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FUEL INJECTION APPARATUS

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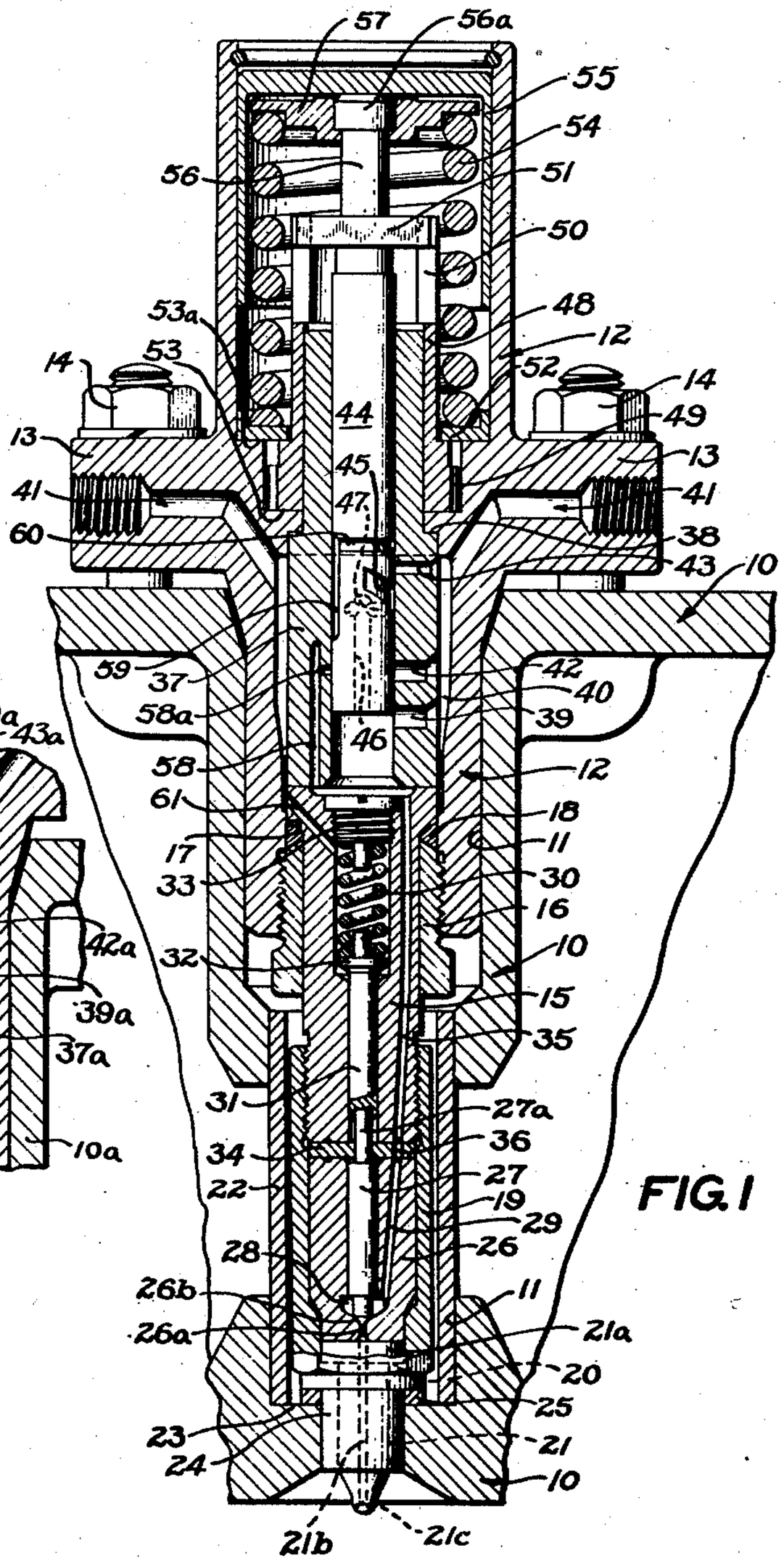


