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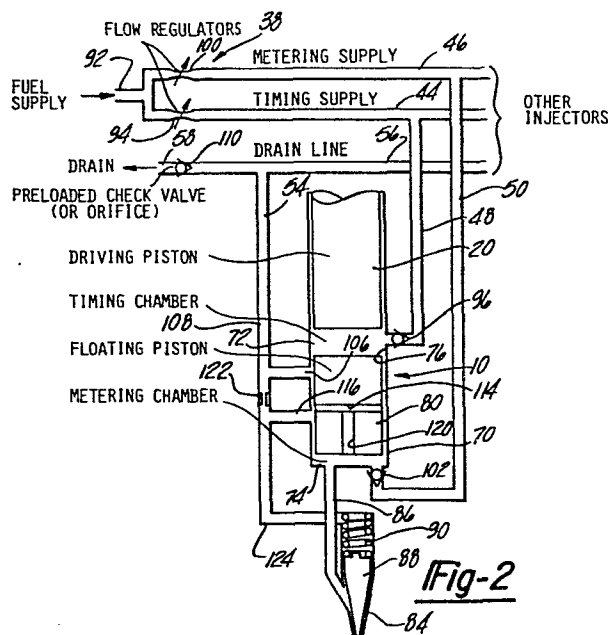
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Control system for controlling the supply of fuel to an internal combustion engine.

A control system for controlling the supply of fuel from a source (32) to an internal combustion engine (16) having a crankshaft (26) and a plurality of cylinders, the system comprising at least one injector (10) having a body (70), a primary pumping plunger (20) and a secondary plunger (80) positioned within said body for movement therein, a nozzle (84) situated contiguous with the engine (16), a timing chamber (72) defined in said body between said primary pumping plunger (20) and said secondary plunger (80), a metering chamber (74) defined in said body between said secondary plunger (80) and said nozzle (84), timing and metering passages (42, 44, 46, 48, 50, 92) in said body (70) of said injector (10) for receiving pressurized fuel and transmitting said fuel into said timing chamber (72) and said metering chamber (74), means (38, 94, 100) for controlling (1) the timing of the discharge of fuel from the metering chamber (74) through the nozzle (84) and (2) the quantity of fuel stored in said metering chamber (74), characterized in that it includes a control valve (94, 100) in each of said timing and metering passages (44, 46) for controlling the flow of fuel from the source (32) to said timing chamber (72) and said metering chamber (74), and means for pulsing in an on/off fashion, each of said control valves in response to engine operating conditions.



CONTROL SYSTEM FOR CONTROLLING THE SUPPLY
OF FUEL TO AN INTERNAL COMBUSTION ENGINE

The instant invention relates generally to fuel injection systems, and more particularly to mechanically or electrically operated controlled control valves for separately regulating each of the timing and metering of fuel in a fuel injector forming a part of the fuel regulating system, thereby permitting separate adjustment of both timing and metering of fuel from the various nozzle portions of the injectors in response to engine operating conditions.

Fuel injectors that are driven mechanically from the crankshaft of an internal combustion engine to deliver fuel into the cylinders of the engine are well known, see for example US Patent No. 2 997 994, issued August 29, 1961. The movement of the crankshaft is translated into a force by a lever mechanism which periodically depresses the pump plunger in response to movement of a cam, cam follower and rocker arm mechanism. Since the rotation of the crankshaft reflects only engine speed, the frequency of the fuel injection operation was not readily adjustable with respect to other engine operating conditions. Particularly, such adjustment was not permitted to be adaptive in controlling the injection process in response to specific engine operating conditions occurring immediately before or contemporaneous with the injection process.

US Patents Nos. 4 235 374 and 4 281 792 disclose a single solenoid fuel injector which utilizes a primary pumping piston disposed to be actuated by the cam operated lever mechanism, a floating piston slidably mounted within the interior of the injector, and a nozzle portion contiguous with the fuel induction or combustion chamber of the engine. A timing chamber is formed between the primary pumping piston and the floating piston, the amount of fuel being fed to the timing chamber determining the timing of injection relative to engine operations. Also, a metering chamber is formed between the floating piston and the nozzle portion, the quantity of fuel fed to the metering chamber determining the amount of fuel being injected into each engine cylinder. The injector incorporates a single solenoid control valve which is utilized to control both the timing and metering for the injector. Particularly,

upon downward motion of the primary pumping piston, a control unit selects the time when the injection is to commence. When the injection is to start, the solenoid is actuated to form a hydraulic link between the primary piston and the floating piston by means of the fuel trapped in the timing chamber. Upon further downward motion of the pumping piston, the fuel in the metering chamber is injected into the engine in response to the pressure on the floating piston. At a certain point in the downward travel of the primary piston, the floating piston uncovers certain dump ports to cause the fuel in the timing chamber and metering chamber to be dumped back to the reservoir. During upward motion of the primary piston, the solenoid valve still being energized, fuel is metered into the metering chamber for injection in the subsequent cycle and the end of metering is determined by the deenergization of the solenoid valve. The primary piston continues to travel upwardly filling the timing chamber with fuel. The injector is then prepared for a subsequent timing and injection cycle.

US Patent No. 3 951 117, granted April 20, 1976 to Julius Perr, discloses a fuel supply system including hydraulic means for automatically adjusting the timing of fuel injection to optimize engine performance. The embodiment of the system shown in Figures 1-4 of the patent comprises an injection pump 17 including a body 151 having a charge chamber 153 and a timing chamber 154 formed therein. The charge chamber is connected to receive fuel from a first variable pressure fuel supply, such as valve 42, passage 44, and line 182, and a timing chamber is connected to receive fuel from a second variable pressure fuel supply by means of line 231. The pressure is controlled by means of pressure modifying devices 222 and 223. Fuel is delivered sequentially to each injector 15 within a set of injectors by means of a distributor 187.

The timing piston 156 is reciprocally mounted in the body of the injection pump, the piston 156 being disposed between the charge and timing chambers. A plunger 163 is reciprocally mounted in the body for exerting pressure on the fuel in the timing chamber from the cam mechanism 164. 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 supplied to the timing chamber. The fuel quantity is a function of the pressure of the fuel being supplied thereto, the pressure, in turn, being responsive to certain engine operating parameters such as speed and load. Movement of the plunger 163 in an injection stroke results in movement of the hydraulic

link and the timing piston, thereby forcing fuel into the associated combustion chamber. The fuel in the timing chamber is dumped at the end of each injection stroke into spill port 177 and spill passage 176.

The invention proposes a control system for controlling
5 the supply of fuel from a source to an internal combustion engine having a crankshaft and a plurality of cylinders, the system comprising at least one injector having a body, a primary pumping plunger and a secondary plunger positioned within said body for movement therein, a nozzle situated continuous with the engine, a timing chamber defined in said body
10 between said primary pumping plunger and said secondary plunger, a metering chamber defined in said body between said secondary plunger and said nozzle, timing and metering passages in said body of said injector for receiving pressurized fuel and transmitting said fuel into said timing chamber and said metering chamber, means for controlling (1) the timing
15 of the discharge of fuel from the metering chamber through the nozzle and (2) the quantity of fuel stored in said metering chamber, characterized in that it includes a control valve in each of said timing and metering passages for controlling the flow of fuel from the source to said timing chamber and said metering chamber, and means for pulsing in
20 an on/off fashion each of said control valves in response to engine operating conditions.

With the system of the present invention, in one embodiment a variable orifice control device is provided for each of the timing and metering functions, a single device being provided for all of the injectors
25 being utilized with a particular engine for each function. In another embodiment the timing and metering functions are controlled by controlled pulses of fuel being fed to each of the timing and metering chambers.

