

Dec. 30, 1969

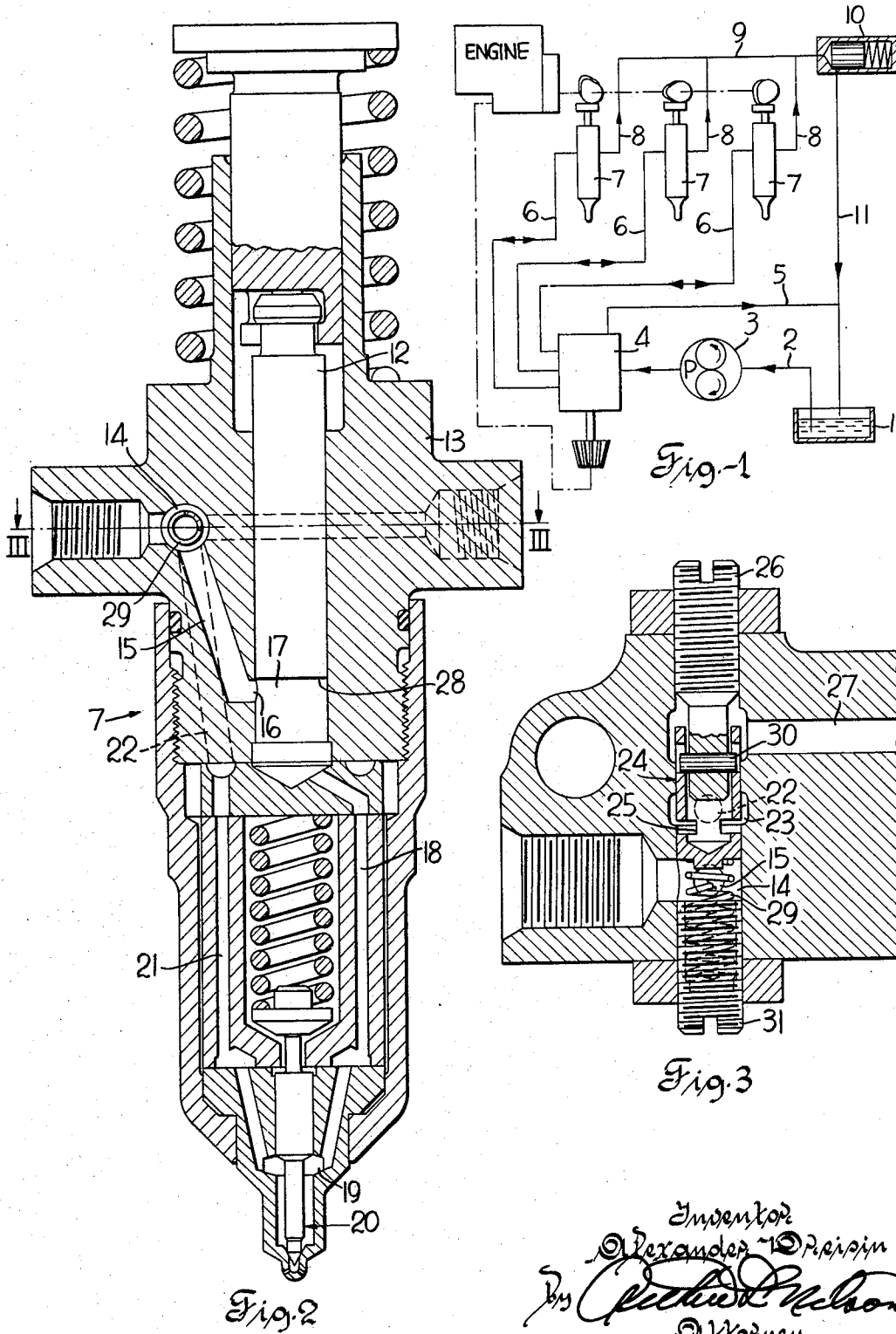
A. DREISIN

3,486,493

FUEL INJECTION UNIT

Filed Feb. 13, 1968

3 Sheets-Sheet 1



Inventor
Alexander Dreisin
By *Richard Nelson*
Attorney