FIG. 1

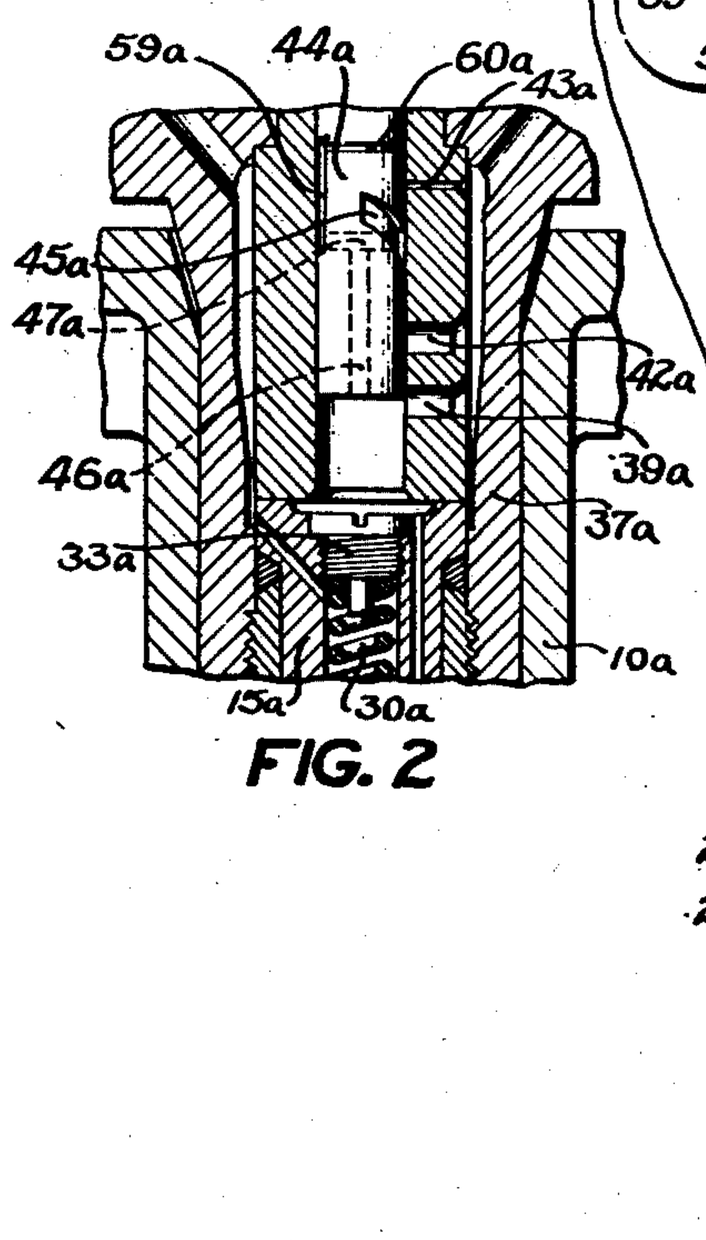


FIG. 2

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## FUEL INJECTION APPARATUS

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14 Claims. (Cl. 103—41)

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This invention relates to fuel injection apparatus and more particularly to means for controlling and effecting the delivery of fuel under pressure to the cylinders of a solid fuel injection engine.

One of the objects of the present invention is to provide a novel fuel injection apparatus whereby pilot injection, that is the injection of a small charge of fuel just prior to the injection of the main charge to effect more efficient burning of the latter, is efficiently achieved.

Another object is to provide a novel fuel injection unit embodying a fuel pump and injection nozzle in a unitary structure.

A further object is to provide a novel fuel pump for obtaining pilot and main injections, which pump embodies only a single pumping member or plunger.

A still further object is to provide a fuel injection pump having a novel plunger and cylinder arrangement for effecting pilot and main injections in a definite predetermined relation to each other.

Still another object is to provide novel apparatus of the above character which is extremely compact and wherein both pilot and main injections take place successively during a continuous movement of the plunger in one direction.

The above and further objects and novel features of the invention will more fully appear from the following detailed description when the same is read in connection with the accompanying drawings. It is to be expressly understood, however, that the drawings are for the purpose of illustration only and are not intended as a definition of the limits of the invention, reference for this latter purpose being had primarily to the appended claims.

In the drawings, wherein like reference characters refer to like parts throughout the several views,

Fig. 1 is a sectional elevation view, with parts broken away, of one type of unit or uni-flow fuel injector embodying the present invention; and

Fig. 2 is a fragmentary view of a modification of the plunger and cylinder arrangement of the above injector.