The system of the present invention includes an injector
30 which is similar to the injector described in US Patents 4 235 374 and 4 281 792 and in that it contains a timing and metering chamber separated by a floating piston. However, in the preferred embodiment of the present system, a controllable variable area orifice is interposed between the source of fuel and each of the timing and metering chambers to separately
35 control the amount of fuel being supplied to the timing and metering chambers during the non-injection portion of the injector cycle. In this way, a single timing orifice is supplied for the entire system, including all of the injectors for a single engine, and a single meter-

ing orifice is supplied to control the metering function for all of the injectors of a single engine. This system has an advantage over the variable pressure type systems in that the quantity of fuel supplied is a function of the square of the variation in fuel pressure whereas with
5 a variable orifice the relationship is one to one between fuel flow and orifice area.

Thus, the system may be more precisely controlled and the range of control need not be as great as would be the case with a variable pressure system. As may be perceived from a description of the
10 present invention, the control, which is responsive to various engine conditions, may take several forms. These forms include both mechanical and electrical control for each of the variable orifice control helmets. Thus, the instant invention easily lends itself to adaptive control of
15 both the timing and metering phases of operation of an internal combustion diesel engine. An alternative embodiment includes substituting pulse duration modulation of pulses of fuel being fed to the timing and metering chambers in lieu of the variable orifice control. Also a number of fixed duration pulses may be fed ^{to} the chambers, the control being accomplished by controlling the number of pulses.

20 The invention will now be detailed with reference to the accompanying drawings wherein :

- Figure 1 is a schematic diagram illustrating the various portions of the diesel fuel control system incorporation the features of the present invention ;

25 - Figure 2 is a schematic diagram illustrating certain details of the injector and control valves of the system of the present invention ;

- Figure 3 is a schematic diagram of a mechanical control system for controlling the variable orifices in the control elements of
30 Figure 2 ;

- Figure 4 is a sectional diagram illustrating one form of a variable orifice device, which is electromagnetically operated ;

- Figure 5 is a cross-sectional view of another form of variable orifice which may be mechanically or electrically operated ;

35 - Figure 6 is a schematic block diagram of an electrical control system of the present invention ;

- Figure 7 is a timing diagram illustrating the relationship between the cam profile associated with the cam shaft of a diesel engine

and the quantity of fuel and vapor in the timing chamber and the quantity of fuel in the metering chamber, the cumulative flow and flow rate into the timing chamber, and the cumulative flow into the metering chamber ;

5 - Figures 8a to 8f illustrate the relationship of the cam profile with specific functions being performed by the injector during the engine cycle ; and

10 - Figure 9 is a timing diagram illustrating the relationship between the cam profile and the pulse duration modulated pulses, which are utilized to control the flow into the timing and metering chambers in a modified form of the system of the present invention.

Turning now to the drawings, in particular Figure 1 thereof, there is schematically illustrated the major components of a fuel injection system employing a mechanically or electronically operated pair of control valves for regulating the timing and metering functions of each injector within the system. It is to be understood at the onset that a single control valve is provided for each of the timing and metering functions, the control valve being operated as a variable orifice, the orifice being varied in response to certain engine operating conditions. The system includes a fuel injector 10 that includes a connector block 12 and is controlled to deliver fuel through a nozzle 14 either directly or indirectly 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 in the form of a primary pumping plunger or piston being biased upwardly by heavy duty spring 18.

30 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, the crankshaft being 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 is driven by the pistons (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 translates the movement of the roller into axially directed forces acting on the primary pumping plunger or

piston 20. The forces act in opposition to the main spring 18 and vary in magnitude with the speed of the engine and the profile of the cam. The cam profile may be varied within the scope of the present invention to achieve a desired timing and primary piston speed as determined by
5 the operation of the engine and the configuration of the control system.

A reservoir 32 serves as a source of supply for the fuel used for control and to be dispensed by each injector 10, the fuel being withdrawn from the reservoir by constant pressure transfer pump 34. Filters 36, 37 remove impurities in the fuel and fuel is introduced to a
10 control unit 38 by means of a conduit 40, the fuel being at supply pressure. The controlled fuel flow rate out of the control unit 38 is fed to the series of injectors, injector 10 being shown, through a pair of conduits 44, 46, one conduit 44 supplying fuel for the timing function and the other conduit 46 supplying fuel for the metering function, as
15 will be more fully explained hereafter. The conduit 44 is connected to the block 12 of injector 10 by means of a conduit 48 and the conduit 46 is similarly connected to the block 12 by means of a conduit 50. During the dumping and/or venting portion of the injector cycle, fuel is returned from the injector 10, and the other injectors in the system, to the re-
20 servoir 32 by means of conduits 54, 56, 58. This is the fuel that is not injected into the engine and is primarily the fuel used to control the timing function of the system of the present invention. However, it is to be noted that this circulating fuel is kept at a minimum due to the configuration of the system.

25 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 to camshaft 24; several sensors 60 may be operatively associated with engine 16 to determine, inter alia, engine speed, temperature, manifold absolute pressure,
30 load on the engine, altitude and operator command. The sensors 60 generate electrical signals representative of the measured parameters and deliver the electrical signals to an electronic control unit 62, by means of a plurality of conductors 64. The electronic control unit then compares the measured parameters with reference values which may be stored
35 within a memory in the electronic control unit, the rotational speed and angular position of cam 22 also being taken into account, and the electronic control unit generates a signal to be delivered to the control unit 38. These signals, in turn, govern the control of the timing and

metering functions for each injector as determined by the control incorporated into the control unit 38. The signals from the electronic control unit 62 are fed to control unit 38 by means of conductors 66, 68.

Referring now to Figure 2, there is illustrated the details of the injector, the controlled supply of fuel to the injector, and the drain configuration. The injectors are shown in schematic form ; however for a better understanding of the operation of the injector, reference is made to US Patents 4 235 374 and 4 281 792. Specifically, the injector 10 includes a body member 70 which is divided into a timing chamber 72 and a metering chamber 74. The main driving piston or primary pumping plunger 20 is shown at the upper end of a cavity 76 formed within the body 70. The driving piston is adapted to be reciprocally driven within the cavity 76 along an axial direction thereof. The timing chamber is formed by the lower end of the driving piston 20 and a floating piston or secondary plunger 80, and the metering chamber is formed by the lower end of the secondary plunger 80 and the bottom of the cavity 76. The output from the metering chamber 74 is fed to a nozzle 84 by means of a conduit 86, the increase in pressure in metering chamber 74 created by the downward motion of driving piston 20 increasing the pressure at the nozzle 84 to raise a needle type valve element 88 against the force of a spring 90. This operation will be more fully explained hereafter.

Referring first to the timing function, fuel is fed to an input conduit 92 from the reservoir 32 of Figure 1. The fuel is directed through a variable orifice 94, the area of the orifice being varied in accordance with the signals being fed from electronic control units 62 to the control unit 38. Obviously, as orifice 94 is reduced, the flow of fuel through conduit 44 is similarly reduced and the amount of fuel fed to the timing chamber 72 per unit of time is similarly reduced. The fuel flows through conduits 44, 48 to the timing chambers 72 through a one way check valve 96, the check valve permitting the smooth flow of fuel into the timing chamber, but precluding the fuel from flowing out of the timing chamber through conduit 48.

The metering function is similarly controlled by means of a controllable variable orifice 100, the area of the orifice 100 again being controlled by control unit 38 in response to signals from the electronic control unit 62. The control of flow of fuel to the metering chamber 74 is directed through conduits 46, 50 through a one way check valve 102, the check valve permitting the smooth flow of fuel into the metering

chamber 74, but precluding fuel from flowing out of that chamber when the pressure is raised in metering chamber 74.