Dec. 30, 1969

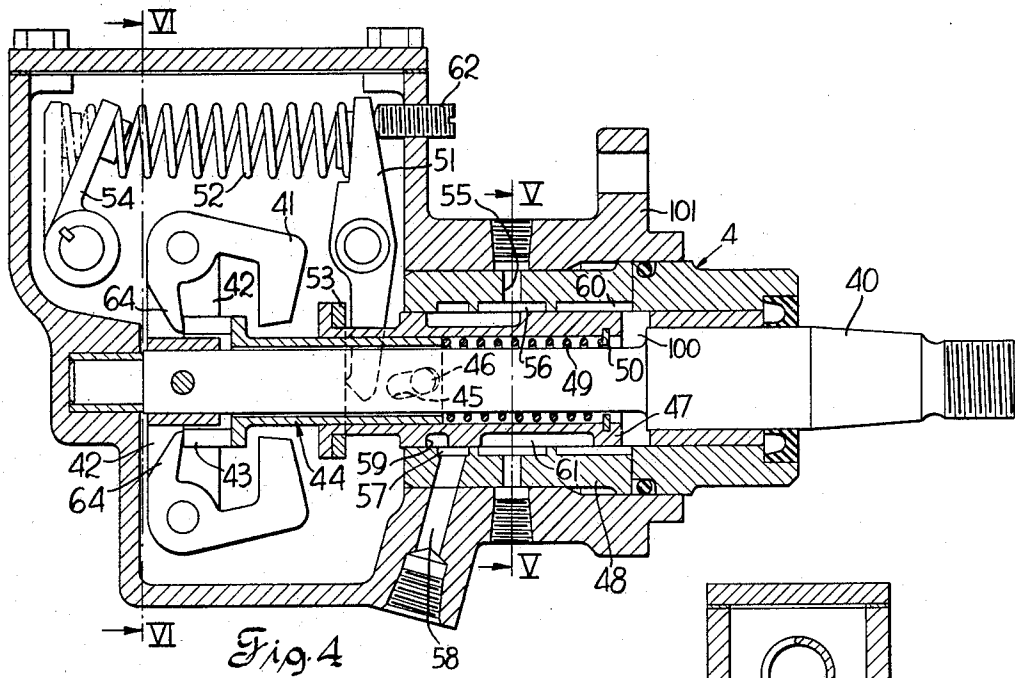
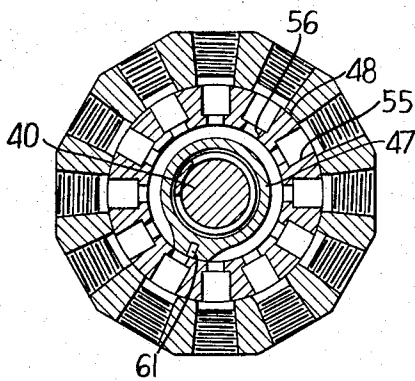
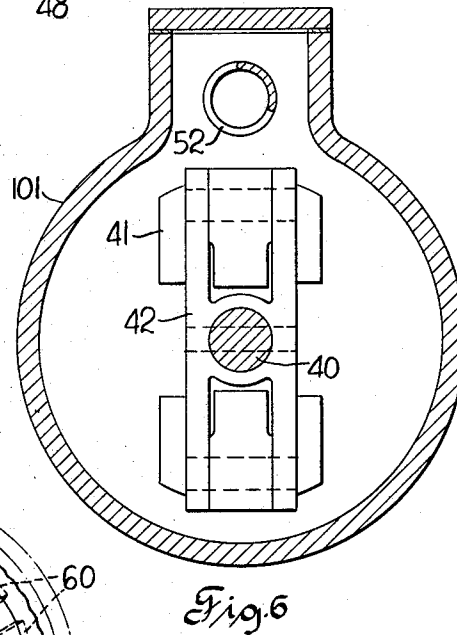
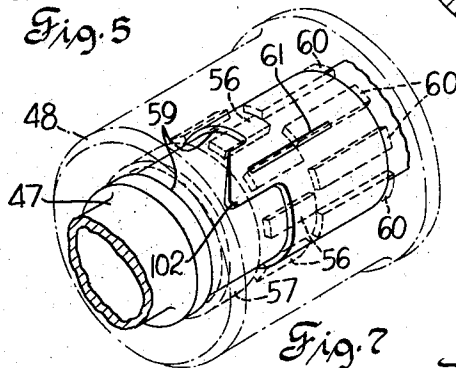
A. DREISIN