Referring to Fig. 1, the present invention is shown embodied in a unit injector, i. e., a unitary structure wherein a fuel pump and fuel injection nozzle are combined. Said injector is operatively positioned in the head 10 of a cylinder of a solid fuel injection engine, said cylinder head having a recess 11 therein for receiving said injector. The latter preferably comprises a main barrel or

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housing 12 having a flange 13 formed intermediate the ends thereof and secured to cylinder head 10 by bolts 14 so that the lower end of said housing extends into recess 11. A nozzle holder body 15 having an external shoulder 17 formed at the upper end thereof is mounted in the lower end of housing 12 and is secured in operative position by a gland nut 16 which screws into said housing and cooperates with said shoulder, a gasket 18 being preferably interposed between said shoulder and said gland nut. The latter is effective to hold nozzle body 15 in abutting sealing engagement with the lower end of a fuel pump cylinder 37 to be hereafter described.

Threaded on the lower end of body 15 is a sleeve nut 19 which is provided at its lower end with an internal shoulder 20 for supporting engagement with the flanged upper end 21*a* of a nozzle tip 21, said nozzle having a central bore or duct 21*b* therein and a plurality of radially extending orifices 21*c* adjacent the lower end or tip thereof. The nozzle tip 21 projects into the combustion chamber of the engine cylinder so that fuel can be sprayed from orifices 21*c* into said chamber and the shank of said nozzle tip is mounted in a sleeve 24 which is an integral extension of nut 19 and fits tightly into the lower end of recess 11. Sleeve nut 19 seats on a gasket 25 which in turn engages a shoulder 23 in cylinder head 10 for preventing gas leakage from the combustion chamber. A liner 22 constitutes a portion of the wall of recess 11 where the latter extends through the cooling chamber in cylinder head 10, said liner surrounding sleeve 19 and being supported at its lower end by internal shoulder 23.

Removably mounted in nut 19 above nozzle tip 21 is a valve guide 26 that is centrally bored for slidably receiving the stem or piston portion of a needle valve 27. The bore through said guide member terminates at the lower or inner end of the latter in a small orifice 26*a* which is coaxial with passage 21*b*, and a conical seat 26*b* is provided adjacent said orifice for cooperation with the tapered lower end of needle valve 27. The latter is thus effective to control the flow of fuel from member 26 into duct 21*b* and hence into the engine cylinder. Preferably, the bore in member 26 is enlarged immediately above valve seat 26*b* to provide a fuel pressure chamber 28 through which a reduced portion of valve 27 extends. Fuel supplied under pressure to chamber 28 through a suitable passage 29 in member 26 in a novel manner hereinafter described acts against the shoulder formed on the valve by the reduction in the diameter thereof, and is thus

effective to lift the latter off its seat and permit the flow of fuel from said chamber through passages 26*a*, 21*b* and 21*c* into the engine cylinder.

Valve 27 is normally held in seated or closed position by suitable means comprising resilient means, such as a coil spring 30, which applies yielding pressure to the valve through a pressure pin or spindle 31 that freely extends through the central bore in body 15. The lower end of spindle or rod 31 is preferably recessed for freely receiving a pin 27*a* formed by a reduced portion at the upper end of valve 27. A collar 32 may be formed near the upper end of the valve spindle to serve as a seat for one end of spring 30. The other end of the spring engages the inner end of a plug nut or screw 33 which is threaded or otherwise suitably secured in the upper end of the bore in nozzle body 15, said bore being of enlarged diameter at its upper end to receive spring 30 and said plug screw.

Between the adjacent ends of body 15 and valve member 26 there is preferably interposed a washer member or plate 34 having a central recess therein through which pin 27*a* of valve 27 extends, said washer being adapted to engage the upper end of the shank of the valve to limit the upward movement of the latter. A passage 35 extending from the upper end of body 15 connects with passage 29 in guide member 26 through an orifice 36 in plate 34. The latter may be readily replaced if it becomes worn by the constant hammering of valve 27 thereagainst.