During the dump or pressure relieving stage of the operational cycle of the invention, as will be more fully explained hereafter, when floating piston 80 is driven to a point where the timing chamber 72 is in fluid communication with a conduit 106, the pressure within the timing chamber 72 is relieved to permit the fuel within chamber 72 to flow out of the timing chamber 72 through conduit 106 and a conduit 108 back to the reservoir through the drain conduit 58 and a check valve 110. This permits the driving piston 20 to be driven to the full extent of the downward motion of cam follower 30 depicted in Figure 1. In the preferred embodiment, prior to the fluid communication between chamber 72 and conduit 106, a passageway 114 in floating piston 80 is placed in fluid communication with a conduit 116 to relieve the pressure in metering chamber 74. The fluid in chamber 74 flows through an internal passageway 120, the passageway 114 and conduit 116 to the drain conduit 54. A restriction 122 is provided between passages 106 and 116 to create a pressure spike below the restriction 122. This pressure spike is utilized to pressurize the upper end of needle valve 88 through a conduit 124. This aids in seating the needle valve 88 within the nozzle 84 to terminate the injection of fuel into the internal combustion engine. The operation of the injector will be fully explained in conjunction with the description of Figures 8a through 8f. However, for purposes of clarity, a brief description of the operation will be given at this point.

Assuming the driving piston 20 is at its lowermost position and floating piston 80 is also at its lowermost position, and the timing chamber 72 and metering chambers 74 are not under pressure, the driving piston 20 starts its upward motion in response to the force of spring 18 (Figure 1) forcing the injector up as the follower arm 30 moves up. This reduces pressure in chamber 72, causing floating piston 80 to rise. This rise of floating piston 80 also creates a reduced pressure in metering chamber 74. This reduced pressure, plus the pressure created in conduits 44, 46 by the pressure pump 34 on valves 96, 102 permits fuel to fill metering chamber 74 and partially fill timing chamber 72. The flow rate of fuel into these chambers are controlled by variable orifices 100 and 94, respectively. The filling process continues until such time as the driving piston 20 has reached its upwardmost position. The time it takes for driving piston 20 to reach this portion is, of course, determined by

the engine speed. As the piston 20 moves downwardly, the valves 96 and 102 are seated to increase the pressure in chambers 72, 74 after the vapor portion of the volume in timing chambers 72 has been taken up by the volume of driving piston 20. Thereafter the increased pressure is
5 fed to the end of nozzle 84 by means of the conduit 86 to raise the needle valve 88 and commence injection. The driving piston continues its downward movement until such time as the pressure is relieved in timing and metering chambers 72, 74.

Referring now to Figure 3, there is illustrated a mechanical
10 control for the orifices 94, 100 described above in conjunction with descriptive of Figure 2. Specifically, the control system of Figure 3 includes an operator controlled throttle pedal 130, which feeds an operator command signal to a speed responsive device 132. The speed responsive device may take the form of a fly ball governor having a bias element
15 which is variable in response to the changing in position of the throttle pedal 130. The output of the speed response device may be a shaft 134 which is used to control the orifice of a variable orifice device 136, as is common in the art.

A variable-orifice timing valve 138 is controlled by a second
20 speed-responsive device 140, which again may take the form of a variable bias fly-ball governor. Both speed-responsive devices 132, 140 are driven by the engine. However, the variable input to the speed-responsive device 140 takes the form of a mechanical lever 142, the output of which is fed to the speed responsive device 140 by means of a mechanism 144 (depicted
25 as a single line). The pivot point for the lever 142 is formed by a fulcrum device 146, the position of the fulcrum device 146 being controlled by the speed-responsive portion of the speed responsive device 132. What would normally be the fixed point 148 is made variable in response to the position of the shaft 134. Thus, a feed-forward mechanism is
30 utilized to bias the speed-responsive device 140 in response to the operation of the speed-responsive device 132. This is utilized to control the area of the variable orifice device 138 by means of a shaft 150. Thus, the variable orifice metering valve 136 is controlled in response to operator command and speed, and the timing valve variable orifice device 138
35 is controlled in response to engine speed and engine load, the engine load exhibiting itself through the operation of the linkage 144.

As stated above, the system of the present invention could also be operated electrically and the electrical operation may be accomplished by a variable orifice device such as depicted in Figure 4. In Figure 4, fuel is introduced into the control device by means of a conduit 156 and the output fuel is fed to the plurality of injectors associated with the engine by means of a conduit 158. The control of fuel through the body 160 of the control element is accomplished by varying the area of the orifice between a movable valve member 162 and fixed valve seat formed by edge 164. Thus, as the area between plate 162 and seat 164 is varied, the flow of fuel is similarly varied in a linear fashion. The position of valve plate 162 is controlled by means of a magnetic voice coil 166, in the preferred embodiment the input signal to the coil 166 being supplied from the electronic control unit 62 described in conjunction with Figure 1. The signal to coil 166 has a tendency to raise plate 162 against the force created by a spring 168.

Another type of valve which could be substituted for the plate 162/valve seat 164 arrangement shown in Figure 4 is depicted in Figure 5. The valve assembly of Figure 5 is a spool valve having a movable body member 170 which is slidably mounted in a body 172. An input conduit 174 supplies fuel to a chamber 176 and the output thereof is fed to the injector by means of a conduit 178. Thus, as spool valve 170 is axially moved within the body 172, the fluid communication between chamber 176 and conduit 178 is varied. The spool valve 170 could be mechanically actuated or electrically actuated in a manner similar to that described in conjunction with Figure 4.

Referring now to Figure 6, there is illustrated a schematic block diagram of an electronic control system for use with the fuel system of the present invention. A comparison of the functions of Figure 6 with those of Figure 3 will indicate an analogy between the mechanical and electrical configurations. Specifically, an operator command signal is fed to a throttle sensor circuit 180 by means of an input connection 182. An actual engine speed signal is generated by means of an engine speed sensor circuit 184 in response to the output of an engine speed sensor 186. The two signals from circuits 180, 184 are compared by a comparator circuit 188 and the difference between the two outputs generates a control signal on a conductor 190, which control signal is utilized to control a variable area control circuit 192. The output of the variable area control circuit 192 may be utilized to control the variable

orifice 100 described in conjunction with the description of Figure 2. This signal is fed to the variable area device by means of a conductor 194. The comparator 188 operates to null the signal on conductor 190 to fix the position of the variable area device connected to conductor 194 during steady state operations of the engine.

The output signal on conductor 194 is also fed to a divide circuit 196, which is provided inputs from control circuit 192 by means of a conductor 198, and a speed signal from the speed sensor circuit 184 by means of conductors 200, 202, 204. The output signal from the variable area control circuit 192 is representative of power, the operator commanded signal input 182 as compared to the sensed signal at input 186, and this power signal is divided by a speed signal on conductor 204. Thus, the output of circuit 196 will provide an engine load signal on a conductor 208. This signal is utilized to aid in the control of the variable orifice timing circuit, which includes a variable area control circuit 210. The output of circuit 210 controls the variable area orifice 94 described in conjunction with Figure 2 by means of a signal on conductor 212. The input to the variable area control circuit 210 includes a speed signal from a conductor 214, the speed signal being trimmed by the load signal on conductor 208 by means of a load trim circuit 216. The main signal being fed to the variable area control circuit 210 is the speed signal on conductor 214 as modified by the load signal on conductor 208.

Thus, a purely electrical control for the system of the present invention has been provided with the system of Figure 6. It is to be understood that other control laws may be utilized to control the variable orifice devices to fit the needs of a particular diesel engine.

