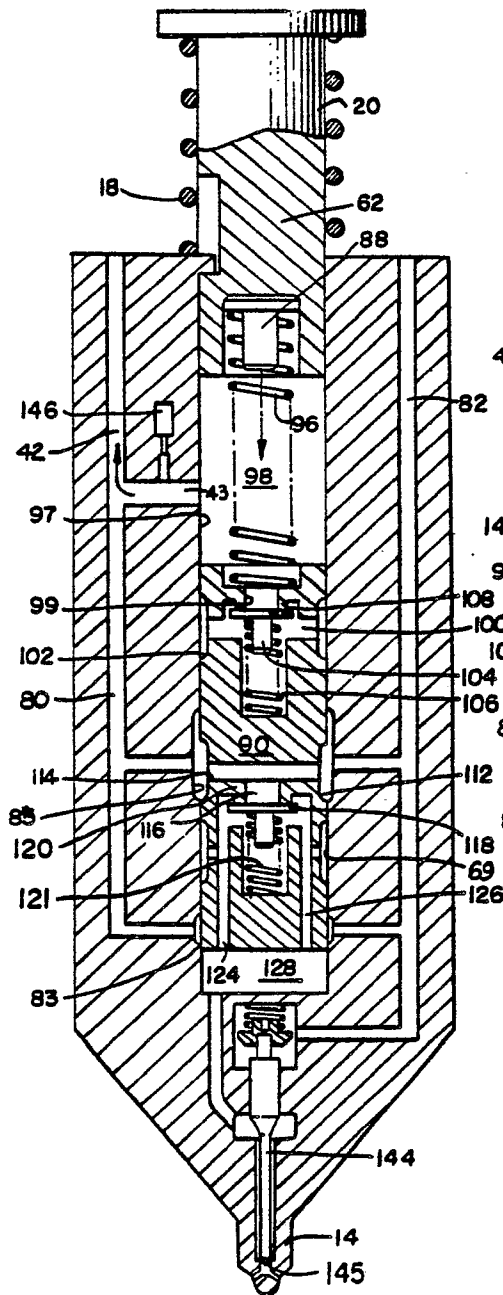


FIG. 4.

INJECTION OPERATION

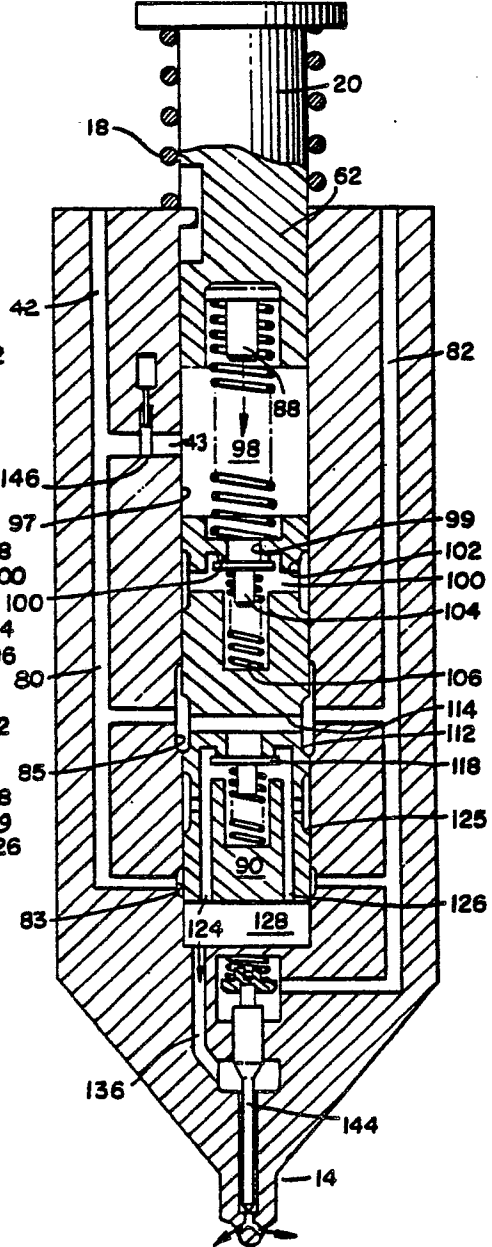


FIG. 5.

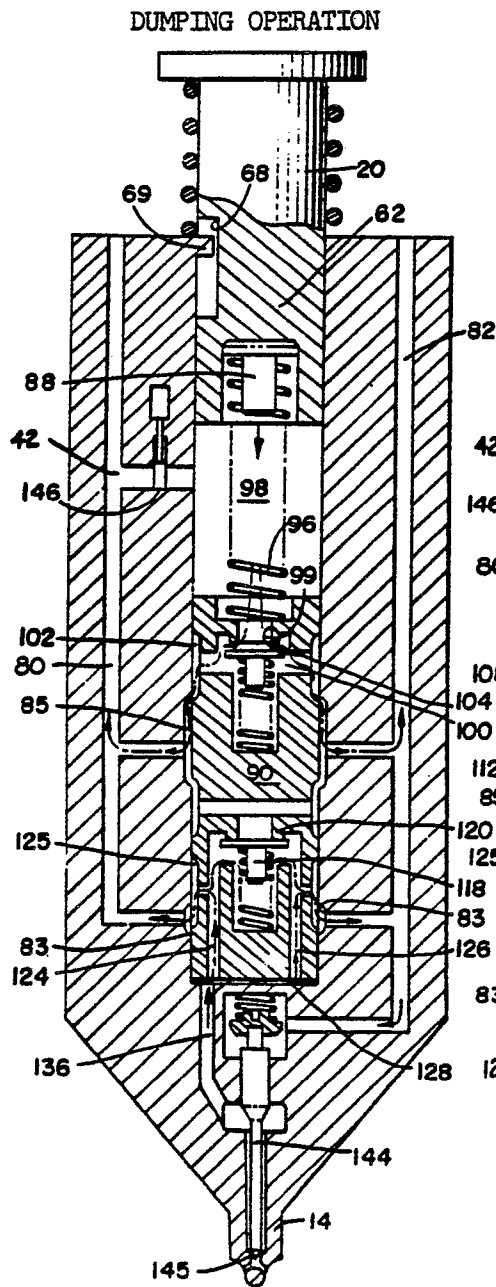


FIG. 6.

