Dec. 7, 1948. H. C. EDWARDS 2,455,571

FUEL INJECTION PUMP

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Fig. 1.

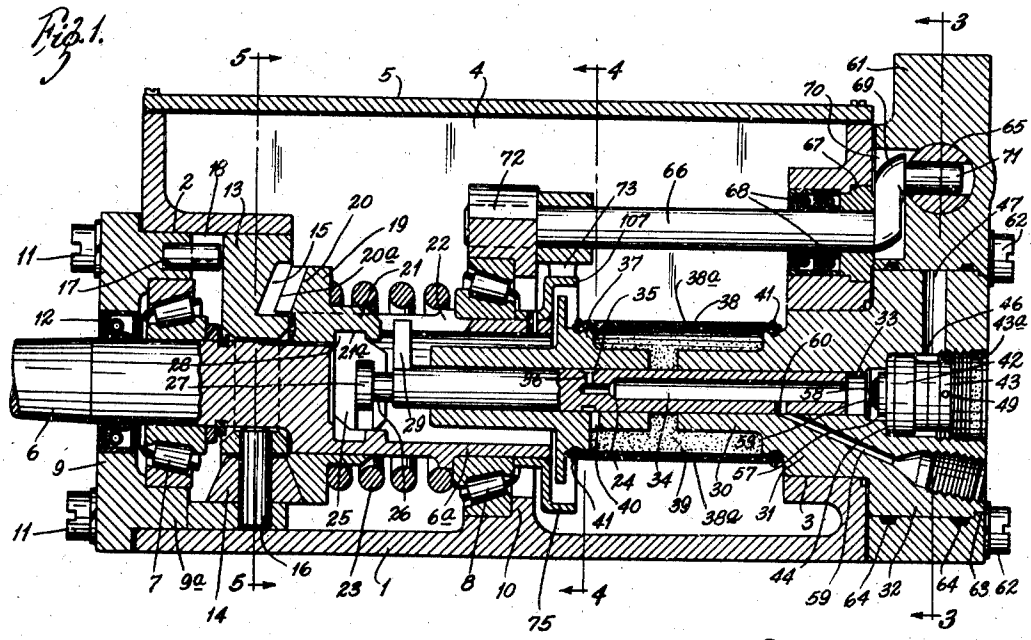


Fig. 2.

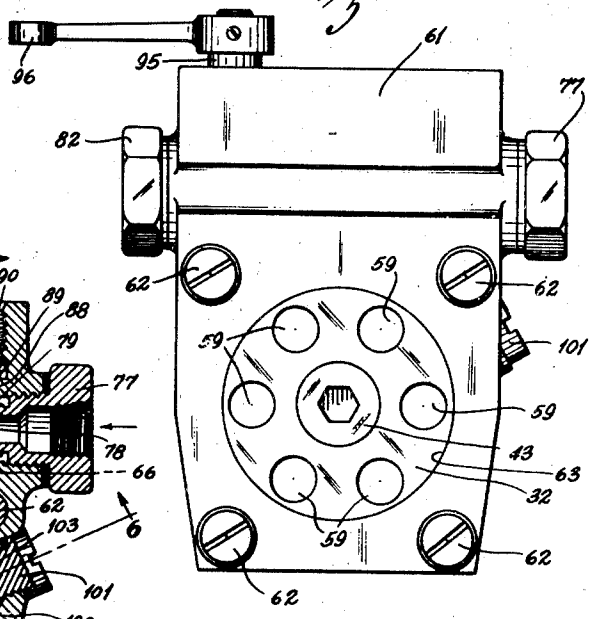
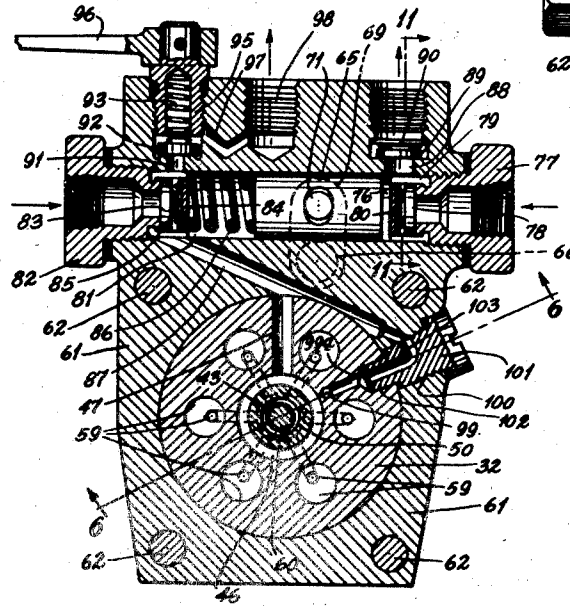


Fig. 3.



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Fig. 4.

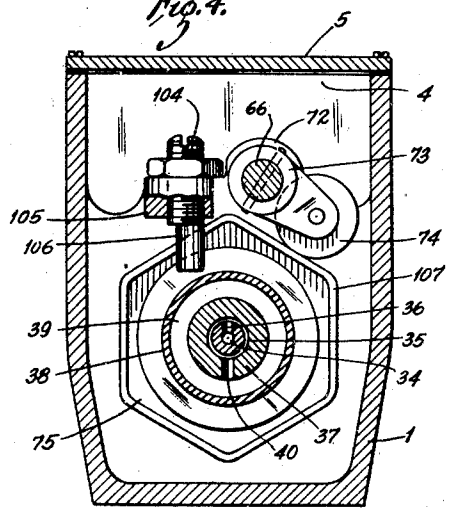


Fig. 5.