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FUEL INJECTION UNIT

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3 Sheets-Sheet 2



Inventor
Alexander J. Reppin.
By Richard H. Brown
Attorney

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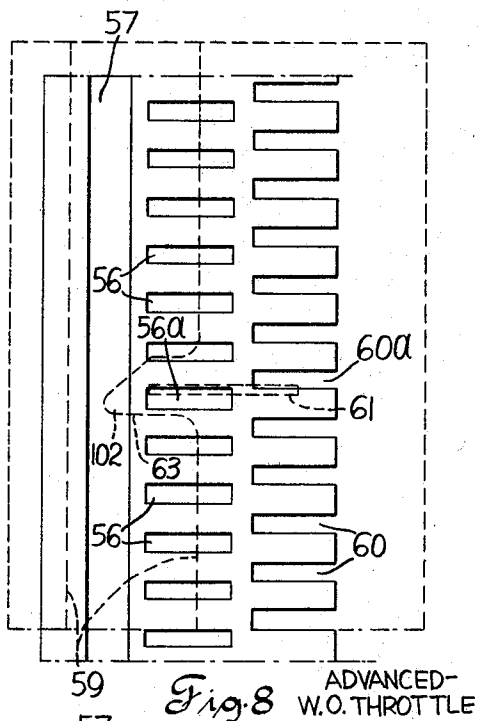
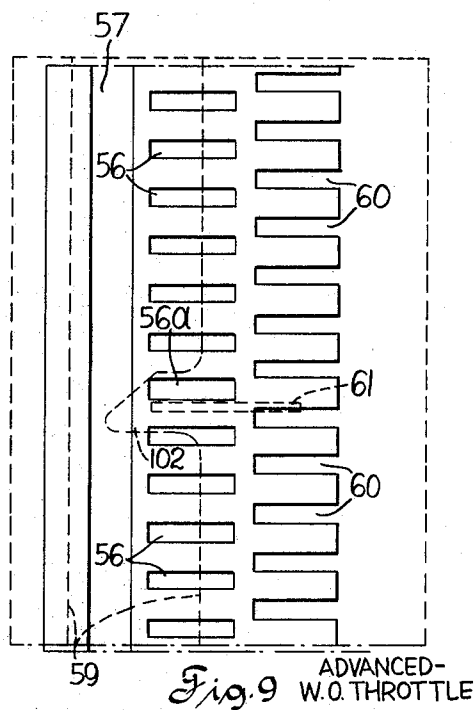
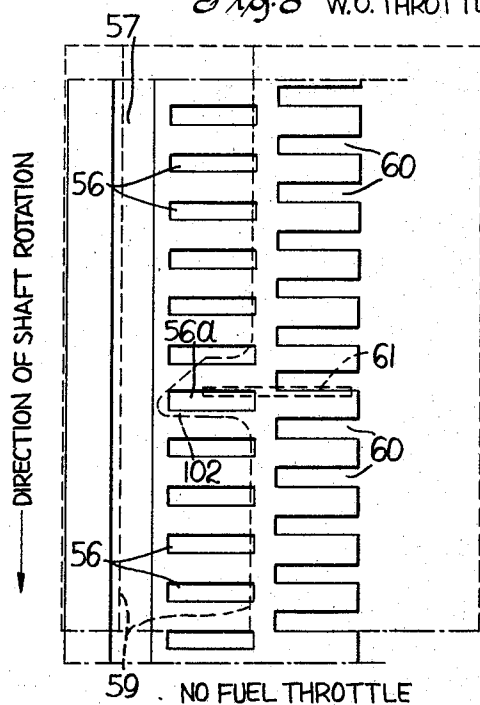
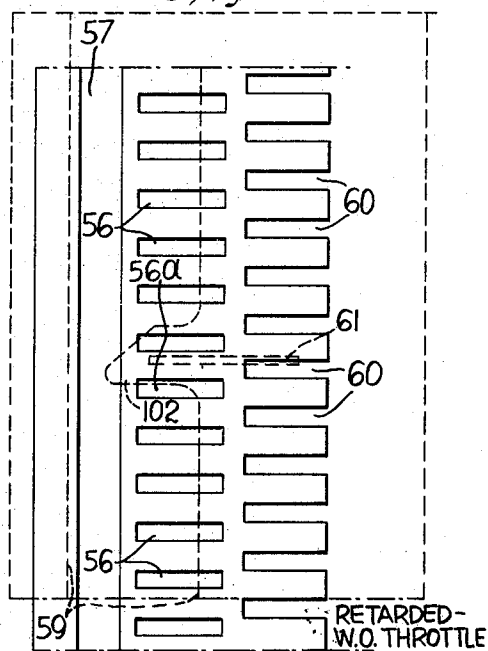
A. DREISIN

3,486,493

FUEL INJECTION UNIT

Filed Feb. 13, 1968

3 Sheets-Sheet 3



RETARD

WIDE OPEN ← → SHUT-OFF

ADVANCE

Fig-10

Fig. 1-1
Inventor
Alexander Weiss
Richard Nelson
Attorney

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3,486,493

FUEL INJECTION UNIT

Alexander Dreisin, Olympia Fields, Ill., assignor to
Allis-Chalmers Manufacturing Company, Milwaukee,
Wis.

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Int. Cl. F02m 39/00; F02d 1/04, 1/06

U.S. Cl. 123—139

10 Claims

ABSTRACT OF THE DISCLOSURE

A fuel injector and a hydraulic pressure control unit for controlling initiation and termination of fuel injection.

This invention relates to a fuel injector and more particularly to a hydraulic control unit for controlling the timing and fuel delivery rate of the fuel injector.