Referring now to Figure 7, there is illustrated the timing diagrams for the control devices of the present invention. Specifically, the cam profile is shown pictorially by means of a profile line 220 at the upper portion of Figure 7. When the cam reaches the uppermost portion of the stroke of the main driving piston and starts on a downward travel, it is seen that a cumulative flow into the metering chamber is derived and depicted in Figure 7 by means of dashed line 222. Similarly, the timing chamber accumulation of fuel is depicted by dashed line 224 and the amount of vacuum or vapor space in timing chamber is depicted by the distance between line 224 and line 220.

Another depiction of the timing chamber is illustrated in the middle graph wherein the cumulative flow into the timing chamber at the time the downward stroke commences is shown by a straight line having a positive slope which terminates at the point of injection. Thus, a constant flow of fuel into the timing chamber creates an accumulation of fuel. For purposes of illustration, this accumulation is shown as being linear. Injection occurs and is depicted by the horizontal line terminating in the dump mode of operation. Upon dumping, the pressure or the flow in the chamber is substantially reduced and the cycle commences again. The flow rate into the timing chamber is also depicted in the middle graph and is shown to be generally rising function which levels off to a constant flow rate until such time as injection occurs. At that time, the flow rate ceases until the dump mode occurs. Upon dumping, the fuel accumulated in the timing chamber is returned to the reservoir as depicted by the negative flow.

A similar graph is illustrated at the bottom of Figure 7, but relating to the metering chamber. However, for purposes of clarity, the flow rate diagram has been omitted. Thus, the flow accumulates in the metering chamber from the zenith point on the cam profile until such time as injection occurs. At injection, the flow ceases until the dump mode is achieved. At that time the flow goes negative to depict the slight flow of fuel out of the metering chamber.

Referring now to Figures 8A to 8F, which best depict the operation of the injection of the system of the present injection, there is illustrated a cam profile in Figure 8A and various phases of operation of the injector in Figures 8B to 8F. It is to be understood that the injector shown is merely a graphic showing and is not intended to actually represent a commercial embodiment of the injector. For purposes of clarity, the reference numerals utilized in conjunction with the description of Figure 2 will also be utilized in conjunction with the description of Figures 8B to 8F.

Figure 8A illustrates the cam profile and certain positions on the cam profile have been noted with numerals 1 through 6. Numerals 1 through 5 correspond in operation to Figures 8B through 8F respectively, and numeral 6 corresponds to the starting point at numeral 1. At position 1 on Figure 8a, the cam has reached a point whereby the piston is at its lowermost position, corresponding to the injector of Figure 8B. Subsequently, the driving piston rises to reach position 2, is at a

constant position between positions 2 and 3, and is driven downwardly at position 4 and 5. The driving piston 20 then reaches starting point at point 6 again.

Referring to Figure 8B, the driving piston 20 is at its lower-
5 most position and timing chamber 72 and metering chamber 74 have been relieved of pressure therein. Valves 96 and 102 are seated, needle valve 88 is seated in nozzle 84 and fuel is ready to be fed to the injector in response to the operation of the engine.

Referring now to Figure 8C, it is seen that the driving piston 20 has risen to the upper level and vapor has been created in the
10 timing chambers 72. The floating piston 80 is generally down at the bottom of the cavity in the body of the injector. It is to be noted that valves 96 and 102 are open to permit fuel to flow into the timing chamber 72 and metering chamber 74. The needle valve 88 is still seated in the
15 nozzle 84.

During the travel from point 2 to point 3 in Figure 8A as shown in Figure 8D, the timing chamber 72 has been partially filled with fuel to the level indicated while the check valve 96 is open, and metering chamber 74 is similarly filled, check valve 102 being open. It is
20 to be noted that the floating piston 80 has moved up, thereby closing the entrance to passages 106 and 116. In this way, fuel is precluded from spilling into the drain conduit 108.

Referring now to Figure 8E, the piston 20 is now at point 4 and is starting the downward travel to compress the vapor and pressurize
25 the fuel in the timing chamber 72 and metering chamber 74. The check valves 96 and 102 are closed due to the increased pressure in chambers 72, 74. The increased pressure in chamber 74 unseats the needle valve 88 in nozzle 84, thereby injecting fuel into the engine from the end of nozzle 84. The fuel is fed from the metering chamber to the nozzle end
30 by means of the conduit 124.

When the driving piston 20 reaches an area toward the bottom of the stroke, Figure 8F and position 5 on Figure 8A, the entrance to conduit 116 has been opened and fuel flows from metering chambers 74 through conduit 120 and conduit 114. Thus, the pressure within the metering chambers 74 is relieved. As explained previously, the restriction
35 122 creates a pressure spike in conduit 124 to force the needle valve 88 into the closed position. Similarly, the entrance to conduit 106 is uncovered, thereby permitting further downward travel of the floating pis-

ton 80 to thereby dump or vent the fuel from the timing chamber 72. Further downward movement of driving piston 20 from position 5 to position 6 on Figure 8A causes further fuel to be dumped from timing chamber 72.

5 As an alternative to the above described control mechanisms and circuits, the amount of fuel in the timing and metering chambers may be controlled by pulsing an on/off control valve which is positioned in the same part of the hydraulic circuit as the variable orifice control
10 injector would be provided with a controlled pulse of fuel for both the timing and metering chambers for each of the injectors. Thus, the on/off valve which replaces the variable orifice device will provide at least a single pulse of fuel for each injector per engine cycle, multiple
15 pulses being contemplated. This may be accomplished by reversing the lobe on the cam such that lobe is represented as a depression rather than a projection of the cam with the remaining portion of the cam such that it will hold the main piston down during the period metering of fuel into the timing and metering chamber is not occurring.

20 This is graphically illustrated at the top of Figure 9, the cam profile being shown as a dashed line. Thus, a window is created for metering fuel into the injector during the time that the cam profile is at the low point A. When metering is not occurring, the cam is at a high point B and remains there until metering is desired for that injector. It is to be understood that the remaining injectors are all at the high
25 point to preclude metering. Thus, each injector is isolated, one from the others, during metering there being no overlap of the depression at point for any two or more injectors.

Referring particularly to Figure 9, there is illustrated a timing diagram, which is correlated to the cam profile which is illustrated as the top curve in Figure 9. It is to be understood the cam
30 profile may be the negative of that shown. The middle curve, designated flow rate into timing chamber, illustrates a fuel pulse which is fed to the timing chamber of a single injector. As is seen from the dashed lines, the fuel pulse can be either lengthened or shortened, depending on the
35 amount of fuel which is desired to be introduced into the timing chamber. Similarly, the metering chamber pulse, illustrated at the bottom of Figure 9; is fed to the metering chamber of the injector of Figure 2. Again, this time-duration pulse may be lengthened or shortened, depending on the

amount of fuel desired to be introduced into the metering chamber.

With the state of the technology of the spark ignited gasoline engine art, it is conceived that a sequential electronic control unit utilized with such spark ignited engine, with the proper input sensing signals to sense engine parameters, could be utilized to generate the pulses disclosed in Figure 9. Thus, a sequential pulse-duration modulation of the quantity of fuel being introduced to the timing and metering chambers of a diesel fuel injector may be utilized as a control law for the system of the present invention,; as an alternative modification.

Many changes or modifications in the above described embodiments of the invention may of course be carried out without departing from the fair meaning and scope of the invention disclosed. Accordingly, the scope of the invention is intended to be limited only by the scope of the appended claims.