In order to deliver fuel under pressure in a novel manner to chamber 28 and thence to the combustion chamber of the engine cylinder, novel pumping means are embodied in the injector unit. In the form illustrated, said means comprise a pump cylinder 37 mounted in the bore of housing 12 on the upper end of body 15 and having an external shoulder 38 thereon in engagement with a shoulder in said bore, whereby said cylinder is rigidly secured against axial movement by gland nut 16. Suitable means, such as a set screw (not shown), may also be provided for holding said cylinder against rotary movement. One or more fuel inlet ports 39 extend radially through the wall of cylinder 37 adjacent the lower end thereof and connect with an internal annular groove 40 in housing 12 which, in turn, communicates with the fuel supply line through passages 41. A pair of axially spaced by-pass or metering ports 42 and 43 are also provided in the wall of cylinder 37 to connect the interior thereof with groove 40. There is mounted in the cylinder bore for reciprocating movement therein a plunger 44 cooperating with said inlet and by-pass ports as a slide valve to control the flow of fuel therethrough in a manner more fully described hereinafter. A pressure chamber is thus formed in cylinder 37 between the lower end of plunger 44 and the upper plugged end of nozzle body 15 and fuel conducting passage 35 opens into said chamber. By providing a passage 41 on each side of the pump, one of which communicates with a sump, a continuous circulation of fuel may be maintained through annular chamber 40 for cooling the pump.

To control the point of main fuel by-pass, i. e., the termination of main fuel injection, a helical groove 45 is provided in the surface of plunger 44 for cooperation, in a manner well understood in the art with by-pass port 42, said groove being continuously connected to the pressure chamber of the pump by suitable passages, such as connected axial and radial passages 46 and 47, respectively. To vary the angular relation between metering groove 45 and cut-off or by-pass port 42 and thereby vary the effective pumping stroke of the piston, suitable means for angularly adjusting plunger 44 are provided and, in the form shown, comprise a sleeve 48 loosely surrounding the upper end of cylinder 37 in the enlarged interior of the upper end of housing 12. Gear teeth 49 are formed on the lower end of sleeve 48 for cooperation with a rack member (not shown) in a manner well-known in the art. The upper end of sleeve 48 is axially slotted at 50 for slidably receiving a cross bar 51 rigidly connected to plunger 44. Sleeve 48 seats on an internal shoulder 53 in housing 12 and is held against axial movement relative to cylinder 37 by a ring member 52 which engages an external shoulder on said sleeve and is positioned against an internal shoulder 53*a* in housing 12, said ring member being held on the latter shoulder by a spring 54 which constitutes an element of the plunger reciprocating means. The latter comprises a tappet cup 55 which is slidably positioned in the upper end of housing 12 for engagement with an enlarged head portion 56*a* of a member 56 operatively connected to or integrally formed with the upper end of piston 44. The latter may be moved downwardly by a cam actuated tappet lever (not shown) or other suitable means which is adapted to engage the closed end of tappet cup 29 in a manner well understood in the art. The downward movement of said plunger is resisted and the upward movement thereof is effected by spring 54 which has the lower end thereof seated on ring member 52 and the upper end thereof engaging a washer 57, which, in turn, engages a downwardly facing shoulder formed by the enlargement of head 56*a* to transmit upward forces to plunger 44.

Novel means are provided for effecting a primary or pilot fuel injection into the combustion chamber of the engine cylinder in a predetermined time relation to the main fuel injection during a continuous down or power stroke of plunger 44. In the form illustrated, said means comprise a by-pass or relief passage 58 provided in cylinder 37, which passage is connected at its lower end with the pressure chamber of the pump and at the upper end thereof with a port 58*a* which opens into the bore of said cylinder. An axially extending groove 59 is provided in the surface of plunger 44 and is adapted to overlap the upper end of passage 58 at a predetermined point in the plunger stroke to thereby connect said passage with an annular peripheral groove 60 in said plunger. Pilot by-pass port 43 in cylinder 37 is axially spaced above main by-pass port 42 and is adapted to connect groove 60 to inlet channel 40 for a predetermined part of the plunger stroke.

To prevent the trapping of fuel which leaks past valve 27 to the upper end of the bore of nozzle body 15, a relief passage 61 is provided between said bore and groove 40.