A fuel injector is a well-known device used to supply fuel in a highly atomized state to the combustion chamber of the internal combustion engine. The injector is usually actuated mechanically by means of a cam which is driven by an engine usually through a gear train. The cam motion is transmitted through a mechanical linkage to a reciprocating plunger which during the pumping stroke displaces fuel which is fed to the nozzle which injects the fuel through spray orifices into the combustion chamber.

The conventional unit injector is mechanically actuated, and mechanically controlled by a control device which senses engine speed and throttle position and is connected to each unit injector by mechanical linkages. Movement of the linkages is transmitted to the unit injector plunger which varies the effective length of the stroke. The mechanical connection between the control device such as a governor and the individual injectors increases in complexity with the increasing number of engine cylinders. It induces friction into the control system which requires higher control forces from the governor and requires maintenance because a change in the relative position of these mechanical linkages can disturb the output balance of the individual injectors. In addition the injector timing is fixed in relation to the engine cycle.

A modification of the unit injector provides that the fuel quantity of each injection is premetered separately at low pressure by another device and is preloaded into the injector pumping chamber preceding each stroke. This system does not require mechanical control linkages but has a disadvantage of injecting the fuel from an intermediate portion of the plunger stroke to the bottom of the plunger stroke or the top of the cam lift. Such injection has inherent disadvantages, namely, the end portion of the injection occurs at decreasing plunger velocity which adversely affects the atomization of the fuel and subsequently the quality of combustion. Another disadvantage common with the first described type of unit injector is that the system also has fixed injection timing.

Modern engine speeds of diesel engines are increasing and it becomes necessary to change the relative timing between fuel injection and the engine combustion cycle. At low engine speed the optimum position of injection start can be close to the engine top dead center at the end of the compression stroke. As the engine speed increases,

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the engine crankshaft turns through a larger angle during the time required to prepare the injected fuel for combustion. This preparation time consists essentially in the time required to preheat and partially evaporate the injected droplets of fuel and the time needed to accomplish the so-called preflame oxidation reactions. As an example this might be on the order of two crankshaft degrees at 600 engine r.p.m. and twelve crankshaft degrees at 3000 engine r.p.m. For optimum conditions throughout the speed range, injection timing therefore should be advanced by about ten crankshaft degrees in respect to the engine top dead center.

The proposed hydraulically controlled unit for initiating and terminating injection eliminates the disadvantages of the conventional injector systems without adding to the overall system complexity. The control unit is designed to supply to the individual injectors the fuel which was originally pressurized by a supply pump and to distribute to the individual injectors control pulses or hydraulic pressure signals to initiate and terminate injection. The control unit governs the timing and the durations of the pressure signals as a function of engine speed and throttle position.

The control pulses or pressure signals change the pressure supplied to the control valve in the injector during movement of the pump plunger. The differential pressure created by the pressure signals cause the control valve to close which interrupts communication between the pumping chamber and the drain passage and initiates fuel injection.

Reestablishment of the supply pressure to the control valve eliminates differential pressures acting on the control valve which cause the control valve to open the communication between the pumping chamber and the drain passage and thereby terminate fuel injection. Supply and ambient pressures are referred to in the description of this invention to illustrate the operation of the injection. It is understood that only a change in pressure is required to control injection and the specific pressures or magnitude of the change is not critical.

It is an object of this invention to provide a fuel injector having control means for supplying two levels of supply pressure to initiate and terminate injection.

It is another object of this invention to provide a fuel injector control by a change in fuel supply pressure to initiate fuel injection and reestablishing initial fuel supply pressure to terminate fuel injection.

It is a further objection of this invention to provide a control unit sensitive to speed and/or a manual control control such as the throttle so as to change the timing and duration of fuel injection.

It is a further object of this invention to provide a control for timing and duration of fuel injection by changing and reestablishing supply pressure to the fuel injector.

It is a further object of this invention to provide a combination fuel distributor and pressure control for initiating and terminating injection and angularly dephasing a control element to regulate injection timing and axially displacing the control element to meter the quantity of fuel injection.

The objects of this invention are accomplished through the use of mechanically actuated fuel injection pumps for injection of high pressure fuel sequentially into a plurality of combustion chambers. A control valve controls

the initiation and termination of fuel injection and is positioned in the hydraulic line supplying and returning fuel for cooling of the injector and the nozzle during the phase of the cycle when the injector is not in the process of injection. The control valve has a chamber which receives fuel from the control unit which enters at the supply line pressure. The return passage from the fuel injector is also in communication with the control valve and fuel normally passes through a return line to the fuel supply. The control unit includes a rotating shaft rotating synchronously with the engine and also has a distributor housing and distributor stator with a plurality of delivery passages in communication with unit injectors. Radially intermediate the shaft and the stator is positioned a distributor rotor which is adapted for movement axially to control injection quantity and angularly to control injection timing relative to the shaft. The movement of the distributor rotor relative to the shaft is controlled by a governor driven sleeve. Dephasing the rotor angularly in reference to the distributor stator changes injection timing without affecting injection duration. Axial displacement of the rotor in reference to the distributor stator varies injection duration, which in turn governs the injected quantity.