CLAIMS

1. A control system for controlling the supply of fuel from a source (32) to an internal combustion engine (16) having a crankshaft (26) and a plurality of cylinders, the system comprising at least one in-
5 jector (10) having a body (70), a primary pumping plunger (20) and a secondary plunger (80) positioned within said body for movement therein, a nozzle (84) situated contiguous with the engine (16), a timing chamber (72) defined in said body between said primary pumping plunger (20) and
10 said secondary plunger (80), a metering chamber (74) defined in said body between said secondary plunger (80) and said nozzle (84), timing and metering passages (42, 44, 46, 48, 50, 92) in said body (70) of said injector (10) for receiving pressurized fuel and transmitting said fuel into said timing chamber (72) and said metering chamber (74), means (38, 94, 100) for controlling (1) the timing of the discharge of fuel from
15 the metering chamber (74) through the nozzle (84) and (2) the quantity of fuel stored in said metering chamber (74), characterized in that it includes a control valve (94, 100) in each of said timing and metering passages (44, 46) for controlling the flow of fuel from the source (32) and means for pulsing in an on/off fashion each of said control valves
20 in response to engine operating conditions.

2. A control system according to claim 1, characterized in that said control valves (94, 100) control the admission of fuel into said timing chamber (72) creating a hydraulic link between said primary pumping and secondary plungers (20, 80).

25 3. A control system according to claim 2, characterized in that it includes valve means (96, 102) in each of said timing and metering passages (48, 50) for precluding the flow of fuel out from said chambers.

30 4. A control system according to claim 2, characterized in that it includes a drain passage (58) and a check valve (110) interconnected to control fuel flow between said timing chamber (72) and said drain passage (58) for periodically eliminating said hydraulic link between said primary pumping (20) and said secondary plungers (80).

35 5. A control system according to claim 4, characterized in that said check valve (110) is unseated to release fuel from said timing chamber (72) into said drain passage (58) when the secondary plunger (80) approaches its most downward position.

6. A control system according to claim 1, characterized in that said secondary plunger (80) has a passage (114, 120) defined therein, said passage opening at one end into said metering chamber (74), and said passage dumping fuel into a dump passage (116) when the injection
5 phase of the cycle of operation is terminated.

7. A control system according to claim 1, characterized in that the volumes of said timing chamber (72) and said metering chamber (74) are varied during the cycle of operation of said fuel injector.

8. A control system according to claim 7, characterized in
10 that a portion of said operation is metering and said metering chamber volume is varied during said metering portion.

9. A control system according to claim 1, characterized in that said control valves (94, 100) are pulsed a plurality of times for each injection from said injector, the supply providing fuel at a constant pressure to said control valves.
15

10. A control system according to claim 1, characterized in that it includes an electronic control unit (38), said control unit sequentially pulsing said control valves (94, 100) to provide fuel to said timing and metering chambers (72, 74) of each injector (10) through said
20 timing and metering passages (44, 46).

11. A control system according to claim 1, characterized in that it includes a plurality of injectors and a cam element (22) associated with the crankshaft (26) for controlling the operation of said primary plunger (20) for each injector, said plunger (20) being held in
25 one position when metering is not to occur, and moving to another position when metering is to occur.

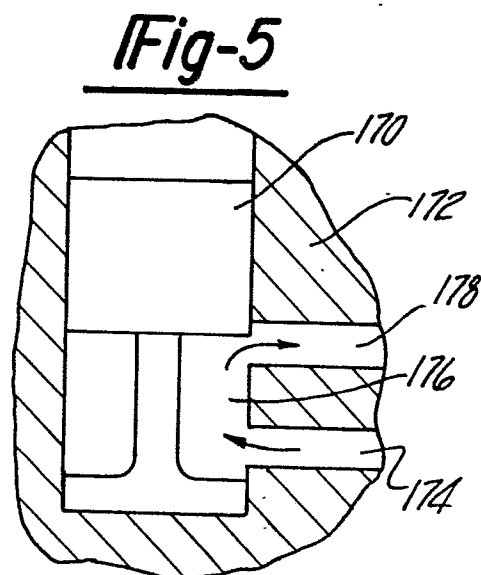
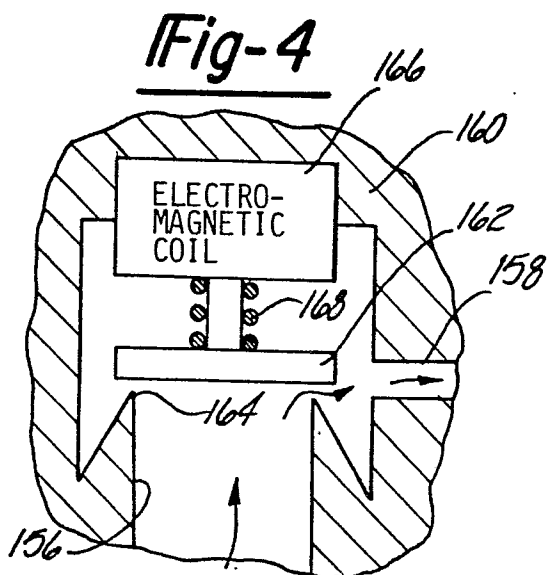
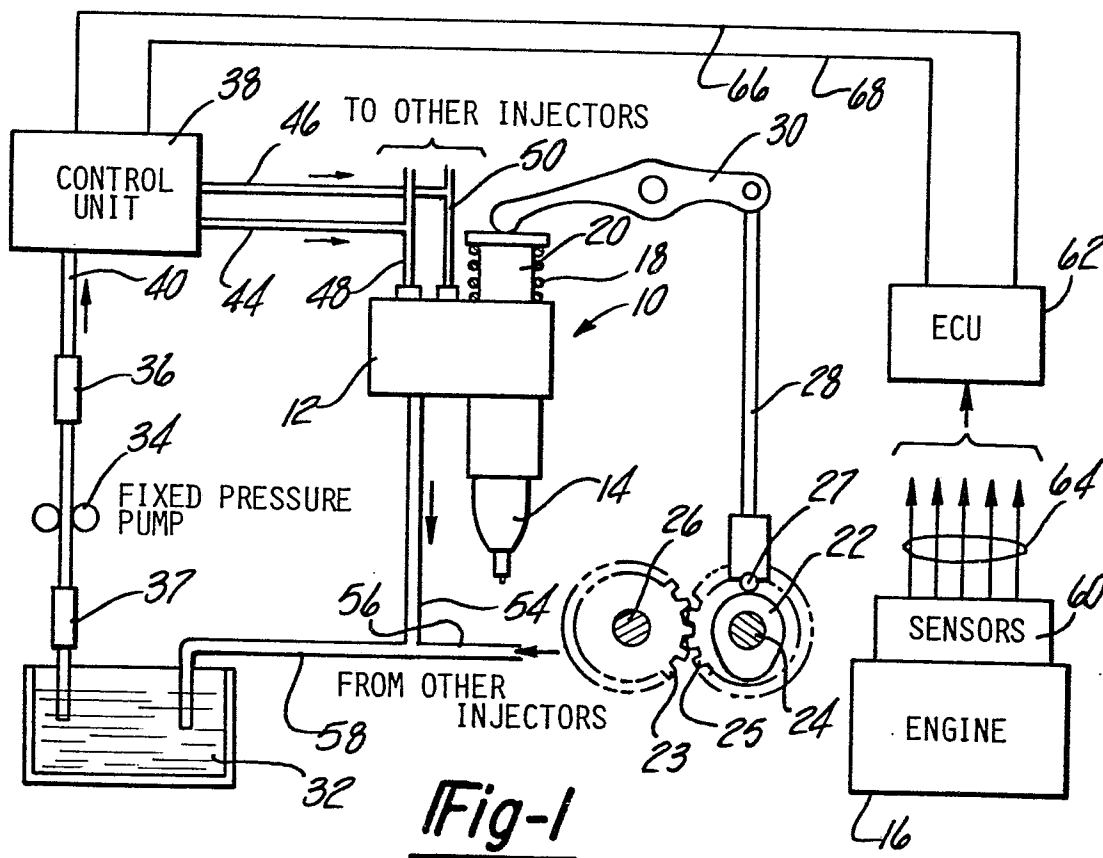
12. A control system according to claim 11, characterized in that all but one injector is held in said one position at any one time to isolate one injector from all others during metering.