In operation, when plunger 44 is at top dead center position prior to the down or power stroke thereof, the pump pressure chamber and the fuel conducting passages 35, 29, 28 are filled with fuel at supply line pressure, port 39 is open and port 58*a* is closed. When plunger 44 moves downward to close inlet port 39 the pressure of the fuel in the pressure chamber is built up after closure of said port and is transmitted to chamber 28, raising valve 27 and thereby permitting

fuel to be injected into the combustion chamber of the engine cylinder through passages 35, 36, 29, 21*b* and 21*c*. While port 58*a* remains closed this primary delivery of fuel or pilot injection continues, but when the lower edge of groove 59 overlaps port 58*a* the latter is connected through groove 60 and primary or pilot by-pass port 43 to the fuel supply line, thereby by-passing the fuel from the pump pressure chamber and terminating pilot fuel injection. Groove 60 is preferably located so as to connect with port 43 before groove 59 connects with port 58*a* so that the point at which the lower edge of groove 59 overlaps port 58*a* governs the point at which primary or pilot injection is cut off. This point of cut-off, and therefore the period of pilot injection, can be varied by making the lower edge of groove 59 helical so that said groove connects with port 58*a* at different points in the plunger stroke for different angular positions of said plunger.

Fuel by-pass through port 43 continues until the upper edge of groove 60 passes beyond said port, thereby disconnecting the latter from the pressure chamber. At this point main injection begins and continues until the overlapping of helical groove 45 and main by-pass port 42. By changing the shape of the upper edge of groove 60, for example, to a helical contour, the point at which main injection begins can be varied for different angular positions of the plunger. Moreover, the duration of the primary and main injection periods and their timing in relation to the plunger stroke can be accurately predetermined for a given pump unit by the locations and contours of the metering edges of grooves 45, 59 and 60 in the plunger and the locations of ports 39, 42, 58*a* and 43 in the cylinder. This relation between pilot and main injection once established by the assembly of the plunger and cylinder remains constant during use and is not subject to variation because of wear or misalignment of parts, as occurs, for example, where two pistons are used to effect the injections.

A modified form of the piston and cylinder arrangement is shown in Fig. 2 wherein a piston 44*a* is slidably mounted in a cylinder 37*a*, the latter being provided with an inlet port 39*a* and main and pilot by-pass ports 42*a* and 43*a*, respectively. A helical groove 45*a* adapted to control the point of cut-off of main injection is formed in the surface of plunger 44*a* and is connected by passages 46*a* and 47*a* to the pump pressure chamber. Radial passage 47*a* differs from passage 47 of the previously described embodiment by extending to the surface of plunger 44*a* on opposite sides of passage 46*a*. To effect pilot injection grooves 59*a* and 60*a*, similar to grooves 59 and 60, respectively, of the previous embodiment, are provided in the surface of plunger 44*a* and connect with the pump pressure chamber through radial passage 47*a*. As a result, groove 60*a* is in continuous communication with said pump chamber and pilot injection begins when inlet port 39*a* is closed by the plunger and terminates when groove 60*a* overlaps port 43*a*. At the latter point in the stroke, fuel by-pass begins through passages 46*a*, 47*a*, 59*a*, 60*a* and 43*a* and continues until the groove 60*a* moves beyond port 43*a*. The point at which the lower edge of groove 60*a* overlaps port 43*a* thus determines the point of cut-off for the pilot injection while the point at which the upper edge of said groove moves past the lower edge of said port is the point at which main injection begins. In this embodiment, pilot injection takes place for



the same length of time and injects the same quantity of fuel into the engine cylinder for all loads and angular positions of the plunger. The termination of pilot injection and the beginning of main injection may, however, be varied by properly designing the upper and lower edges of groove 60*a*.

There is thus provided a fuel injector embodying novel means for efficiently achieving pilot and main fuel injections in a predetermined relation to each other, the timing and duration of said injections being subject to accurate control. According to the invention, a single pump plunger is utilized to obtain the injections and, if desired, the timing of the pilot as well as the main injection can be regulated by angular adjustment of the plunger. The novel structure for attaining these results is compact and readily assembled and can be embodied in a unit injector or in a fuel injection system where the pump and injector comprise separate units.