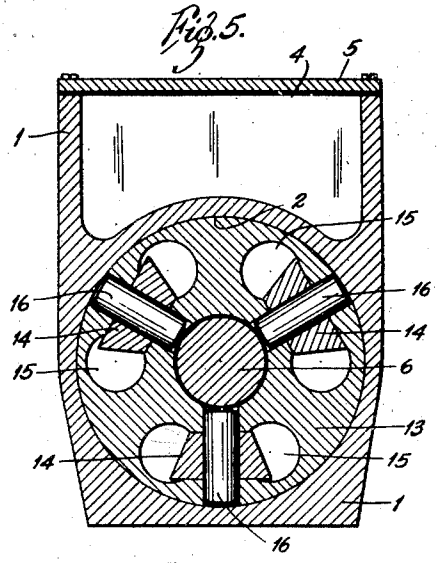


Fig. 6.

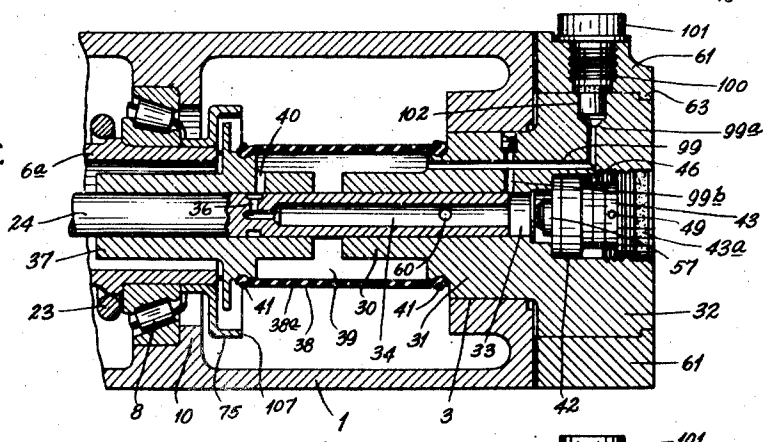
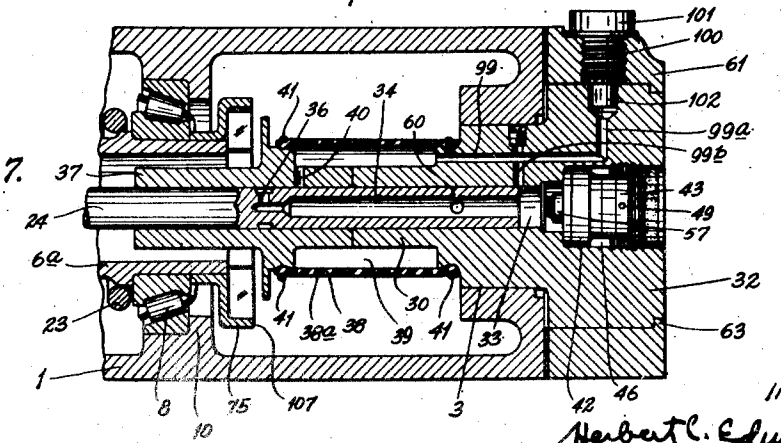


Fig. 7.



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Fig. 8.

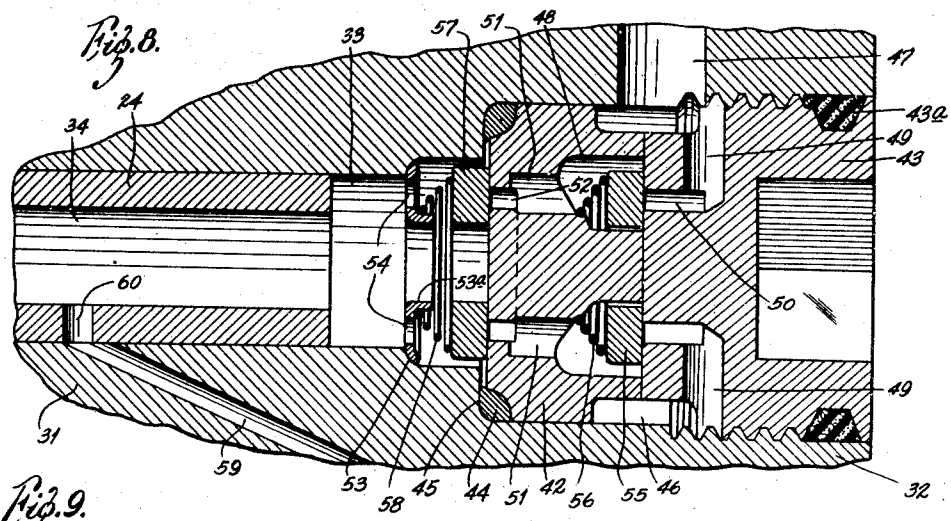


Fig. 9.

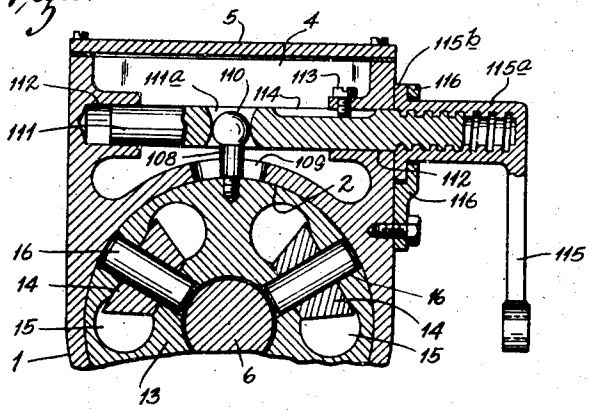


Fig. 11.