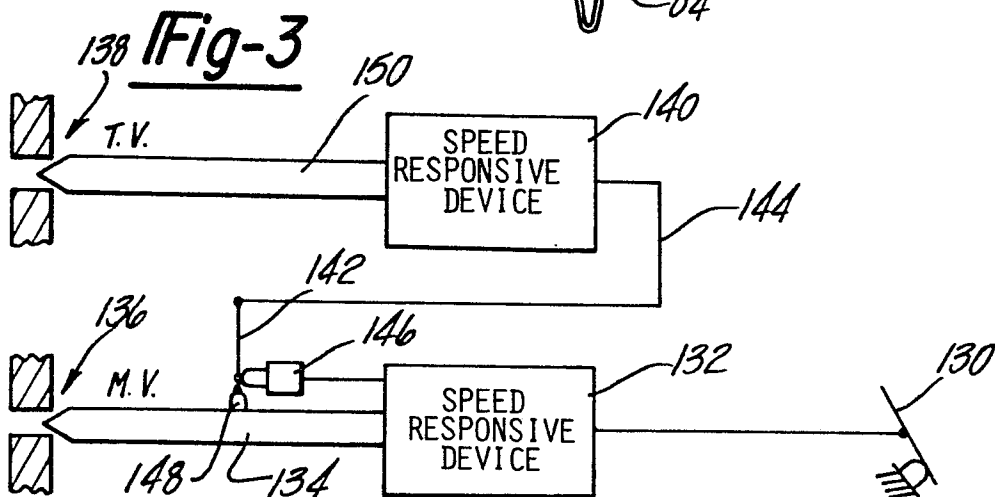
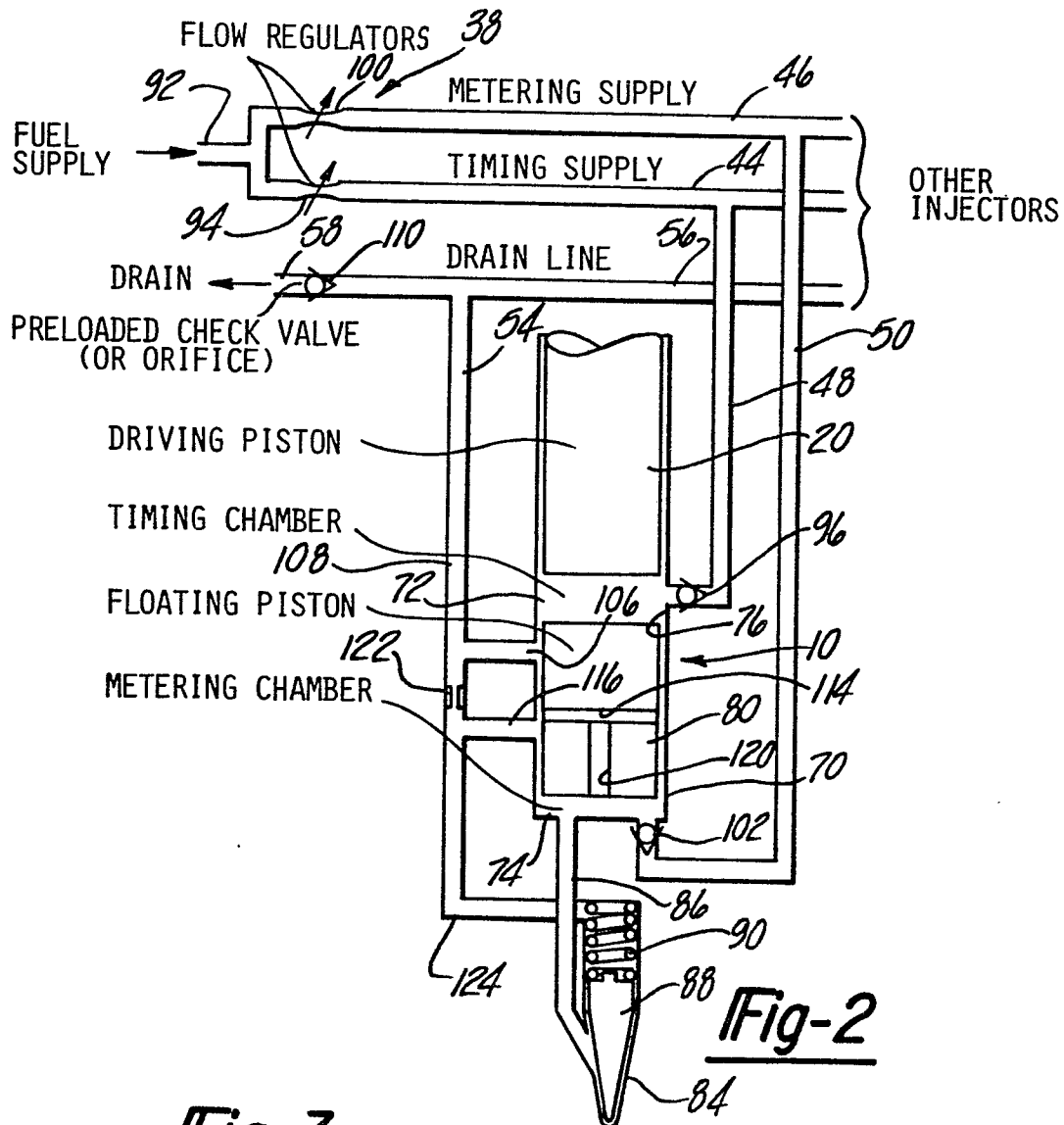
13. A control system according to claim 1, characterized in that said controlling means includes a variable orifice control valve (94, 100) in each of said timing and metering passages (44, 46) for controlling the flow of fuel from the source (32) to said timing and metering chambers (72, 74), and means (140) for controlling the variable orifice of each of said variable orifice control valves in response to
35 engine operating conditions and means for controlling said metering orifice in response to engine speed (132) and an operator command (130).

14. A control system according to claim 13, characterized in that said timing control valve (94) is controlled in response to an engine speed (132) and operator command signal (130), and a further engine speed signal (140).

5 15. A control system according to claim 13, characterized in that said timing control valve (94) is controlled as a function of engine speed and engine load.