Although only two embodiments of the invention have been illustrated and described, it is to be expressly understood that the same is not limited thereto. For example, it will now be apparent to those skilled in the art that in the novel arrangement for obtaining pilot injection in Fig. 2, the connection between groove 60*a* and the pressure chamber could be achieved by extending axial passage 46 to the plane of said groove and providing a radial passage in the plunger to connect said axial passage with groove 60*a*. Various other changes may be made in the design and arrangement of parts without departing from the spirit and scope of the invention. For a definition of the invention, reference will be had primarily to the appended claims.

What is claimed is:

1. In a fuel pump, means comprising a pressure chamber and including a cylinder and a plunger, said plunger being mounted for reciprocation in said cylinder, means comprising two axially spaced parts in said cylinder, a passage in said cylinder for continuously connecting one of said ports to said chamber and a passage in said plunger for connecting said ports to effect a first fuel by-pass from said chamber during the plunger power stroke to terminate a pilot fuel delivery from said chamber, and means comprising a third port in said cylinder and a second passage in said plunger for effecting a second by-pass of fuel during the same plunger power stroke to terminate the main fuel delivery from said chamber.

2. In a fuel pump, means comprising a pressure chamber and including a cylinder and a plunger, said plunger being mounted for reciprocation in said cylinder and adapted to begin effective pumping prior to the main fuel injection to effect a primary injection of fuel, and means comprising a passage in said cylinder communicating with said chamber, a port in said cylinder and a cooperating passage in said plunger for connecting said cylinder passage and port to effect a by-pass of fuel from said chamber to terminate the primary fuel injection prior to the beginning of main injection.

3. In a fuel pump, means constituting a pressure chamber, said means comprising a cylinder and a plunger, a port being provided in said cylinder for admitting fuel to said chamber, said plunger closing said port during the power stroke thereof to begin effective pumping, means comprising two passages in said cylinder and passage means in said plunger, said second-named means

being rendered operative upon the overlapping of one of said passages and said passage means during the plunger power stroke after the beginning of effective pumping to by-pass fuel from said chamber and thereby interrupt the effective pumping of said plunger, said plunger thereafter disconnecting said passage means from the other of said passages during the power stroke to effect a resumption of effective pumping.

4. In a fuel pump of the type comprising a cylinder, a plunger mounted for reciprocation in said cylinder and means constituting a main system for by-passing fuel from said cylinder, the combination therewith of means comprising passages in said plunger and said cylinder constituting a primary by-pass system for interrupting the effective pumping during the plunger power stroke to control the duration of a pilot delivery and the timing of the main delivery of fuel from the cylinder, the opening of said system being determined by the cooperation of said plunger and one passage in said cylinder and the closing of said system being effected by the closing of another passage in said cylinder by said plunger.

5. In a fuel injection pump having a compression chamber comprising a cylinder and a plunger, means for interrupting the pumping during the power stroke of the plunger to terminate a pilot injection, said means comprising a by-pass port in said cylinder, a passage in said plunger and a passage in said cylinder communicating with the compression chamber, said plunger passage overlapping said cylinder passage to connect said compression chamber to said by-pass port to begin by-pass and said plunger passage being adapted to move out of overlapping relation with said by-pass port to terminate by-pass and effect the beginning of main injection.

6. In a fuel injection pump having a pressure chamber comprising a cylinder and a plunger, means for interrupting the pumping during the power stroke of the plunger to terminate pilot injection, said means comprising a by-pass port in said cylinder, a passage in said plunger and a passage in said cylinder in continuous communication with said pressure chamber, said plunger passage overlapping said cylinder passage to begin by-pass and moving out of overlapping relation with said port to terminate by-pass.

7. In a unit injector, a fluid pressure pump and a nozzle rigidly connected together to form a rigid unit, said pump including a cylinder and a plunger slidably mounted in said cylinder to define a pressure chamber, means including a pressure responsive valve connecting said chamber to said nozzle, and means comprising a plurality of passages in said plunger and ports in said cylinder for successively effecting pilot and main fuel deliveries from said chamber to said nozzle during each power stroke of said plunger.