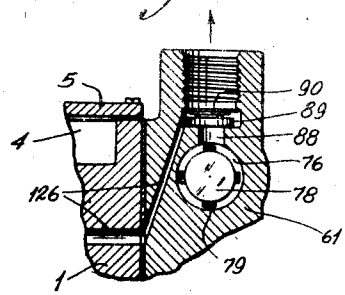
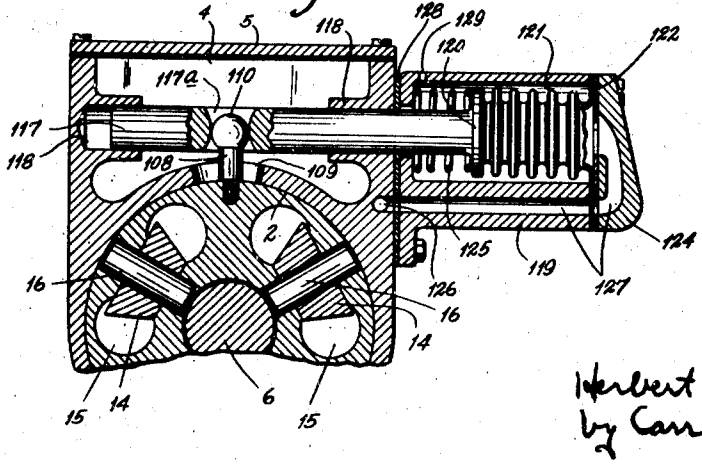


Fig. 10.



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Patented Dec. 7, 1948

2,455,571

UNITED STATES PATENT OFFICE

2,455,571

FUEL INJECTION PUMP

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Application November 11, 1944, Serial No. 562,962

11 Claims. (Cl. 103—5)

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This invention relates to pumps, particularly single plunger fuel injection pumps for multi-cylinder compression ignition engines. The principal objects of the present invention are to provide a simple, economical and compact pump of the above type that will deliver a correct quantity of fuel to each working cylinder of the engine in proper timed relation to the working cycle thereof; that will provide a unit injection and supply pump construction in which the supply pump is operated by the injection pump; that will utilize the varying pressure developed by the pump for automatically regulating the quantity and the time of the fuel injection in accordance with the speed of the engine; that will provide for manually adjusting the timing of the fuel injection; that will provide manually operable means for changing the maximum pressure of the fuel bypassed from the pump to set the pump for different engine speeds; and that will obtain other advantages hereinafter appearing. The invention consists in the single plunger, multiple discharge fuel injection pump and in the parts and combinations and arrangements of parts hereinafter described and claimed.

In the accompanying drawings, which form part of this specification and wherein like symbols refer to like parts wherever they occur,

Fig. 1 is a central longitudinal sectional view of a fuel pump embodying my invention,

Fig. 2 is an end elevational view of the supply pump end of said fuel pump,

Fig. 3 is a cross-sectional view on the line 3—3 in Fig. 1,

Fig. 4 is a cross-sectional view on the line 4—4 in Fig. 1,

Fig. 5 is a cross-sectional view on the line 5—5 in Fig. 1,

Fig. 6 is a central longitudinal section on the line 6—6 in Fig. 3, the fuel control sleeve being shown in no throttle position,

Fig. 7 is a view similar to Fig. 6, showing the fuel control sleeve in full throttle position,

Fig. 8 is an enlarged fragmentary central longitudinal section through the fuel inlet end of the injection pump barrel,

Fig. 9 is a fragmentary sectional view similar to Fig. 5, showing the pump provided with means for manually changing the time of the fuel injection,

Fig. 10 is a view similar to Fig. 9, showing the pump provided with means for hydraulically actuating the fuel timing mechanism; and

Fig. 11 is a fragmentary section on the line 11—11 in Fig. 3 showing the manner in which the

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hydraulically operated fuel injection timing means is placed in communication with the supply pump for operation by the pressure developed thereby.

The single plunger, multiple injection fuel pump shown in the accompanying drawings is adapted for use with a six-cylinder, four cycle, compression ignition engine. Said fuel injection pump comprises an elongated housing or casing 1 having axially alined cylindrical end openings 2 and 3, respectively, and a side opening 4 closed by a removable cover plate 5. A drive shaft 6 extends into the housing 1 through the end opening 2 thereof and is adapted to be driven by or in unison with the engine at one-half engine speed. The drive shaft 6 is supported in two rotary anti-friction bearings 7 and 8 mounted respectively in an annular end cap 9 for the end opening 2 of the housing 1 and in a cross wall 10 formed in said housing intermediate between the ends thereof. The end cap 9 is removably secured to the housing 1 by cap screws 11 and has a cylindrical plug portion 9a that fits within the end opening 2 of said housing. A suitable oil seal 12 surrounds the drive shaft 6 and is supported in the opening provided therefor in the annular end cap 9.

Mounted in the end opening 2 of the housing 1 in endwise abutting relation to the inner end of the plug portion 9a of the annular end closure 9 for said opening is an annular holder 13 which supports three circumferentially spaced conical cam rollers 14 that are disposed radially of said holder and taper inwardly towards the axis thereof. The conical cam rollers 14 are located in pockets 15 provided therefor in the annular holder 13 and are journaled on pins 16 mounted in radial bores provided therefor in said holder. The annular roller holder 13 is prevented from rotating with the drive shaft 6 by means of a dowel pin 17 which is fixed in the inner end of the plug portion 9a of the annular end closure 9 and fits within a radial slot 18 provided therefor in the adjacent end of said holder.