16. A control system according to claim 13 or 14, characterized in that said control is an electrical system.





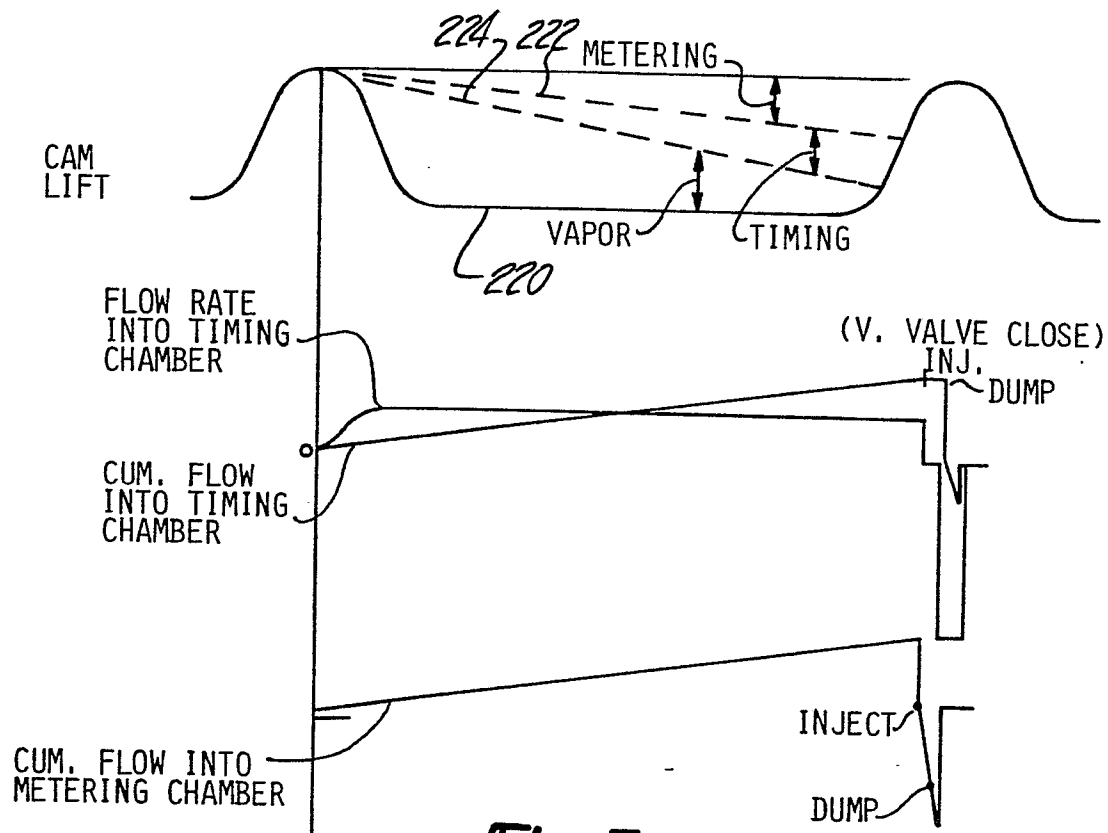


Fig-7

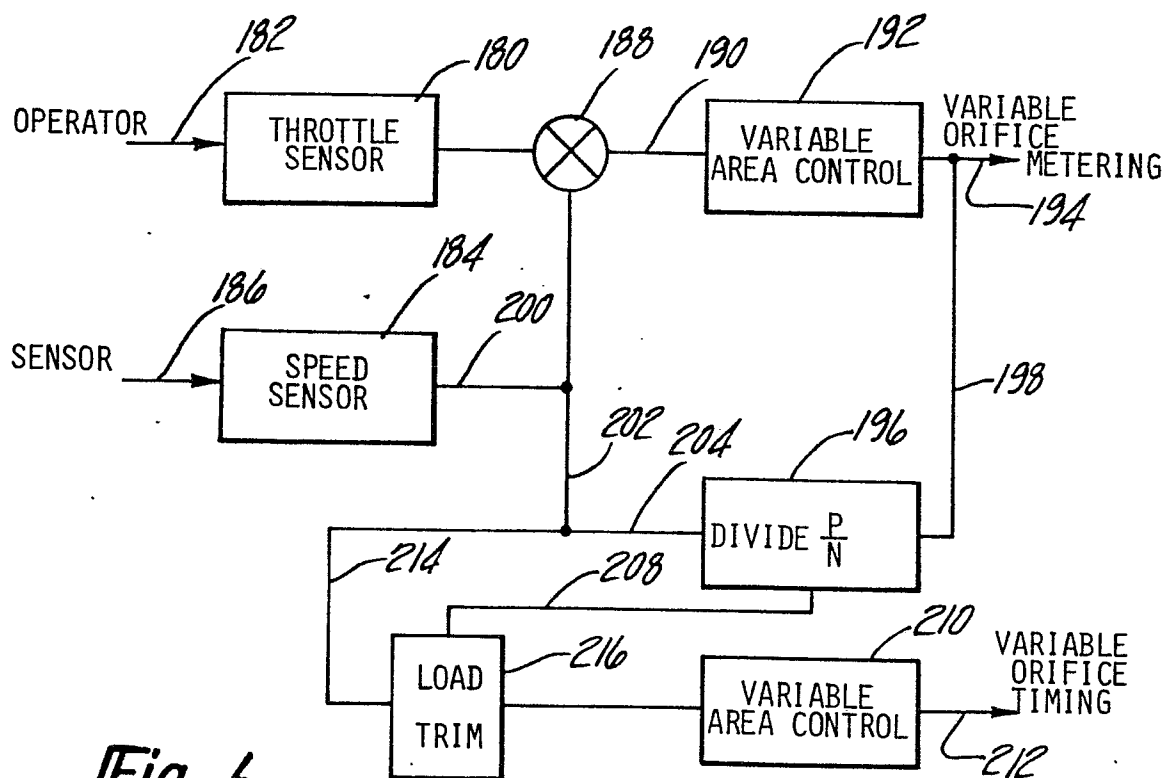


Fig-6

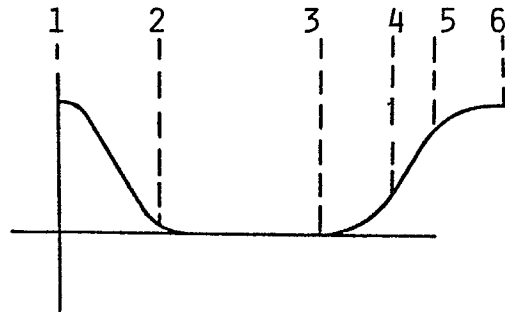


Fig-8A

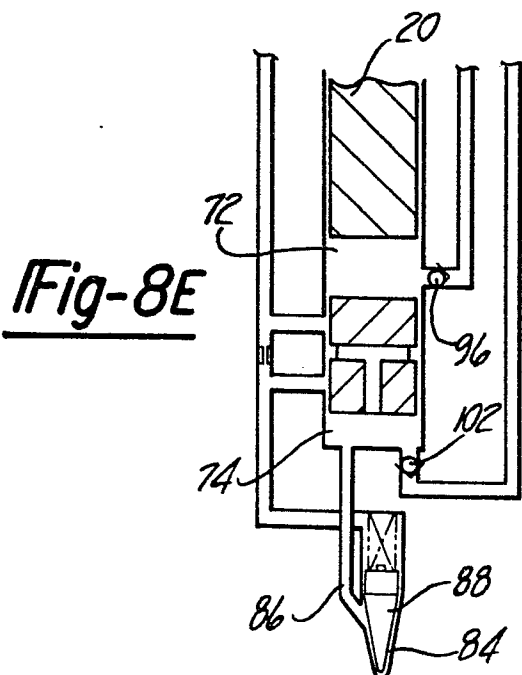
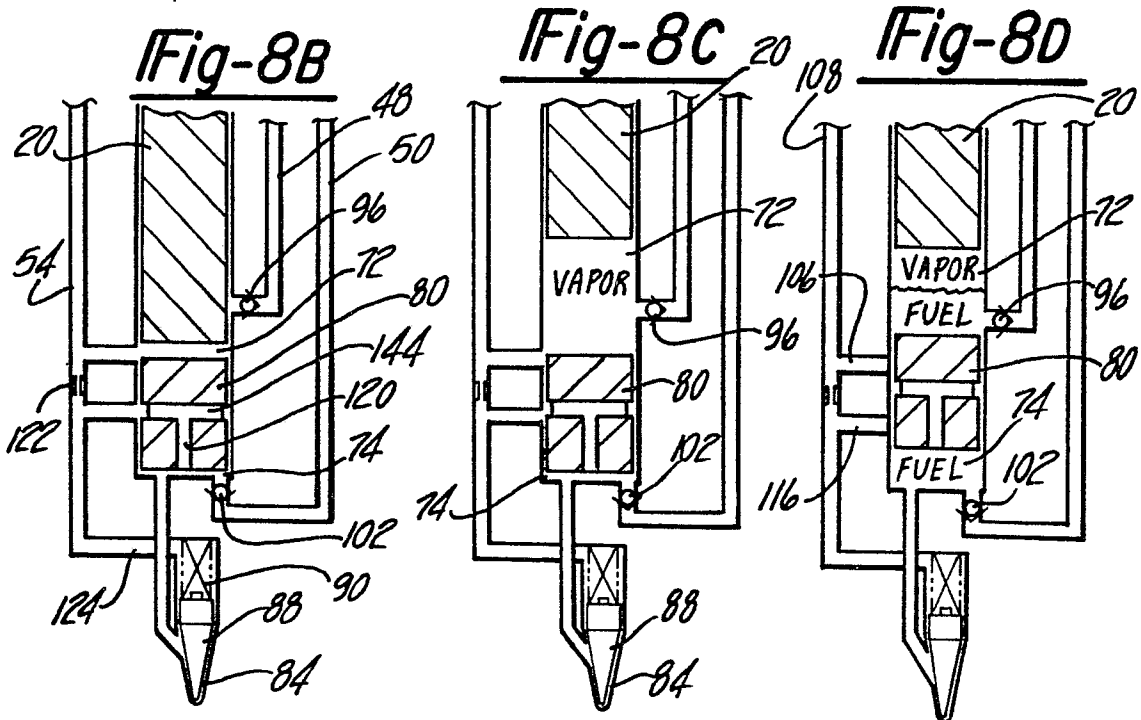