The preferred embodiment of this invention will be described in the following paragraphs and illustrated in the attached drawings.

FIG. 1 schematically illustrates a hydraulic system for fuel injection.

FIG. 2 illustrates a cross section of the injector.

FIG. 3 illustrates a cross section view taken on line III—III of FIG. 1.

FIG. 4 illustrates a cross section view of the control unit.

FIG. 5 is a cross section view taken from line V—V of FIG. 4.

FIG. 6 is a cross section view taken on line VI—VI of FIG. 4.

FIG. 7 is a three dimensional view of the distributor rotor in solid lines and the distributor stator in phantom lines with its slots in dotted lines.

FIG. 8 is a developed view of the distribution stator in solid lines and the distributor rotor in dotted lines at 30° before engine top dead center with rotor advanced and the throttle in wide open position at start of injection.

FIG. 9 is a view showing stator and rotor positions at the end of injection with throttle in wide open position.

FIG. 10 is a view similar to FIG. 8 at the start of injection with throttle in no fuel position. The view includes directions of shaft rotation, timing, and throttle movement which are common to FIGS. 8, 9, and 10.

FIG. 11 is a view similar to FIG. 8, 30 degrees before top dead center with the rotor in the retarded position and throttle in wide open position.

Referring to the drawings, FIG. 1 illustrates a schematic drawing of the hydraulic system. The fuel tank 1 is connected to the low pressure conduit 2 through fuel filters to the supply pump 3. The supply pump 3 develops a steady flow of fuel at a constant pressure of 50 to 100 pounds per square inch approximately. The fuel is supplied to the control unit 4 which is driven by the engine at a constant speed ratio with the engine. The control unit 4 has a fuel return line 5 under substantially ambient pressure which returns excess fuel back to the tank 1. In addition the control unit is connected by individual supply lines 6 to the respective injectors 7. These lines 6 are subjected alternately to the supply pressure or to the ambient pressure as will be further described. The two pressures applied to the injectors are not critical, but it is the changing of the pressure levels that controls injection.

After passing through the injectors the fuel passes through the drain lines 8 and the manifold 9 through

the relief valve 10 and back to the tank by the return line 11.

Each of the unit injectors 7 are cam actuated by the engine and the cam imparts reciprocating motion to the plunger 12 which is closely fitted into the bore of the housing 13. During the interval between injections fuel under supply pressure is furnished by the line 6 which fills the control spring chamber 14. From there it passes through a drilled passage 15 in the housing and through the inlet portion 16 into the injection pumping chamber 17. The fuel then flows through the passage 18 into the gallery 19 surrounding the valve 20 and continues its flow through the passages 21 and 22 to the control annulus 23 which surrounds the control valve 24. The control valve is formed with radial slots 25 through which the fuel flows from the annulus 23 and through the clearance between the control valve and the stem of the adjusting screw 26. It then passes unobstructed through the passage 27 to the drain line 8 into the drain manifold 9. The circuit is completed across the pressure relief valve 10 which is set at approximately 50 to 100 pounds per square inch and through the valve drain line 11 back to the fuel tank.

From the above flow path description it is clear that the pressure in the drain lines 8 and the manifold 9 is of the same order as in the supply lines 6. A small difference will only be induced by the resistance to flow of the passages inside of the unit injectors which are arranged in parallel. In the first approximation and for simplicity of further explanation we can assume the pressure in the lines 8 and the manifold 9 is equal to the supply pressure furnished by the pump 3 to the control unit 4.

The control unit is designed to supply to the unit injectors the fuel which was originally pressurized by the supply pump, and to distribute to the individual injectors controlled pressure pulses. The control unit governs the timing and duration of the pressure changes as a function of engine speed and throttle position.

Referring to FIG. 4 the control unit is mounted on the engine and driven synchronously at half engine speed for four stroke cycle engine and at engine speed for two stroke cycle engines. This driven is transmitted by the drive shaft 40 to the governor weights 41 by the governor carrier 42 which is pinned to the shaft. The axial prongs 43 of the shifter sleeve 44 fit slideably between the arms of the governor carrier 42 and allow the sleeve to move axially in relation to the drive shaft 40. The shifter sleeve is equipped at its opposite end with one or more timing slots 45 which engage the pins 46 which are pressed into the distributor rotor 47. The distributor rotor 47 is closely fitted to the distributor stator 48 in which it can move rotatably and can slide axially. A timing spring 49 is arranged around the drive shaft 40 between the shifter sleeve 44 and the snap ring 50 positioned inside the rotor 47.