Mounted on the drive shaft 6 opposite the inner end of the fixed roller holder 13 is an annular cam member 19 having a conical cam face 20 at its holder opposing end adapted to cooperate with the conical cam rollers 14 journaled in said holder. The annular cam member 19 is splined to the shaft 6 for rotation therewith and for axial sliding movement relative thereto by the cam rollers 15, the cam member being forced inwardly along said shaft when a rise 20a on the cam face 20 thereof engages a cam roller. The splined con-

nection between the cam member 19 and the shaft 6 comprises an internal longitudinal rib 21 that fits in a corresponding groove or opening 22 in said shaft.

The rotary and axially slidable cam member 19 is yieldably held in engagement with the cam rollers 14 by means of a coil compression spring 23 that is mounted around the inner end portion of the drive shaft 6 with one end bearing against said cam member and with the other end seated against the innermost drive shaft bearing 8.

The drive shaft 6 has a tubular inner end portion 6a adapted to receive a fuel injection pump plunger 24 which rotates with said tubular end portion but is reciprocable axially therein with the annular cam member 19 splined thereon. The reciprocating motion of the cam member 19 is imparted to the plunger 24 through a transfer plate 25 which is located in the tubular portion 6a of the drive shaft 6 and has a T-slot 26 adapted to rotatably receive the adjacent headed end 27 of said plunger and a lug 28 that fits in a notch 21a in the internal rib or spline 21 in the drive shaft receiving bore of said cam member. The rotary driving connection between the rotary but non-axially slidable drive shaft 6 and the cam reciprocated pump plunger 24 comprises a lug 29 that is rigid with said plunger near the headed end 27 thereof and is slidable in the longitudinal spline receiving slot 22 in the tubular plunger receiving inner end portion of said drive shaft.

The rotary and reciprocable pump plunger 24 works in a pump cylinder or barrel 30 having an enlarged intermediate portion 31 that fits the end opening 3 in the pump housing 1 and a larger head portion 32 that is disposed in endwise abutting relation to the outside face of said housing around said end opening. The plunger 24 cooperates with the barrel 30 to form a pressure chamber or space 33 therein; and said plunger has an axial bore 34 that extends from the working end thereof to a point beyond the inner end of the barrel 30 and communicates with and forms part of said pressure chamber or space. The plunger 24 has an exterior annular groove 35 formed therein adjacent to the blind end of the axial bore 34 thereof and one or more radial pressure relief ports 36 leading from said bore to said annular groove.

Slidable on the plunger 24 between the barrel 30 and the driving lug 29 is a fuel control sleeve 37 which is connected to said barrel by means of an axially extensible sleeve 38 that cooperates with said control sleeve, barrel and plunger to form therewith an annular chamber 39 that is adapted to be placed in communication with the exterior annular groove 35 in said plunger through one or more radial ports 40 in said control sleeve. The extensible sleeve 38 preferably comprises a length of oil resistant rubber tubing containing a metallic coil spring reinforcement 38a which resists radial expansion of said tubing while permitting axial elongation thereof by the pressure of the fuel in the annular chamber 39. The ends of the elastic sleeve 38 are secured to the barrel 30 and to the control sleeve 37 preferably by means of conventional hose clamps 41 which provide leakproof connections between said extensible sleeve and said barrel and control sleeve. If desired, the axially extensible sleeve 38 may be in the form of a Sylphon bellows.

The pump barrel 30 has the outer end of its plunger supporting bore enlarged to receive a high pressure double fuel inlet valve assembly, through which fuel is supplied to the pressure space or chamber 33. Said inlet valve construction comprises a cylindrical inner valve body 42 and a cylindrical outer valve body 43 that is threaded into the enlarged outer end portion of the plunger receiving bore of the barrel member and bears against said inner valve body and presses the latter endwise against a gasket 44 that seats against an annular shoulder 45 provided therefor by the enlarged outer end portion of said bore. The outer valve body 43 carries a packing ring 43a which seals the joint between said body and the supporting bore therefor. The abutting ends of the inner and outer valve bodies are reduced to form with the enlarged outer end portion of the plunger supporting bore of the barrel 30 an annular fuel inlet chamber 46; and the head 32 of the barrel member has a radial fuel passageway 47 leading from the outer periphery of said head to said annular fuel inlet chamber. The outer end of the inner valve body 42 has an annular groove formed therein that cooperates with the adjacent inner end of the outer valve body 43 to form an annular valve chamber 48. The outer valve body 43 has a series of circumferentially spaced radial passageways 49 leading inwardly from the annular fuel inlet chamber 46 to an annular groove 50 formed in the inner end of said valve body and opening into the annular valve chamber 48.

The annular valve chamber 48, in turn, opens through a circular series of longitudinal ports 51 in the inner valve body 42 into an annular groove 52 in the inner end thereof. The annular groove 52 communicates with the pressure space or chamber 33 in the pump barrel 30 through a washer 53 which seats against an annular shoulder provided at the outer end of said chamber. As shown in the drawing, the washer 53 has a circular series of fuel ports 54 therein between the central opening therethrough and the outer margin thereof. Located in the annular valve chamber 48 is an annular disk valve 55 which closes the annular groove 50 in the outermost valve body 43 and is normally held in closed position by means of a coil spring 56 interposed between said valve and the inner end wall of said chamber. The annular groove 52 in the inner end of the innermost valve body 42 is closed by a similar annular disk valve 57 which is normally held in closed position by means of a coil spring 58 interposed between said valve and the washer. The washer 53 has an outstanding flange 53a around the central opening therein, said flange and the small openings 54 in said washer tending to prevent broken valve spring parts from entering the pressure chamber 33.

The pump barrel member 30 has a plurality of fuel discharge passageways 59 therein, one for each of the six working cylinders of the engine supplied by the pump. The fuel discharge passageways 59 are spaced apart equally about the axis of the barrel member 30 with their inner ends opening into the plunger supporting bore inwardly of the double inlet valve construction and with their outer ends opening through the outer end face of the head 32 of said barrel member where they are threaded for connection with injection lines or conduits (not shown) that lead to the injection nozzles (not shown) for the respective working cylinders of the engine. Communication is established between the pressure space or chamber 33 and the several fuel discharge passageways through a radial port 60 in the axial bore of the pump plunger 24.

The barrel or cylinder 30 of the fuel injection pump is held in the end opening 3 of the pump housing 1 by means of an end cap or plate 61 which is secured by cap screws 62 to the adjacent end of said housing and has a circular hole therethrough adapted to snugly receive the cylindrical head portion 32 of said pump barrel or cylinder. The hole in the retaining plate or cap 61 has an annular lip or flange 63 at the outer end thereof that overlaps the head 32 of said barrel and retains the same in said hole. The head supporting opening in the retaining plate 61 is sealed against leakage by two sealing rings 64 located therein one on each side of the radial fuel inlet passageway 47 in the barrel head 32.

The pump chamber 33 is supplied with fuel by a supply pump mechanism operated from the drive shaft 6 of the fuel injection pump. This supply pump comprises a piston 65 mounted in a bore that extends through the retaining plate 61 from side to side thereof crosswise of the axis of the pump plunger 24. The piston 65 is reciprocated by means of a rocker shaft 66 that is located in the housing 1 parallel with the plunger 24 and extends through the pump barrel supporting end wall of said housing and is supported in said end wall by a suitable anti-friction bearing 67 with suitable oil seals 68 at the inner end thereof. The outer end of the rocker shaft 66 terminates in a crank 69 that operates in a recess 70 in the plate 61 and has a pin 71 that fits within a transverse opening provided therefor in the piston 65, whereby said piston is adapted to be reciprocated when said shaft is oscillated. The inner end of the piston operating shaft 66 is supported in a suitable anti-friction bearing 72 provided therefor in the transverse wall 10 of the housing 1; and said shaft is provided adjacent to said wall with a rocker lever 73 having a cam roller 74 journaled on the free end thereof. The cam roller 74 cooperates with a hexagonal edge cam 75 which is fixed to the inner end of the drive shaft 6 for rotation therewith, whereby the rocker shaft 66 is oscillated by the rotary movement of said drive shaft.

Fuel from a tank or other source of supply (not shown) is supplied to a chamber 76 at one end of the piston supporting bore through a valved inlet fitting 77 threaded therein. The fitting 77 is provided with an inlet valve comprising a disk valve 78 that is mounted in a cage 79 secured to the inner end of said fitting and is yieldably held against said end of said fitting by means of a spring 80 mounted in said cage. Fuel is also supplied to a chamber 81 at the opposite end of the piston supporting bore through an inlet valve fitting 82 threaded therein. The fitting 82 comprises a disk valve 83 that is mounted in a cage 84 carried by said fitting and held against the inner end thereof by a spring 85 mounted in said cage. A coil spring 86 is interposed between the valve cage 84 and the opposing end of the piston 65 for moving said piston in one direction of its reciprocating movement. The piston 65 is moved in the other direction of its reciprocating movement by the hexagonal cam 75 on the inner end of the drive shaft 6. Continuous communication is provided between the chamber 81 and the radial fuel inlet passageway 47 in the pump barrel head 32 through a fuel supply passageway 87 in the retaining plate 61.

The chamber 76 formed between the inlet valve fitting 77 and the adjacent end of the piston 65 communicates with an outlet passageway 88 which opens through the end cap 61 and is provided

with an outwardly opening disk valve 89 which is held to its seat by means of a spring 90. The chamber 81 formed between the inlet fitting 82 and the adjacent end of the piston 65 opens into a by-pass passageway 91 having an outwardly opening disk valve 92 therein that is held to its seat by means of a spring 93. The by-pass passageway 91 is provided with a threaded plug 95 having an axial recess therein for supporting the valve closing spring 93. The threaded plug 95 has a throttle lever 96 fixed to the exposed outer end thereof, whereby said plug may be rotated to vary the valve closing pressure of the valve spring 93. The passageway 91 communicates outwardly of the valve 92 therein through a passageway 97 with a fuel outlet opening 98. By this arrangement, the reciprocating movement of the fuel supply piston 65 causes oil to be drawn from the supply tank through the fitting 77 into the chamber 76, thence through the valved passageway 88 to a suitable filter (not shown), thence through the inlet valve fitting 82 to the chamber 81 and thence through the supply passageway 87 and double inlet valve to the pressure space 33 of the fuel injection pump for delivery through the fuel discharge passageways 59 to the engine cylinders, the surplus fuel being returned to the fuel supply tank through the by-pass passageways 91, 97 and 98.

The pump barrel member 30 has a longitudinal fuel passageway 99 therein which opens at one end into the annular fuel chamber 39 formed by the extensible sleeve 38 and terminates at its outer end in a portion that is disposed radially of said barrel member and opens through the outer peripheral face of the head portion 32 of said barrel member. The pump barrel retaining plate 61 has an opening 100 therein that is threaded to receive a cap screw 101 which terminates at its inner end in a dowel plug 102 that fits within the radially disposed outer end portion 99*a* of the passageway 99 in the pump barrel member 30 and thus prevents said member from rotating. The fuel supply passageway 87, which leads from the supply pump chamber 81 to the radial fuel inlet passageway 47, is extended to communicate with the dowel screw receiving opening 100; and the dowel screw 101 has a fuel passageway 103 therein that establishes communication between said fuel supply passageway and the radially disposed outer end portion of the fuel passageway 99 leading from the axially expansible annular chamber 39 formed by the extensible sleeve 38. The fuel by-pass passageway 99 also has a branch passageway 99*b* intermediate between the ends thereof that is disposed radially of the pump barrel 30 and opens into the pressure chamber or space 33 therein adjacent to the double inlet valve end thereof.

Movement of the axially slidable fuel control sleeve 37 in the direction of the pump barrel 30 is limited by means of a stop screw 104 that is threaded through a lug 105 provided therefor on the cross wall 10 of the housing 1 and has an eccentric end portion 106 disposed in the path of travel of an outstanding circumferential flange 107 on said sleeve. By rotating the stop screw 104, the position of the eccentric stop pin portion 106 thereof may be changed to vary the travel of the control sleeve 37 in the direction of the pump barrel 30.

The operation of the hereinbefore described pump is as follows: The drive shaft 6 is continuously rotated from the engine at one-half engine speed and the fuel injection pump plunger 24 rotates with said drive shaft while being recip-

rocated in the pump barrel or cylinder 30 by the roller actuated cam 79 splined on said shaft, the pump plunger making one complete rotation for each engine cycle and the plunger making six reciprocating cycles for each rotation that it makes. At the same time, the crank shaft 66 is operated by the cam 75 on the drive shaft 6 to impart one complete reciprocating cycle to the supply pump piston 65 for each complete reciprocating cycle of the fuel injection pump plunger 24. During this reciprocating movement of the supply pump piston 65, fuel from the supply tank is drawn through the valved inlet fitting 77 into the primary fuel inlet chamber 76 at one end of said piston and is forced through the valved outlet passageway 88 into the filter and thence through the valved inlet fitting 82 into the secondary fuel inlet chamber 81 at the opposite end of said piston. The fuel in this secondary inlet chamber 81 is then forced by the piston 65 through the inclined supply passageway 87 and through the radial fuel inlet passageway 47 in the pump barrel head 32 into the annular chamber 46, radial passageways 49 and annular groove 50 of the double fuel inlet valve assembly for the working chamber 33 of the fuel injection pump.

During the suction stroke of the injection pump plunger 24, the supply pump piston 65 produces enough pressure to lift the two high pressure inlet valves 55 and 57 off their seats and fill the entire pressure space or chamber 33 of the injection pump with fuel. During the forward or working stroke of the pump plunger 24 part of the fuel drawn into the pump chamber 33 flows into the overflow or by-pass passageway 99 until the branch 99b thereof is covered by the plunger; whereupon the remaining fuel trapped in said chamber is forced therefrom under high pressure through the radial discharge port 60 into one of the fuel discharge passageways 59 leading to the injection nozzle supplied thereby. The fuel injection terminates when the radial port 36 in the pump plunger 24 registers with the radial pressure relief port 40 in the control sleeve 37 and thus relieves the pressure in the pump chamber 33 and permits the inlet valves 55 and 57 to close. The excess fuel flows through the radial ports 36 and 40 into the axially expansible chamber 39 in the axially extensible sleeve 38 and thence through the passageway 99 into the fuel supply passageway 87 to mix with the incoming fuel therein. During the reciprocating movement of the pump plunger 24, said plunger is also rotated due to its connection with the continuously rotating drive shaft 6. Thus, the single fuel discharge port 60 in the pump plunger 24 successively registers with the six fuel discharge passageways 59 in the pump cylinder, the injection plunger making one complete reciprocating cycle for each injection and one complete rotation for each complete engine cycle.

The fuel supply pump has a certain overcapacity and thus delivers an excess quantity of fuel to the secondary fuel chamber 81 of said pump, a predetermined pressure of such excess fuel in said chamber forcing the pressure relief valve 92 to lift off its seat and permit the surplus fuel to return to the supply tank through the passageways 91 and 97 and the by-pass fuel outlet 98. The pressure relief valve 92 also opens to relieve the sudden pressure increase created in the by-pass system when the pressure space 33 of the injection pump is placed in communication with the axially expansible annular by-pass chamber 39 to terminate the delivery of fuel through the fuel discharge passageways 59 of the injection pump.

The quantity of fuel delivered to the engine through the discharge passageways 59 depends upon the axial position of adjustment of the fuel control sleeve 37 on the pump plunger 24. Thus, when the fuel control sleeve 37 is slid along the plunger 24 towards the forward or working end thereof, the pressure relief port 36 in the plunger registers with the port 40 in said sleeve at a point in the pressure stroke of said plunger which will prolong the fuel injection and thus increase the quantity thereof; whereas when the control sleeve is slid axially in the opposite direction, the pressure relief port in the plunger registers with the port in said sleeve at a point in the working stroke of the plunger that shortens the fuel injection and decreases the quantity thereof. When the control sleeve 37 is adjusted so that the pressure relief port 36 in the plunger 24 is in communication with the port 40 in the control sleeve during the entire working stroke of said plunger, said sleeve is in no throttle position and no fuel injection occurs. As shown in the drawings, full throttle position of the control sleeve 37 is established by the eccentric stop pin 105 of the screw 104.

The axial position of adjustment of the fuel quantity control sleeve 37 is determined by the length of the axially expansible actuating sleeve 38 therefor; and the axial length of said expansible sleeve depends upon the by-pass fuel pressure which, in turn, is controlled by the spring-loaded by-pass valve 92. When the control lever 96 is adjusted to increase the spring loading on the valve 92, the by-pass fuel pressure increases and the sleeve 38 is extended to move the control sleeve 37 in the direction of decreased fuel supply, thus decreasing the speed of the engine. When the control lever 96 is adjusted to decrease the spring loading on the pressure control valve 92, the by-pass fuel pressure decreases and the sleeve 38 shortens and pulls the control sleeve 37 in the direction of increased fuel supply, thus increasing the speed of the engine. In each speed setting of the control lever 96, the fuel control sleeve 37 is automatically adjusted according to the speed and load conditions of the engine by the varying by-pass pressure in the axially expansible and contractible operating sleeve 38. Thus, when the speed of the engine increases, there is an increase in by-pass fuel pressure which causes the extensible sleeve 38 to lengthen and move the control sleeve 37 in the direction of decreased fuel feed, and when the engine speed decreases the by-pass fuel pressure decreases and permits the extensible sleeve to shorten and move the control sleeve in the direction of increased fuel feed. Upon a rise in by-pass fuel pressure sufficient to overcome the spring loading of the valve 92, said valve lifts off its seat and permits the excess pressure to be dissipated through the passageway 97 and outlet 98 to the fuel supply tank.

The construction shown in Fig. 9 dispenses with the dowel pin 17, so as to permit rotation of the roller holder 13 in the supporting opening 2 therefor in the housing 1 and provides means for circumferentially adjusting said roller holder relative to the cam 19 to advance or retard the time of the fuel injection. The mechanism for circumferentially adjusting the roller holder 13 comprises a stud 108 which is fixed to and projects radially upwardly from the roller holder 13 through a circumferentially elongated slot 109 provided therefor in the cylindrical wall of the end opening 2 in which said roller holder is rotatably supported.

The stud 108 has a ball-shaped enlargement 110 formed thereon near the upper end thereof that snugly fits in a tranverse opening 111a provided therefor in a cross shaft 111 which is supported for axial sliding movement in alined holes 112 in the opposite side walls of the housing 1, the ends of the said transverse opening being flared to permit rocking movement of said stud therein. The axially movable cross shaft 111 is prevented from rotating by means of a screw 113 which is threaded into the housing 1 with its end located in a longitudinal groove 114 provided therefor in said shaft.

The cross shaft 111 has one end threaded and extended outside of the housing 1 to receive the internally threaded hub portion 115a of a manually operable lever 115. The pump housing opposing end of the hub 115a of the lever 115 has an outstanding circumferential flange 115b thereon which is held between the housing and a retaining plate 116 that is screwed to said housing, thereby preventing axial movement of said lever when the latter is rotated. By this arrangement, when the lever 115 is rotated on the cross-shaft 111, the threaded connection between the hub of said lever and said cross-shaft causes the latter to move axially in the supporting openings 112 crosswise of the rotary axis of the roller holder 13. This endwise movement of the cross-shaft 111 forces the stud 108 to move therewith, thus rotating the roller holder 13 to change the circumferential position thereof relative to the cam 19 and thereby advance or retard the time of the fuel injection relative to the engine cycle.

In Figs. 10 and 11, the pump is shown provided with a device which utilizes the varying pressure developed by the fuel supply pump for automatically regulating the time of the fuel injection in accordance with the speed of the engine. This hydraulically operated timing device, like the manually operable timing device, comprises a stud 108, which extends radially upwardly from the rotatable roller holder 13 through a circumferentially elongated slot 109 in the wall of the opening 2 in which said holder is supported, and a ball 110 formed on said stud near the outer end thereof. In the construction shown in Figs. 10 and 11, the ball portion 110 of the stud 108 snugly fits a transverse opening 117a through a cross-shatf 117 which is supported for axial sliding movement in openings 118 provided therefor in the opposite side walls of the pump housing 1. The shaft 117 extends into a cylinder 119 fixed to the outside face of the adjacent side wall of the housing 1 and terminates in an outwardly flanged end 120 which is soldered to and seals one end of a Sylphon bellows 121 whose opposite end has an outstanding flange 122 that is clamped between the outer end of said cylinder and a closure cap 124 therefor which seals the other end of said Sylphon bellows. A calibrated coil spring 125 is mounted around the shaft between the inner end walls of the cylinder 119 and the Sylphon bellows 121 and serves to yieldably resist endwise expansion thereof.

Communication is established between the fuel supply pump and the Sylphon bellows 121 through a passageway 126 that extends longitudinally of the adjacent side wall of the housing 1 and communicates at one end with the outer end of the Sylphon bellows 121 through a passageway 127 in the side wall of the cylinder and in the end cap 124 therefor. The other end of the passageway 126 opens into the valved outlet passageway 88 of the supply pump chamber 76 outwardly of the outwardly opening discharge valve 89 therefor. Throughout the speed range of the fuel

injection pump, the supply pump is adapted to generate a certain pressure characteristic which is transmitted through the passageways 126 and 127 to the Sylphon bellows 121 which operates against the spring 125 and through the cross shaft 117 and stud 108 to hold the roller holder 13 in a position that will give the best and most efficient fuel injection timing for economical operation of the engine. As the engine speed varies, the spring 125 and the changing supply pump pressure in the Sylphon bellows 121 operate to hold the cross shaft 117 in the position of its axial adjustment that will maintain the fuel injection timing at the most efficient point for the particular speed at which the engine is operating. The cylinder 119 is bolted against the main pump housing 1 with a gasket 128 interposed therebetween; and said cylinder is vented, as at 129 to permit free movement of the Sylphon bellows 121 therein. The fuel pressure, which is relatively high, is sealed within the passageways and the Sylphon valve without the use of sliding glands.

Obviously, the hereinbefore described fuel injection pump admits of considerable modification without departing from the invention. Therefore, I do not wish to be limited to the precise arrangement shown and described.

What I claim is:

1. A fuel injection pump comprising a cylinder having a pump chamber with a fuel inlet passageway and a fuel discharge passageway, a plunger reciprocable in said cylinder and forming therewith said pump chamber, said plunger having a fuel by-pass port in communication with said pump chamber, said pump having a fuel by-pass conduit, a fuel control sleeve slidable on said plunger and having a fuel by-pass port in continuous communication with said by-pass conduit and adapted to communicate with the by-pass port of said plunger during the pressure stroke of the latter, and means operable by variation in the pressure of the fuel in said by-pass conduit for shifting said sleeve to bring the by-pass port thereof into communication with the by-pass port in said plunger at different points in the pressure stroke of the latter to thereby vary the quantity of fuel delivered through said discharge passageway.

2. The combination set forth in claim 1 in which said cylinder has a plurality of circumferentially spaced fuel discharge passageways, said plunger has a fuel discharge port in communication with said pump chamber, means is provided for rotating said plunger to bring the fuel discharge port thereof into successive communication with said fuel discharge passageways and a second pump is provided for supplying fuel to said inlet passageway and includes a piston that is reciprocated by the plunger rotating means.

3. The combination set forth in claim 1 in which the means for reciprocating said plunger comprises a drive shaft disposed in axial alinement therewith, a roller journaled on an axis disposed radially of said shaft, a cam having an axially slidable but non-rotary connection with said shaft and movable by said roller axially of said shaft to impart the pressure stroke to said plunger, and means for adjusting said roller circumferentially of said cam to vary the point in the rotary movement thereof in which the pressure stroke is imparted to said plunger by said cam.

4. The combination set forth in claim 1 in which said plunger has a fuel discharge port in communication with said pump chamber and

said plunger is rotated to bring said fuel discharge port into communication with said fuel discharge passageway during the pressure stroke of said plunger, the means for reciprocating and rotating said plunger comprises a drive shaft having an axially slidable driving connection therewith, a cam rotatable with and slidable axially of said shaft and operatively connected to said plunger to rotate and reciprocate the same, a stationary annular member surrounding said shaft, a roller journaled in said annular member radially thereof, and a spring for holding said cam in engagement with said roller, a second pump is provided for supplying fuel to said inlet passageway, and said annular member is rotatably adjusted relative to said cam by variation in the pressure of the fuel in said second pump.

5. A fuel injection pump comprising a cylinder having a pump chamber with a fuel inlet passageway and a fuel discharge passageway, a plunger reciprocable in said cylinder and forming therewith said pump chamber, a fuel control sleeve slidable on said plunger and having a fuel by-pass port therein, and an axially extensible sleeve surrounding said plunger with one end fixed to said pump and the other end fixed to said fuel control sleeve and forming an axially expansible and contractable fuel by-pass chamber, said control sleeve having a fuel by-pass port opening into said by-pass chamber, said plunger having a fuel by-pass port in communication with said pump chamber and adapted to register with said control sleeve by-pass port during the pressure stroke of said plunger, whereby variation in the pressure of the fuel in said by-pass chamber operates to change the length of said sleeve and the axial position of the by-pass port therein relative to the by-pass port in said plunger to thereby vary the quantity of fuel delivered through said discharge passageway.

6. The combination set forth in claim 5 in which means is provided for varying the maximum pressure of the fuel in said by-pass chamber.

7. A fuel injection pump comprising a cylinder having a fuel inlet passageway and a plurality of circumferentially spaced fuel discharge passageways, a plunger reciprocable and rotatable in said cylinder and having a fuel discharge port adapted to successively register with said fuel discharge passageways during the rotary movement of said plunger, a shaft disposed in axial alinement with and operatively connected to said plunger for reciprocating and rotating the same, a second pump for supplying fuel to said fuel inlet passageway, said second pump including a piston disposed crosswise of the shaft axis, and means for reciprocating said piston comprising a shaft disposed parallel with said shaft axis and having a crank pin fitting in a transverse opening provided therefor in said piston, a roller carried by said shaft, and a cam rotatable with said drive shaft and cooperating with said roller to oscillate said crank shaft.

8. A fuel injection pump comprising a housing having an opening therein, a drive shaft journaled in said opening, a pump cylinder mounted in said housing in axial alinement with the inner end of said shaft and having fuel inlet and discharge passageways, a plunger reciprocable in said cylinder, a holder mounted in said opening, a roller journaled in said holder radially thereof, a cam having an axially slidable driving connection with said shaft and cooperating with said roller for movement thereby axially of said shaft, a connection between said cam and said plunger, whereby the axial movement of said cam is imparted to said plunger, and means for rotating said holder in said opening to vary the point in the rotary movement of said cam in which said plunger is actuated thereby.

9. The combination set forth in claim 8 in which the means for rotating said holder comprises a shaft mounted in said housing crosswise of the rotary axis of said holder, a stud projecting from said holder and operatively connected to said shaft, and means for shifting said shaft axially to actuate said stud.

10. The combination set forth in claim 8 in which the means for rotating said holder comprises a shaft mounted in said housing crosswise of the rotary axis of said holder, a stud projecting from said holder and operatively connected to said shaft, and means responsive to variation in pressure of the fuel in said pump for shifting said shaft axially to actuate said stud.

11. The combination set forth in claim 8 in which the means for rotating said holder comprises a shaft mounted in said housing crosswise of the rotary axis of said holder, a stud projecting from said holder and operatively connected to said cross-shaft, and means for shifting said shaft axially to actuate said stud, said means comprising a Sylphon bellows having one end fixed and closed by one end of said cross-shaft, a cylinder fixed to said housing and enclosing said bellows and closing the other end thereof, and a spring for yieldably resisting the expansive action of said Sylphon bellows, said housing having a fuel conduit opening into said Sylphon bellows, whereby said Sylphon bellows is operable by variation in pressure of the fuel in said conduit.

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