Fig-8E

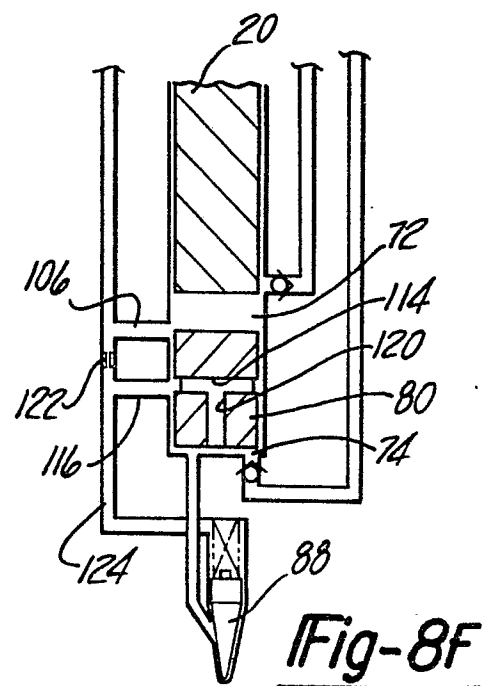
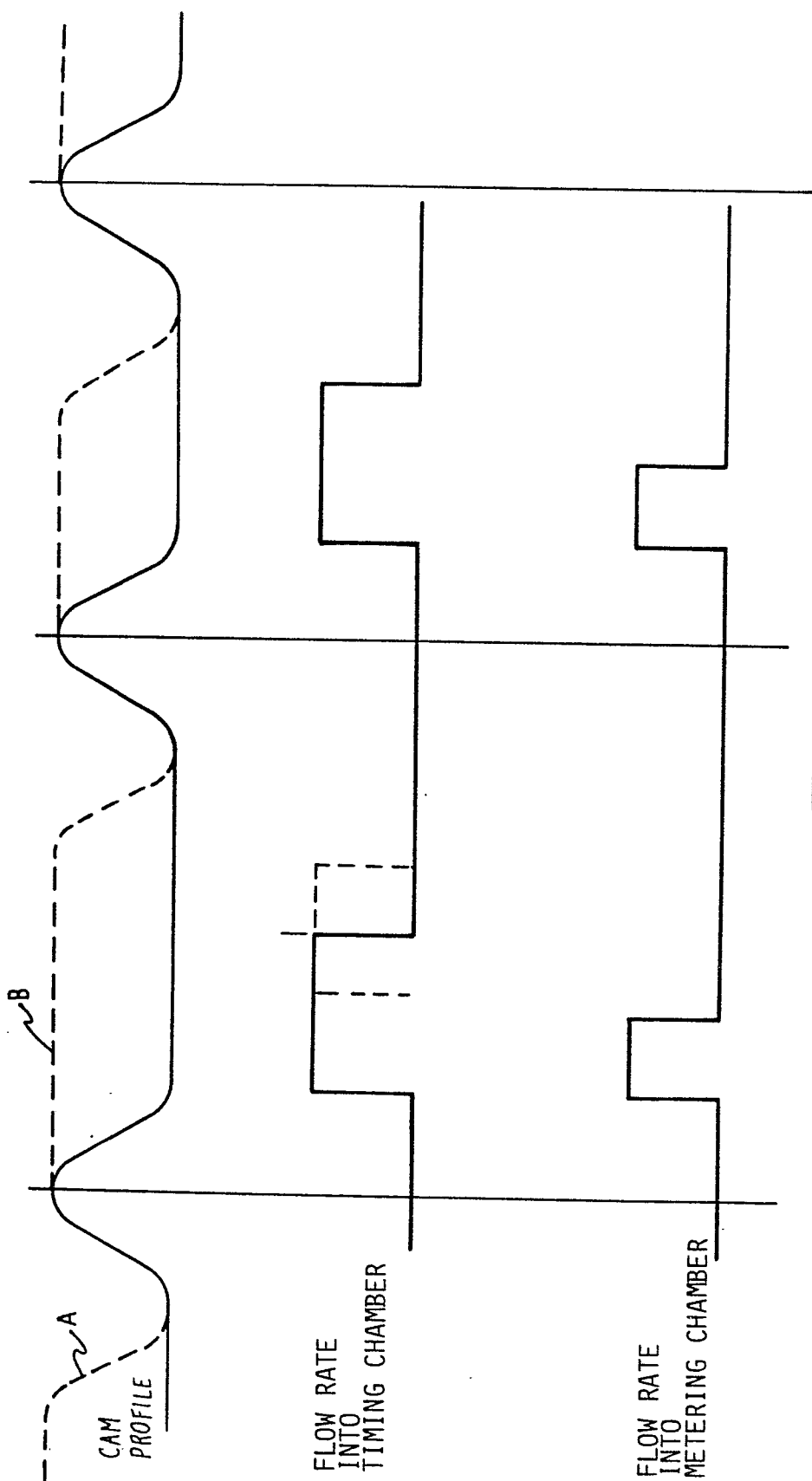


Fig-8F

Fig-9



European Patent
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EUROPEAN SEARCH REPORT

0051530

Application number

EP 81 40 1705

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
Y	<u>GB - A - 2 030 222 (BENDIX)</u> * Page 2, line 2 - page 3, line 77; page 4, line 89 - line 118; page 6, line 124 - page 8, line 35 * --	1,2,4, 6,7,8, 10,11	F 02 M 59/32 59/20 57/02
Y	<u>US - A - 4 036 195 (BAILEY)</u> * Column 2, line 27 - column 4, line 35; figure * --	1,7,8, 11	TECHNICAL FIELDS SEARCHED (Int.Cl. ³)
Y	<u>GB - A - 1 080 311 (FRIEDLANDER)</u> * Column 2, line 41 - page 4, line 38; figures 1-3 * --	1,7,8, 11	F 02 M
Y	<u>FR - A - 2 212 496 (C.A.V.)</u> * Page 1, line 29 - page 3, line 17; figures * --	1,2,7	
A	<u>CH - A - 391 383 (C.A.V.)</u>		
A	<u>GB - A - 490 547 (LA PRECISION MECANIQUE)</u> ----		
			CATEGORY OF CITED DOCUMENTS X: particularly relevant if taken alone Y: particularly relevant if combined with another document of the same category A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: earlier patent document, but published on, or after the filing date D: document cited in the application L: document cited for other reasons &: member of the same patent family, corresponding document
☒ The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		04-02-1982	BICHI