8. In a unit injector, a cylinder, a plunger slidably mounted in said cylinder to define a pressure chamber, a nozzle, means connecting said nozzle to said chamber, and means for controlling the delivery of fuel from said chamber to said nozzle so as to effect primary and main injections during each power stroke, said last-named means comprising a pair of axially spaced grooves in said plunger, a passage continuously connecting one of said grooves to said chamber, a port in said cylinder and passage means having continuous communication with said chamber and adapted to cooperate with the other of said grooves and said port to control the cut-off point of primary injection and a second port in said cylinder



adapted to cooperate with said one groove to control the cut-off of main injection, the beginning of main injection being determined by the movement of said other groove out of overlapping relation with said first-named port.

9. In a fuel injector having a cylinder and a plunger slidably mounted in said cylinder to define a pressure chamber, a passage in said cylinder continuously connected with said pressure chamber, means connecting said passage to the fuel supply line to by-pass fuel from said chamber and cut-off pilot injection, said last-named means including a passage in said plunger and a port in said cylinder which are disconnected by the plunger movement to terminate fuel by-pass, and means for effecting a second by-pass of fuel to terminate the main injection.

10. In a fuel pump, means comprising a pressure chamber, said means including a cylinder and a plunger reciprocable in said cylinder, means comprising a port in said cylinder, a passage in said plunger adapted to communicate with said port and a passage in said cylinder adapted to connect said plunger passage with said chamber for effecting a first fuel by-pass from said chamber during the plunger power stroke to terminate a first fuel delivery from said chamber, and means comprising a port in said cylinder and a passage in said plunger for effecting a second by-pass of the fuel from said chamber during the same plunger power stroke to terminate a second fuel delivery from said chamber.

11. In pumping apparatus for delivering a liquid under pressure to a delivery line, means forming a pressure chamber including a cylinder and a plunger reciprocable therein, an inlet port in said cylinder adapted to be covered by said plunger for determining the beginning of the delivery of liquid to said line, and cooperating passages formed in and by said cylinder and plunger for effecting two deliveries of liquid to said line during one continuous power stroke of the plunger, certain of said passages cooperating to determine the termination of the first delivery and others of said passages cooperating to determine the initiation of the second delivery.

12. In pumping apparatus for delivering a liquid under pressure to a delivery line, means forming a pressure chamber including a cylinder and a plunger reciprocable therein and cooperating ports and passages formed in and by said cylinder and plunger for effecting a temporary by-pass of liquid from said chamber to interrupt the delivery of liquid to said line for an interval during an intermediate part of each pumping stroke of said plunger, the beginning of said interval being determined by the movement of certain of said ports and passages into overlapping relation and the termination of said interval being determined by the movement of others of said ports and passages out of overlapping relation.

13. In apparatus of the class described, means forming a pressure chamber including a cylinder and a plunger reciprocally mounted therein, and cooperating passages formed in and by said cylinder and plunger for effecting two deliveries of a liquid from said chamber to a delivery line during each pumping stroke of said plunger, the termination of the first delivery being determined by movement of a passage in the plunger into overlapping relation with a passage in said cylinder and the beginning of the second delivery being determined by movement of said passage in the plunger out of overlapping relation with a different passage in said cylinder, at least one of said

passages having continuous communication with said pressure chamber and at least one other of said passages being in continuous communication with a region of low pressure.

14. In pumping apparatus for delivering a liquid under pressure to a delivery line, means forming a pressure chamber, said means including a cylinder and a plunger reciprocable therein, said plunger and cylinder cooperating to effect two deliveries of liquid from said chamber to said line during each pumping stroke of said plunger, the interval between said deliveries being determined by the opening of one passage in the cylinder by movement of the plunger and the subsequent closing of another passage in the cylinder by movement of said plunger, one of said passages having communication with said chamber and the other of said passages having communication with a region of relatively low pressure.

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## REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

| Number | Name | Date |
|---|---|---|
| 2,173,813 | Bischof | Sept. 19, 1939 |
| 1,993,759 | Stockmeyer | Mar. 12, 1935 |
| 1,951,215 | Sidney | Mar. 13, 1934 |
| 2,306,364 | Skaredoff | Dec. 21, 1942 |

FOREIGN PATENTS

| Country | Date |
|---|---|
| Great Britain | 1932 |
| Germany | 1933 |
| France | 1920 |

| Number |
|---|
| 375,151 |
| 572,711 |
| 679,312 |