Governor spring lever 51 transmits the force of the governor spring 52 to the rotor across the flanged end 53. The opposite end of the governor spring abuts against the governor throttle lever 54. Varying the position of this lever preloads the governor spring to higher or lower forces.

Fuel lines 6 connect the individual injectors with the distributor stator through the radial passages 55 arranged in the central portion of the distributor stator and through the slots 56. The arrangement of the controlling parts on the rotor and stator is shown for greater clarity in FIG. 7.

As shown in FIG. 4 the supply annulus 57 is in constant communication with the supply pump through passage 58 located in the control unit housing 101 and the distributor stator 48 which is also in communication with the annular recess 59 in the rotor shown in FIG. 4. A spill slot 61 is also shown in FIG. 4 and FIG. 5. The distributor stator is formed with the plurality of distributor slots 56, and the pressure relief slots 60 which are maintained at substantially ambient pressure through the annular chamber

100 which is in communication with the ambient pressure inside of governor housing.

The distributor rotor 47 moves axially and angularly relative to the shaft 40. The distributor rotor 47 forms the annular recess 59 with one side of the recess defining an axially extending tooth 102 having a leading and a trailing edge. Referring to FIG. 7 the tooth 102 of distributor rotor 47 operates as a pressure interrupter while the spill slot 61 sequentially relieves the pressure in the distributor slots 56 through relief slots 60.

Referring to FIGS. 7, 8, 9, 10 and 11 the distributor stator is shown with a plurality of distributor slots 56 each of which is in communication with a unit injector. Similarly a plurality of pressure relief slots 60 are shown which relieve the pressure in the distributor slot 56 sequentially to govern the timing of the injection.

FIG. 8 illustrates the annular recess 57 which supplies the annulus 59 in the distributor stator 47. The pressure interruption and relief will be described in the subsequent paragraphs in the operation.

The operation of the injector and the hydraulic system will be described as well as the control unit which interrupts and relieves the pressure and subsequently restores pressure on the control valve in each injector to initiate and terminate injection. As shown the tooth 102 has an axial leading edge and a diagonal trailing edge. The angular displacement of the rotor relative to the shaft 40 controls timing of fuel injection while the axial displacement of the distributor rotor controls quantity of fuel delivery.

At the beginning of the cam stroke the plunger 12 starts its pumping motion. At this time the fuel is flowing through the pumping chamber to the nozzle and cools the nozzle in its passage and is returned to the tank 1. During its pumping movement the edge 28 of the plunger 12 will override the intake port 16 and will close it. Past this point the advancing plunger still displaces the fuel in the injector which flows, as previously described, through the control valve 24 to the drain manifold. At the appropriate time in relationship to the engine cycle the control unit 4 relieves the pressure in the supply line 6 leading to the particular injector 7.

Considering the control valve 24 prior to the start of injection it was subject to essentially the same pressure on its upper and lower faces. Its lower face on the side of the spring control chamber 14 was subject to the supply pressure arriving through the line 6. Its upper face on the side of the adjusting screw 26 was subject to the same pressure diminished only by the resistance to the fuel flow through the passages 18 through 22 of the unit injector. Control spring 29 exerts a force which is approximately equal to one-half the axial force exerted on the valve 24 by the supply pressure. As long as the supply pressure in chamber 14 exists the sum of the forces of the spring and the hydraulic pressure force on the control valve in the direction of the adjusting screw 26 maintains the valve open. The valve is stopped by the pin 30 which is located across the stem of the adjusting screw 26 and extends through opening in the control skirt. When hydraulic pressure is lowered in the spring chamber 14 the force of the spring 29 is overcome by the hydraulic force which is acting on the valve from the side of the adjusting screw 26.

The control valve moves against the spring. Slots 25 override the edge of the annulus 23. This stops the flow of fuel from the nozzle passage 22. The continuing movement of the plunger 12 now compresses the fuel trapped in the chamber 17 and the nozzle passages 18 through 22. When the opening pressure of the needle 20 is exceeded the nozzle opens in a conventional manner and the injection takes place. To terminate the injection, pressure has to be reestablished in the chamber 14. At that moment the hydraulic force in the spring chamber will balance the hydraulic force on the opposite side of the valve and the spring will shuttle the valve to an open position. Reopening of the valve slots will reestablish communication to

the return manifold 9 which will drop the pressure in the unit injector below the closing pressure of the nozzle. This will cause the nozzle to close and will terminate the injection.

The described unit injector can be controlled by dropping the supply pressure to ambient which initiates injection and reestablishing the supply pressure which terminates the injection. Varying the phasing of this event in relation to the engine will vary the injection timing. Varying the time interval between relief of supply pressure and the reestablishing of supply pressure will change the portion of the plunger stroke during which time the fuel is trapped in the injector and, therefore, will change the fuel quantity injected through the nozzle. The duration of the interval of low pressure therefore determines the effective plunger stroke of the injector.

The valve 24 is provided with an adjusting screw 26 which adjusts the movement of the skirt required to close the annulus 23. A spring adjusting screw 31 controls the spring tension and the rate at which the valve will respond to changing pressures on opposing sides of the valve element. The valve may be adjusted to the pressure signals of supply pressure relief and reestablishment of supply pressure on the valve to produce a repeatable time interval controlling injection.

The control unit functions in the following manner. Filtered fuel is supplied by the supply pump at approximately 50 to 100 pounds per square inch and is continually being fed to the supply annulus 57 in the distributor stator 48. It also fills the annular recess 59 in the rotor, the distributor slots 56, radial passages 55, and supply lines 6 and flows continually through the injectors as previously described.

Let us consider what happens to an injector connected with the distributor slot 56a as shown in FIG. 8. Assume that at this point the engine is approximately 30 degrees before top dead center on a compression stroke. Further let us assume that the throttle lever 54 has compressed the spring 52 to a force corresponding to a wide open position on the engine. Governor spring lever 51 has been pushed against the stop 62 and has forced the rotor all the way to the left as shown in FIG. 4. Axial portion of the metering edge 63 of tooth 102, has just passed the trailing edge of distributor slot 56a shutting off communication between fuel under supply pressure in the annular recess 59 and the unit injector communicating with the distributor slot 56a. As shown in FIG. 8 the spill slot 61 has established communication between the distributor slot 56a and the corresponding pressure relief slot 60a on the right-hand end of the stator. The pressure relief slots are in communication with the interior of the governor housing 101, which in turn has a relief line 5 as shown in FIG. 1 to the tank. The pressure relief slots are therefore at a substantially ambient pressure throughout the control cycle. The moment communication is established between a distributor slot and a pressure relief slot across the spill slot the supply pressure in that particular fuel line and unit injector is dropped to ambient pressure initiating injection as described above. Distributor and pressure relief slots are dephased angularly in the rotor in such a way that communication between them can be established and terminated over very short angles of rotation, for example three degrees after the spill slot overrides the leading edge of a distributor slot, its trailing edge can be made to override the trailing edge of a pressure relief slot. This is important because for small injection quantities we have to be able to reestablish supply pressure in the fuel line shortly after the pressure drop in order to terminate the injection. For no load operation injection duration required might be on the order of 1 to 3 degrees of engine rotation. The angular phasing of the distributor and pressure slots is chosen to satisfy this condition and is fixed during manufacturing. Examining FIG. 8 it is evident that all the rest of the distributor slots and injectors are still in communication with the

annular recess 59 and are therefore receiving a steady flow of fuel under supply pressure.

FIG. 9 shows the end of injection in wide open throttle position. Here spill slot 61 has passed the trailing edge of slot 56a interrupting communication to the low pressure side. The inclined portion of the metering edge of tooth 102 has come into contact with the leading corner of the distributor slot 56a. In its further movement this inclined edge will begin to override the corner of this slot, reestablishing communication between the slot 56a and supply pressure in the annular recess 59. Fuel can now flow under supply pressure through slot 56a, passage 55 and line 6 to the injector and, upon arrival, will open valve 24. This will terminate injection.

Referring to FIG. 10 the start of injection is shown in "no fuel" position. In this position the rotor 47 has moved axially to the right or "shut off" position. As is evident from this view, the inclined portion of the metering edge reestablished communication between injector and supply pressure immediately after pressure was dropped through the registry of the spill slot with distributor and the pressure relief slots.

In actual operation this can take place for example at high speed idle. When engine load has been reduced externally while the throttle is in wide open position, engine speed will increase which in turn will increase the centrifugal force developed by the governor weights 41. This force is transmitted through the governor fingers 64, shifter sleeve prongs 43, timing spring 49, and snap ring 50 to the rotor 47. This force will overcome the governor spring force and move the rotor to the right towards the no fuel position and decrease the fuel quantity.

The fuel quantity can also be decreased by moving the manual throttle lever 54 from the wide open position to a part load position shown in dotted lines in FIG. 4. This will decrease the governor spring force. The centrifugal force which had previously balanced the spring force will now overpower the governor spring and will move the rotor to the right to a reduced fuel quantity.

The above description should clarify the metering function of the control unit. The timing function is explained in the following by comparing FIG. 8 with FIG. 11. In both cases the rotor is shown in wide open position. FIG. 8 shows the start of injection at 30 degrees before top dead center at rated engine speed. At this speed the governor weights are in half open positions as shown in FIG. 4 and are balancing the governor spring force. Assume that the engine speed is beginning to decrease due to an external overload and as the engine speed begins to fall off the centrifugal force decreases. Axial rotor position remains the same because it is dictated by the position of spring lever 51 which is forced against the stop 62 by the force of the governor spring 52; but the decreasing axial force acting on the shifter sleeve will force the timing spring 49 to expand moving the shifter sleeve left towards the weight assembly. The changing relative position between the shifter sleeve and the rotor will cause an angular relative movement between the inclined timing slot 45 and the pin 46 retarding the rotor in relation to the driving shaft and because of it in relation to the engine cycle. FIG. 11 shows a relative position between the stator 48 and the rotor 47 at the same moment of the engine cycle, 30 degrees before top dead center, but at low engine speed. While at the high engine speed shown in FIG. 8, this was the start of injection, at low engine speed the spill slot has not yet reached the leading edge on the distributor slot 56a and injection is retarded.

The number of distributor slots and pressure relief slots corresponds to the number of engine cylinders. When applied to a four stroke cycle engine the control unit drive shaft 10 is driven at one-half engine speed.

For two stroke cycle engines the control unit would be driven at engine speed the rest of the construction remaining the same.

The preferred embodiments of this invention have been

illustrated and described and the attached claims will define the scope of this invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A fuel injector control unit for producing fluid pressure signals for use with a fuel injector operated by a pressure control valve to initiate and terminate fuel injection in response to fluid pressure signals comprising, a control unit including, a rotary member, an engine driving said rotary member and rotating at a variable speed bearing an integer ratio with the speed of rotation of said rotary member, a speed and a manual responsive means sensing the speed and controlling the load of said engine, a distributor rotor defining an annular recess partially filled by an axial tooth pressure interrupter and rotating with said rotary member and connected to said speed and manual responsive means for shifting relative to said rotary member in response to the manual responsive means and the speed of said engine, a distributor stator defining distributor slots and pressure relief slots angularly spaced about its periphery with said distributor slots in fluid communication with said annular recess of said distributor rotor and connected to at least one fuel injector for supplying fuel to said injector, fuel supply means defining supply passage means for supplying pressurized fuel to said annular recess in said rotor of said control unit, said pressure interrupter of said distributor rotor defining a spill slot sequentially connected distributor slots and relief slots for changing and restoring pressure of the fuel supply to said injector to thereby control the timing and duration of the pressure signals relative to engine rotation.

2. A fuel injection control unit as set forth in claim 1 wherein said rotary member is connected to said speed responsive means comprising a governor to advance and retard timing of pressure signals relative to engine rotation.

3. A fuel injection control unit as set forth in claim 1 wherein said distributor rotor is connected to said speed and manual responsive means comprising a governor and a throttle respectively to control the duration of pressure signals.

4. A fuel injection control unit as set forth in claim 1 wherein said distributor stator receives pressurized fuel from the fuel supply and a plurality of fuel injectors are connected to the control unit.

5. A fuel injection control unit as set forth in claim 1 wherein the pressure interrupter of said distributor rotor defines a barrier to fluid flow and said spill slot relieves pressure applied to said injector for sequentially changing pressure applied to the control valve said fuel injector.

6. A fuel injection control unit as set forth in claim 1 wherein said distributor stator defines a plurality of distributor slots each in communication with a mating injector and a plurality of pressure relief slots located in sequence to relieve pressure in each of said distributor slots, the tooth interrupter of said distributor rotor interrupts pressure supplied to each of the plurality of fuel injectors and said spill slot provides communication between the distributor slot and pressure relief slots to relieve pressure for applying to said injector to initiate fuel injection in each of the fuel injectors.

7. A fuel injector control unit as set forth in claim 1 wherein the tooth pressure interrupter interrupts pressure upon covering a distributor slot and said spill slot relieves pressure upon connecting said distributor slot with said relief slot, said interrupter restores the original pressure by uncovering said distributor slot to provide two level pressure signals adapted for initiating and terminating fuel injection of said injector.

8. A fuel injector control unit as set forth in claim 7 wherein said tooth pressure interrupter defines an axial leading edge and an axial spill slot to control relieving pressure to said fuel injector.

9. A fuel injector control unit as set forth in claim 1

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wherein the timing control includes a governor advancing and retarding said rotor angularly relative to said rotory member, a throttle lever controls the axial position of said rotor relative to said stator to thereby control timing and duration of pressure signals adapted for controlling the timing and quantity of fuel injection.

10. A fuel injector control unit as set forth in claim 1 wherein said tooth pressure interrupter defines a diagonal trailing edge controlling the restoration of pressure applied to said injector.

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LAURENCE M. GOODRIDGE, Primary Examiner

U.S. Cl. X.R.

123—140

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,486,493 Dated December 30, 1969

Inventor(s) Alexander Dreisin

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 8, line 28, "connected" should read -- connecting line 38, "I" should read -- 1 --; and line 74, after the word "pressure" insert -- applied --.

SIGNED AND
SEALED
MAY 12 1970

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents