March 27, 1945. H. C. EDWARDS 2,372,559

FUEL INJECTION PUMP

Filed Nov. 4, 1940 6 Sheets-Sheet 1

Fig. 1.

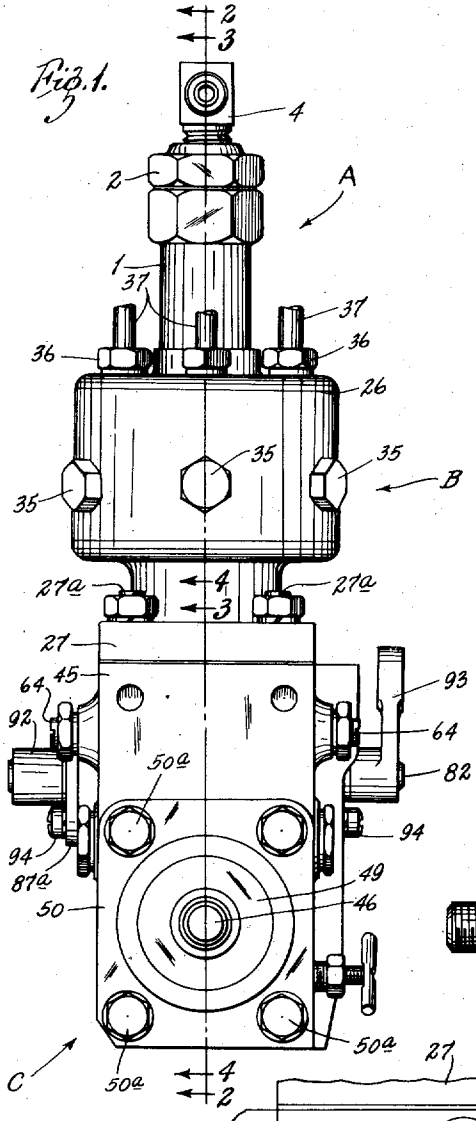


Fig. 2.

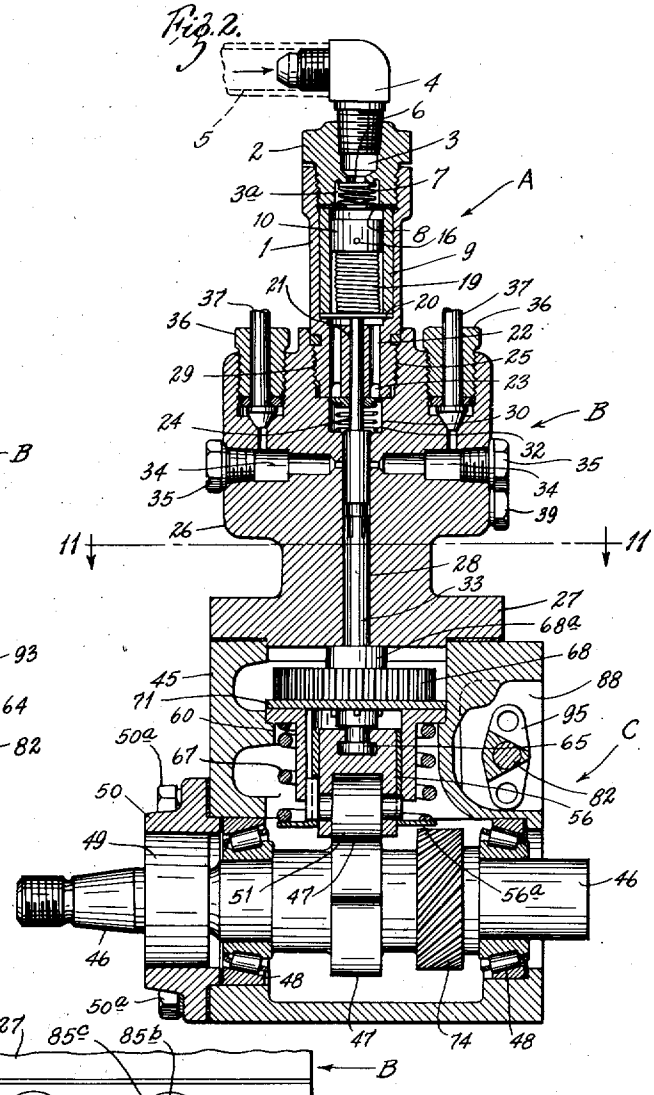
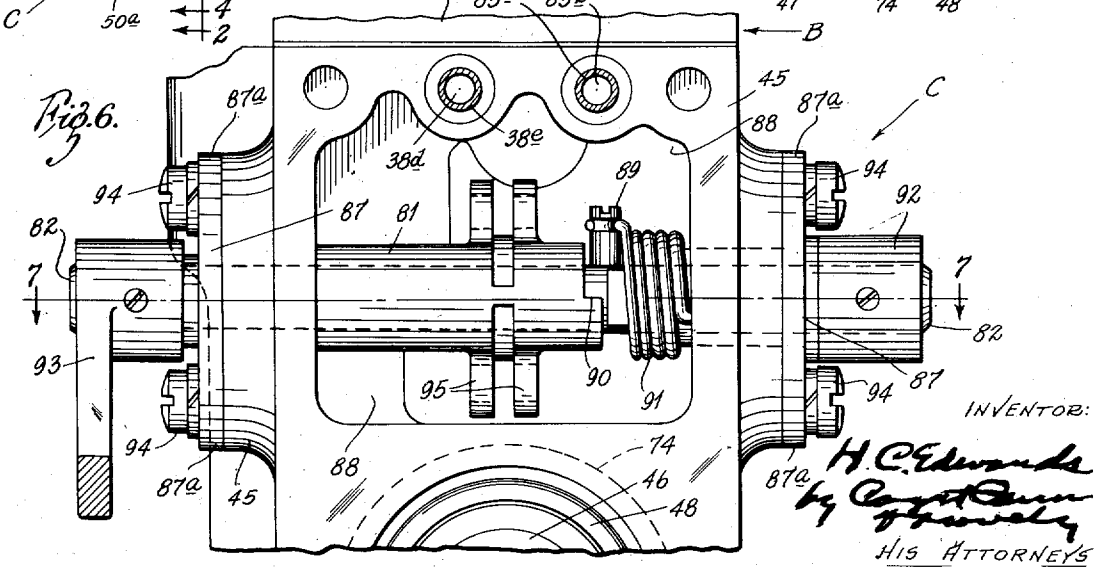


Fig. 6.



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March 27, 1945. H. C. EDWARDS 2,372,559

FUEL INJECTION PUMP

Filed Nov. 4, 1940 6 Sheets-Sheet 2

Fig. 3.

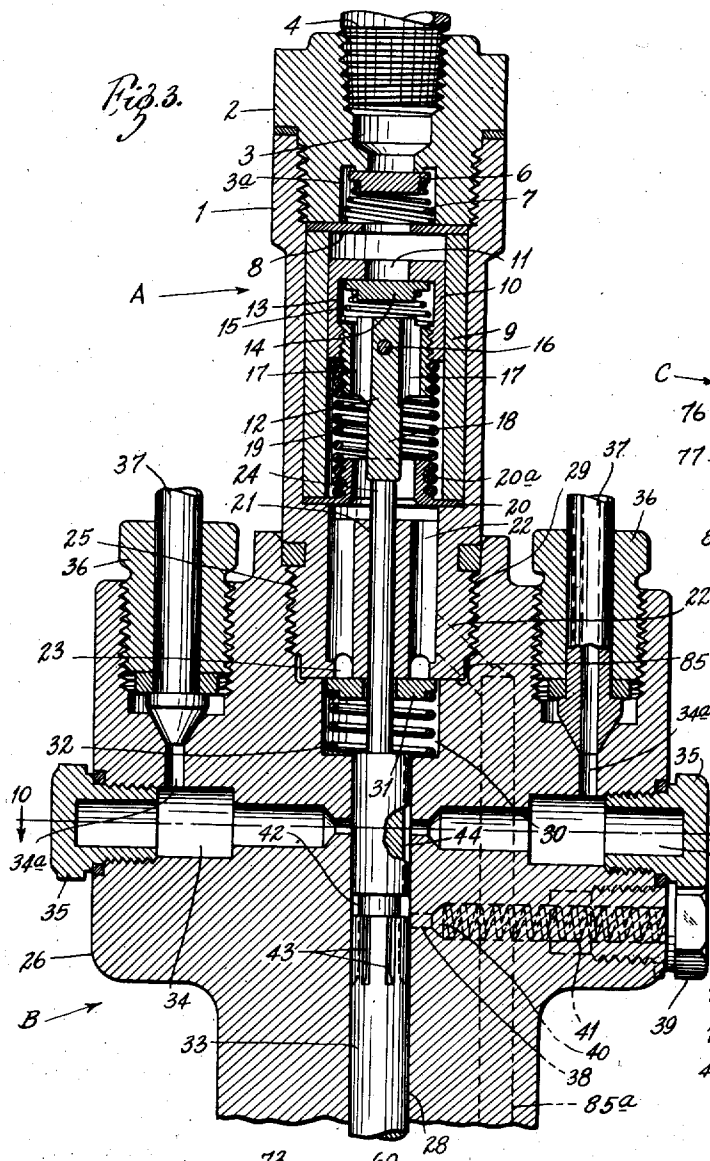


Fig. 8.

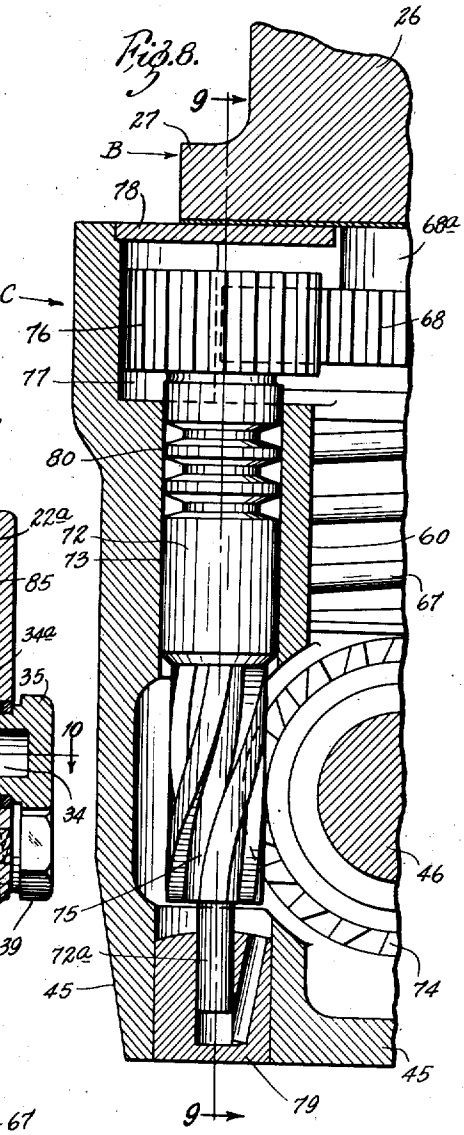
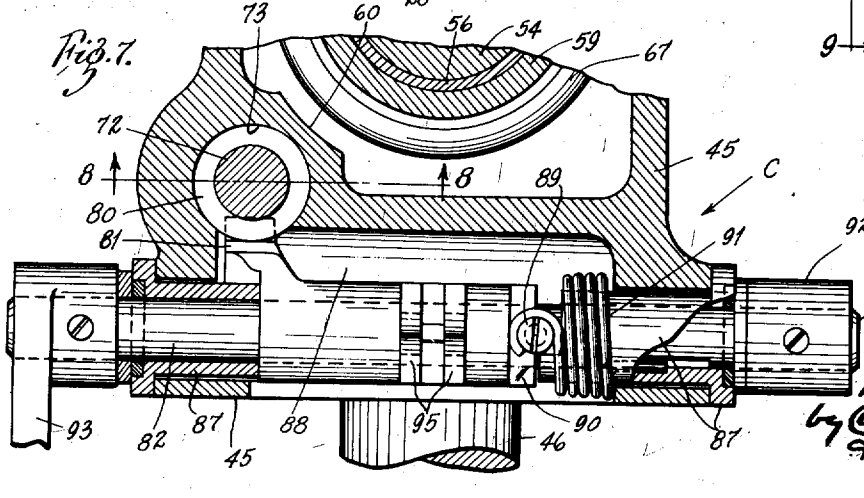


Fig. 7.



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March 27, 1945. H. C. EDWARDS 2,372,559

FUEL INJECTION PUMP

Filed Nov. 4, 1940 6 Sheets-Sheet 3

Fig. 4.

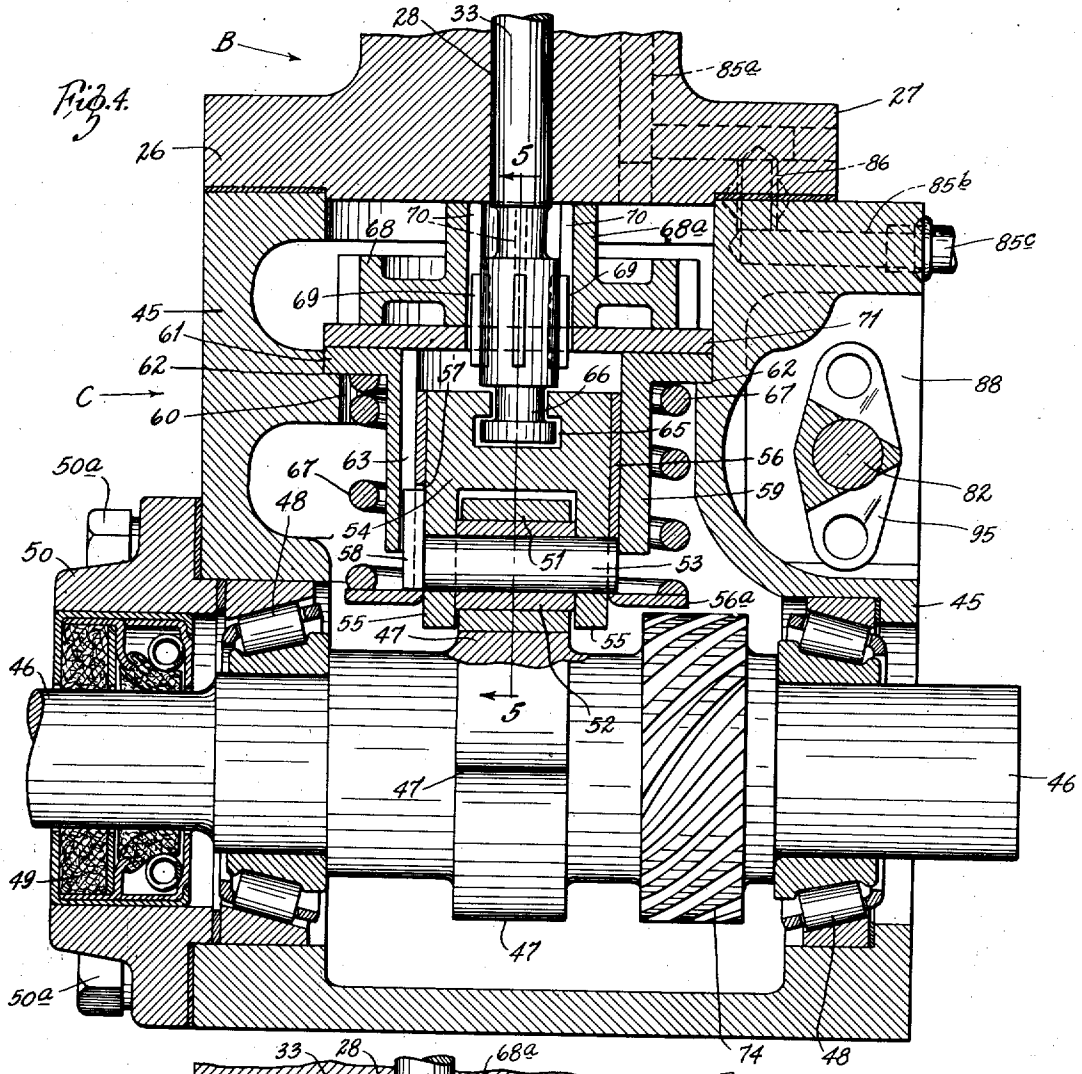


Fig. 5.

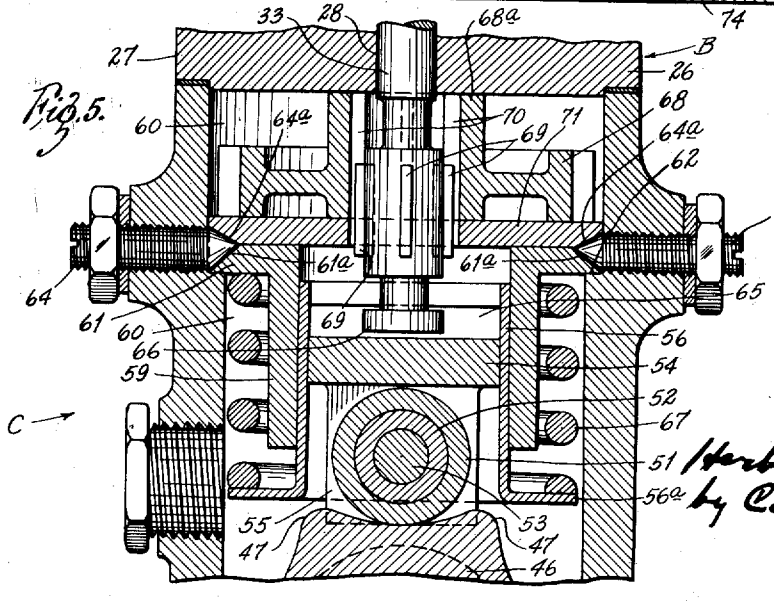
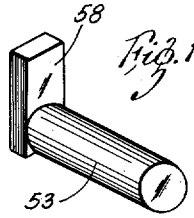


Fig. 14.



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March 27, 1945. H. C. EDWARDS 2,372,559

FUEL INJECTION PUMP

Filed Nov. 4, 1940 6 Sheets-Sheet 4

Fig. 10.

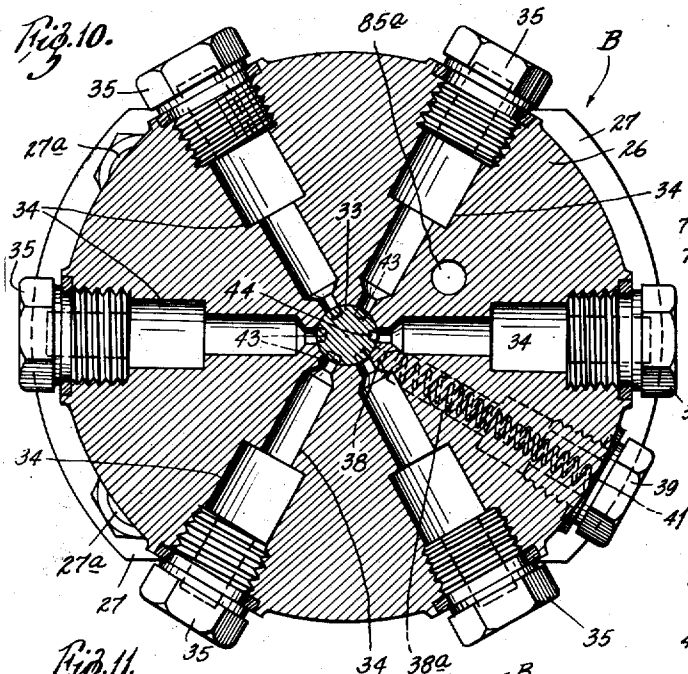


Fig. 9.

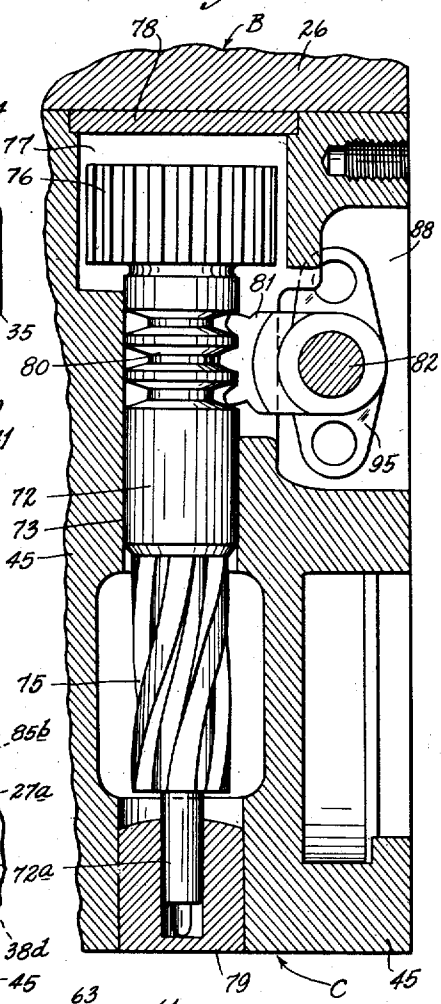


Fig. 11.

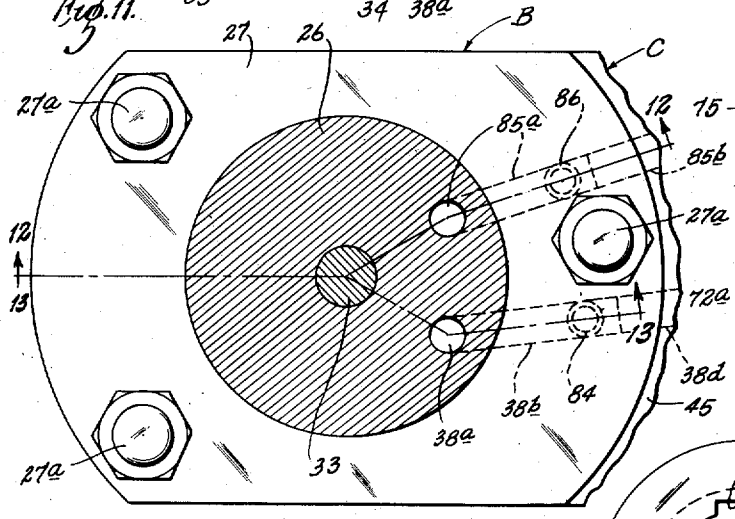


Fig. 15.

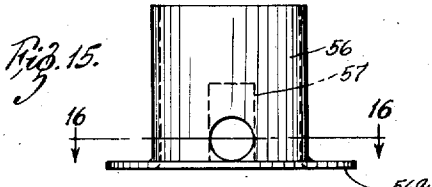


Fig. 16.

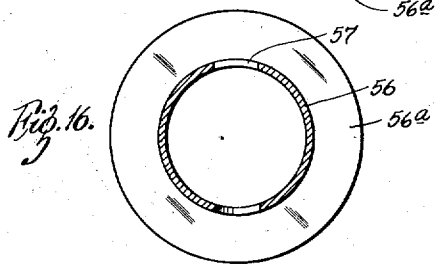


Fig. 17.

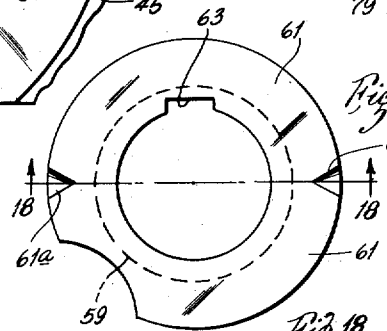
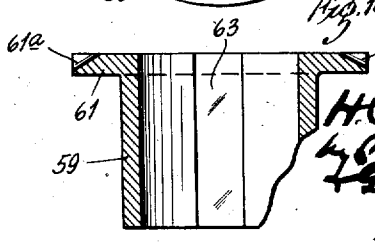


Fig. 18.



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March 27, 1945. H. C. EDWARDS 2,372,559

FUEL INJECTION PUMP

Filed Nov. 4, 1940 6 Sheets-Sheet 5

Fig. 12.

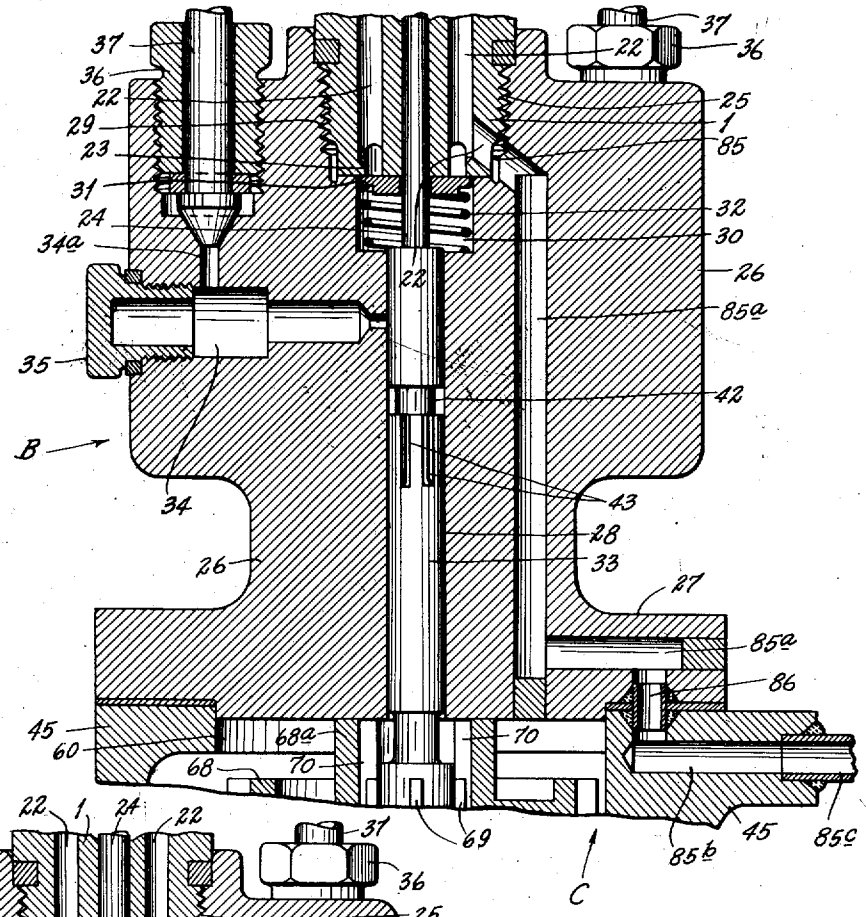
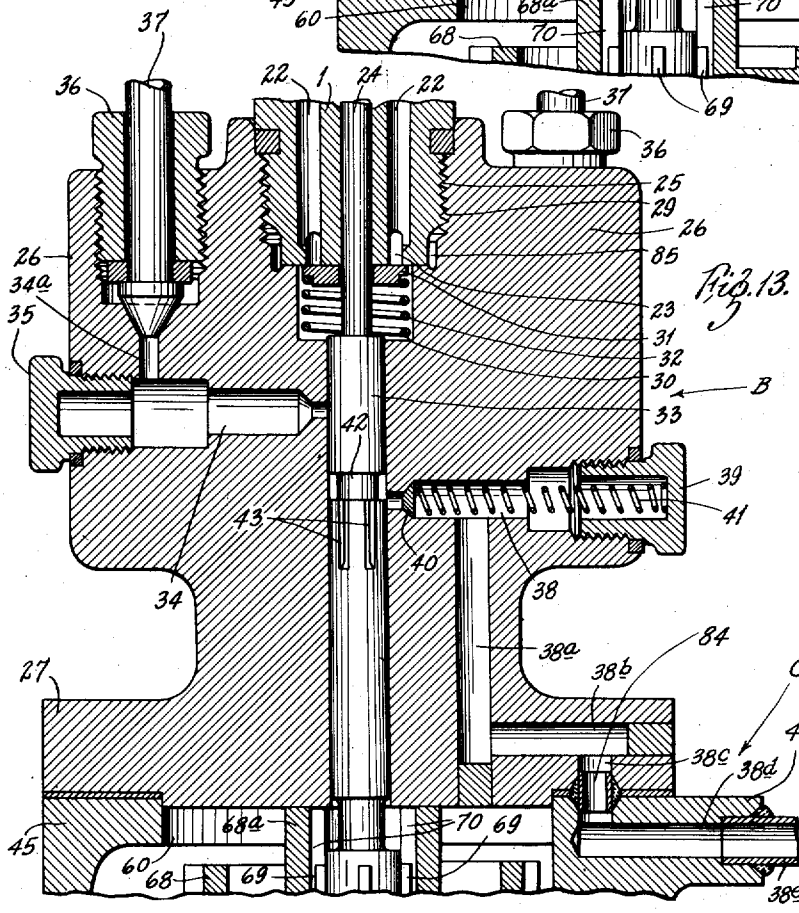


Fig. 13.



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March 27, 1945. H. C. EDWARDS 2,372,559

FUEL INJECTION PUMP

Filed Nov. 4, 1940 6 Sheets-Sheet 6

Fig. 19.

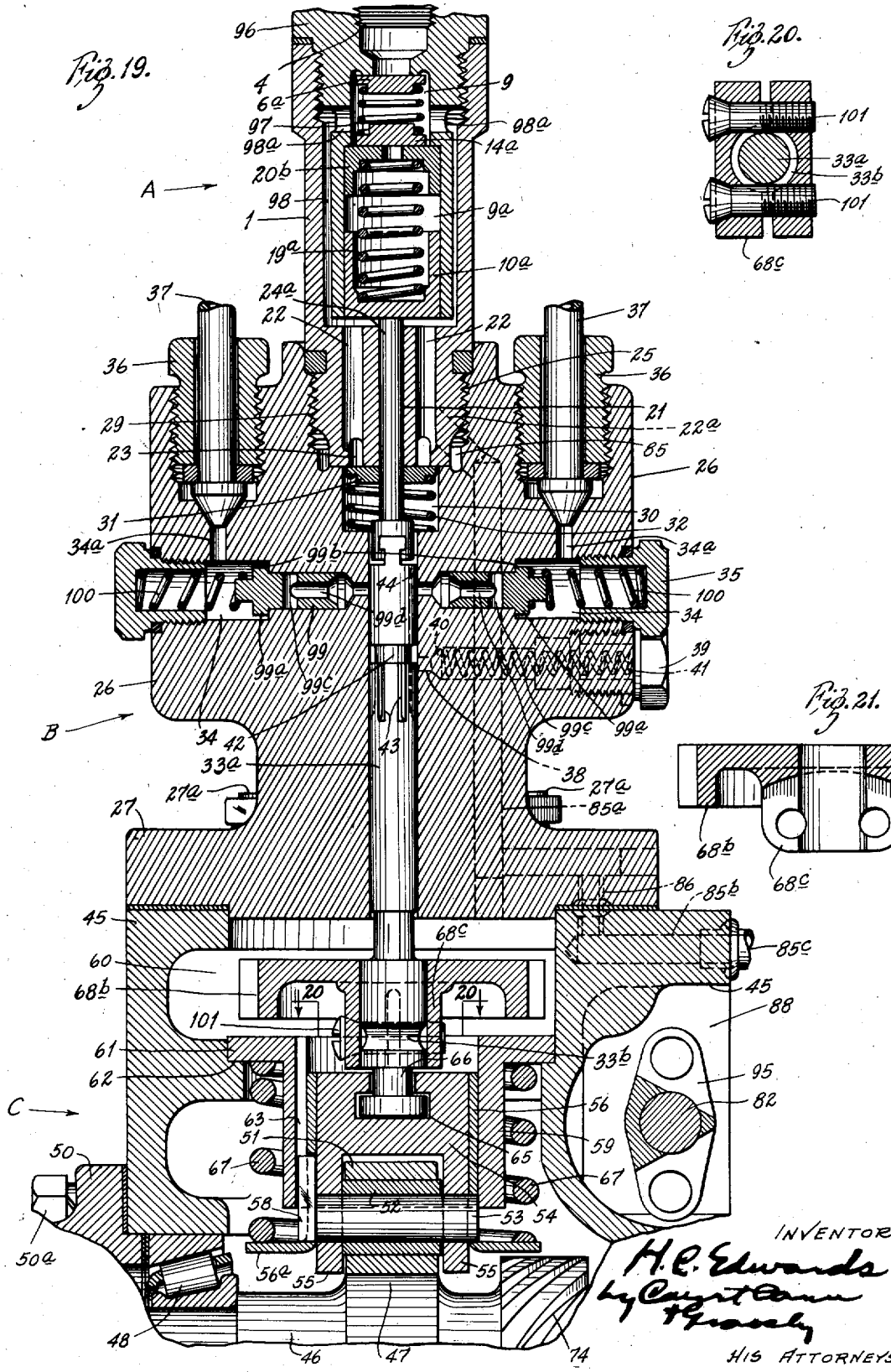


Fig. 20.

Fig. 21.

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Patented Mar. 27, 1945 2,372,559

UNITED STATES PATENT OFFICE

2,372,559

FUEL INJECTION PUMP

Herbert C. Edwards, Massillon, Ohio, assignor to The Timken Roller Bearing Company, Canton, Ohio, a corporation of Ohio

Application November 4, 1940, Serial No. 364,232

19 Claims. (Cl. 103—41)

This invention relates to pumps, particularly single plunger fuel injection pumps for multiple cylinder compression ignition engines. It has for its principal object to devise a single plunger fuel injection pump that will have all of the advantages of a multiple plunger pump; that is, selective delivery of a variable quantity of fuel to each working cylinder of the engine in proper timed relation to the working cycle thereof; to provide a unit injection and supply pump assembly in which the supply pump is operated by the injection pump; to provide for initially adjusting the injection pump to the requirements of the particular engine supplied thereby; and to provide for simplicity of construction, ease and economy of operation, reduced cost of manufacture, reduction in weight and compactness of design. 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 an end elevation of a fuel pump embodying my invention,

Fig. 2 is a central vertical section through said pump on the line 2—2 in Fig. 1,

Fig. 3 is an enlarged section similar to Fig. 2 through the upper portion of the pump on the line 3—3 in Fig. 1,

Fig. 4 is an enlarged section similar to said Fig. 2 through the lower portion of the pump on the line 4—4 in Fig. 1,

Fig. 5 is a fragmentatry central vertical section on the line 5—5 in Fig. 4,

Fig. 6 is a fragmentary end view of the lower or base section of the pump, showing the control shaft and the manner in which said shaft is connected to the pinion shaft to adjust the quantity of fuel delivery,

Fig. 7 is a fragmentary horizontal section on the line 7—7 in Fig. 6,

Fig. 8 is a fragmentary vertical section on the line 8—8 in Fig. 7,

Fig. 9 is a fragmentary vertical section on the line 9—9 in Fig. 8,

Fig. 10 is a horizontal section on the line 10—10 in Fig. 3,

Fig. 11 is an enlarged horizontal section on the line 11—11 in Fig. 2,

Figs. 12 and 13 are fragmentary vertical sections on the lines 12—12 and 13—13, respectively, in Fig. 11,

Fig. 14 is a perspective view of the pin for supporting the tappet roller,

Fig. 15 is a side elevation of the shell for supporting the tappet block,

Fig. 16 is a horizontal section through said shell on the line 16—16 in Fig. 15,

Fig. 17 is a top plan view of the tappet guide sleeve,

Fig. 18 is a central vertical section through said sleeve on the line 18—18 in Fig. 17,

Fig. 19 is a central vertical section through a pump of modified form,

Fig. 20 is a fragmentary horizontal section on the line 20—20 in Fig. 19; and

Fig. 21 is a central fragmentary vertical section through the plunger driving gear shown in Figs. 19 and 20.

The fuel pump illustrated in the accompanying drawings is adapted for use with a six cylinder, four cycle, compression ignition engine and comprises three superposed sections, namely, an upper end or fuel supply pump section A, an intermediate or fuel injection pump section B and a lower end or base section C containing the mechanism for operating the fuel injection pump.

The upper, supply pump section A comprises an upright pump housing or cylinder 1, whose upper end is closed by a screw cap 2 having an axial inlet bore or passageway 3 extending therethrough that is connected at its upper end by a suitable angle inlet fitting 4 to a suitable pipe or conduit 5 leading from a suitable source of fluid fuel supply (not shown). The lower end portion of the inlet passageway 3 in the cap 2 for the upper end of the supply pump cylinder or housing 1 is counterbored, as at 3a, to receive a downwardly or inwardly opening suction or check valve in the form of a disk 6 that is yieldably held against an annular seat provided therefor in the upper end of said counterbore by means of a coil compression spring 7. This inlet valve spring 7 seats on an annular supporting plate 8 that is clamped between the lower end of the cap 2 for the upper end of the pump cylinder 1 and the upper end of a hollow cylindrical sleeve or liner 9 for said cylinder.

Reciprocable in the liner 9 for the pump cylinder 1 is a downwardly opening cup-shaped piston 10 having a central inlet port 11 at the upper end thereof and a plug 12 threaded into the lower end thereof and cooperating with said piston to form therein a chamber 13 for an inwardly opening check valve in the form of a disk 14 that is yieldably held against the upper end of said piston to close the inlet port therein by means of a

coil compression spring 15 which seats on the upper end of said plug. Relative rotary movement of the piston 10 and plug 12 therefor is prevented by means of a pin 16 that is driven through registering transverse holes provided therefor in said piston and plug. The plug 12 has a series of circumferentially spaced cylindrical holes or passageways 17 extending vertically therethrough which establish communication between the inlet valve chamber 13 of the piston and the portion of the liner 9 below said piston. The plug 12 also has a central depending stem portion 18.

The piston 10 is retracted by means of a coil tension spring 19 whose upper end portion is threaded on the threaded portion of the plug 12 below the piston and whose lower end portion is threaded on the exteriorly threaded upstanding central tubular flange 20*a* of an annular spring seat member 20 that is clamped between the lower end of the liner 9 and an annular seat in the pump cylinder 1. The cylinder 1 is provided below the spring seat 20 with an axial bore 21, which opens through the lower end of said cylinder, and with a series of circumferentially spaced discharge passageways 22 that lead downwardly from the space below said spring seat and open into an annular groove 23 formed in the lower end of said cylinder concentric with said axial bore. Reciprocable in the axial bore 21 in the lower end portion of the supply pump cylinder, or housing 1, is a push rod 24 whose upper end is disposed in abutting relation to the lower end of the depending stem portion 18 of the piston plug 12. The lower end portion of the pump cylinder 1 is exteriorly threaded, as at 25, for connection with the injection pump section B.

The intermediate or fuel injection pump section B of my combined supply and injection pump assembly comprises a pump housing or cylinder 26 having an outstanding base flange 27 and a central cylindrical bore 28. The base flange 27 of the injection pump cylinder or housing 26 seats on and is secured by cap screws 27*a* to the top of the base section C of the pump. The bore 28 extends through the pump housing or barrel 26 from top to bottom thereof and has an enlarged or counterbored upper end portion 29 threaded to receive the exteriorly threaded lower end portion 25 of the supply pump cylinder or housing 1. Just below the lower end of the enlarged upper end 29 of the axial bore 28 of the fuel injection pump cylinder 26 is a slightly smaller counterbore, forming a chamber 30 for a downwardly opening valve in the form of an annular disk 31 which is yieldably held against the lower end of the supply pump cylinder 1 and covers the annular groove 23 therein. The valve 31, which serves as the final discharge valve of the supply pump and the inlet valve of the injection pump, is yieldably held in closed position by a coil compression spring 32 that is located in the valve chamber or counterbore 30 and seats on the bottom thereof.

Mounted for axial sliding and rotary movement in the axial bore 28 of the injection pump cylinder below the valve or pressure chamber 30 is a cylindrical plunger 33 that is disposed below and in axial alinement with the supply pump push rod 24, which extends downwardly into the valve chamber 30 through the central opening in the annular check valve 31 therein and is urged downwardly in the direction of said plunger by the pull of the tension spring 19. The injection pump cylinder has a plurality of horizontal fuel delivery or discharge passageways 34 therein, one for each of the six working cylinders of the engine supplied by said pump. The discharge passageways 34 are disposed radially of the pump plunger bore 28 and are spaced apart equally around the axis thereof with their inner ends opening through the wall of said bore below the chamber 30 and with their outer ends opening through the outer surface of the injection pump cylinder 26 and threaded to receive closure caps 35 therefor. The radially disposed passageways 34 have vertical branches 34*a* that extend upwardly therefrom through the top of the pump cylinder or housing 26. These branch passageways are spaced apart equal distances around the axis of the pump and are threaded at their upper ends to receive tube nuts 36 that connect to said passageways injection lines or conduits 37 that lead to the injection nozzles (not shown) for the respective working cylinders of the engine.

The injection pump cylinder 26 has a single horizontal by-pass or overflow passageway 38 therein disposed radially thereof below the level of the discharge passageways 34 and preferably along a plane passing midway between two adjacent discharge passageways. One end of the by-pass 38 opens into the plunger receiving bore 28 of the cylinder 26 below the level of the discharge passageways 34 and the other end opens through the exterior side face of said cylinder and is threaded to receive a cap member or closure 39. As shown in Fig. 13, the by-pass passageway 38 is provided near its inner or inlet end with an outwardly opening check valve 40 that is yieldably held against a seat provided therefor in said passageway by a coil compression spring 41 located in said passageway with one end seated against the cap 39 for the outer end thereof and with the other end bearing against said valve. The by-pass passageway 38 has a vertical branch 38*a*, which extends downwardly therefrom outwardly of the valve 40 therein, a branch 38*b*, which leads horizontally outwardly from the branch 38*a* and a vertical branch 38*c*, which leads downwardly from the horizontal branch 38*b* and opens through the bottom of said base flange 27 of the injection pump cylinder 26.

As shown in the drawings, the pump plunger 33 has an annular groove 42 therein far enough below the upper end thereof to communicate with the by-pass passageway 38 when said plunger nears and is at the end of the downward or suction stroke. The plunger also has six equally spaced longitudinal pressure relief grooves 43 in the periphery thereof that lead downwardly from the lower edge of the annular peripheral groove 42 far enough to establish communication between the by-pass passageway 38 and said annular groove during the entire length of either the suction or pressure stroke of said plunger when any one of the six longitudinal grooves is in communication with the inlet end of said by-pass passageway. The injection pump plunger also has a single longitudinal peripheral distributing groove 44 that extends from the annular groove 42 through the top of said plunger and is adapted to provide continuous communication between said annular groove and the pressure or valve chamber 30 above the upper or working end of said plunger. When the plunger 33 is rotated, the single longitudinal peripheral distributing groove 44 therein is adapted to successively register with the six discharge ports 34 in the pump cylinder during the reciprocating movement of said plunger, and the six longitudinal pressure relief grooves 43 are

adapted to successively register with the by-pass passageway 38.

The lower or base section C of the injection pump comprises a housing 45 which contains the mechanism for continuously reciprocating and rotating the pump plunger 33. This mechanism comprises a cam shaft 46 extending horizontally through the lower portion of the housing 45 below and at the right angles to the pump plunger 33. The cam shaft 46 is driven by or in unison with the engine at one-half engine speed and has six lobe-shaped cams 47 of identical contour spaced apart equal distances circumferentially of said cam shaft in the plane of the axis of the pump plunger 33. The cam shaft 46 is supported in suitable roller bearings 48 mounted in alined openings in opposite ends of the housing 45. Surrounding the cam shaft adjacent to the driven end thereof is a suitable oil seal 49 that is supported in an opening provided therefor in a plate 50 that is removably secured to said housing by cap screws 50*a*.

The cams 47 on the cam shaft 46 are adapted to successively engage a tappet roller 51 located thereabove. This tappet roller is rotatable on a bushing 52 journaled on a pin 53 carried by a tappet block 54. This tappet roller pin 53 has its ends mounted in alined openings provided therefor in a pair of spaced lugs 55 that depend from the tappet block 54; and the tappet roller 51 and bushing 52 are supported on said pin between said depending lugs. The tappet block 54 has the general form of an upright cylinder and is mounted in a cylindrical sheet metal shell 56 which is provided on one side with a cylindrical opening adapted to receive the adjacent end of the tappet roller pin 53 and on the opposite side with a rectangular opening 57 adapted to snugly receive a similarly shaped lateral extension or head 58 formed on the other end of said pin, thereby preventing rotation of said pin relative to said tappet block and shell.

The tappet shell, block, roller, bushing and pin assembly is vertically reciprocable in an upright cylindrical guide sleeve 59 that is disposed in a vertical bore 60 that leads upwardly through the top of the housing 45 from the cam shaft receiving opening which extends horizontally therethrough; and said tappet guide sleeve has an outstanding peripheral flange 61 at its upper end that rests on an annular seat 62 provided therefor in said vertical bore. The tappet guide sleeve 59 extends downwardly across the ends of the tappet roller pin 53, thereby preventing endwise movement of said pin, and has a longitudinal internal groove 63 therein which snugly receives the rectangular head 58 of said pin, whereby the tappet block 54 is slidable axially of said guide sleeve but is held against rotation therein. The outstanding top flange 61 of the guide sleeve 59 is held down on the annular seat 62 provided therefor in the vertical bore 60 of the housing 45 by two diametrically opposed screws 64 that are threaded horizontally through opposite sides of said housing and have tapered or pointed inner end portions 64*a* that seat in correspondingly tapered recesses 61*a* provided therefor in the upper, outer corner portion of said top flange of said guide sleeve, thereby preventing both axial and rotary movement thereof.

The tappet block 54 is disposed in vertical alinement with the pump plunger 33 located thereabove and has a diametrical T-slot 65 in the top thereof adapted to receive a grooved lower end portion 66 of said plunger, whereby said tappet block and plunger are connected together for joint reciprocating movement but may be disconnected by relative movement crosswise of the plunger axis. The upward or pressure stroke is imparted to the pump plunger 33 by the cams 47 of the cam shaft 46 and the tappet roller 51 operatively connected to the lower end of said plunger; and the downward or suction stroke is imparted to said plunger by a coil compression plunger retracting spring 67 which surrounds the reciprocable tappet shell 56 and the fixed tappet guide sleeve 59 with its lower end seated upon an outstanding base flange 56*a* on said tappet shell and with its upper end bearing against the underside of the outstanding top flange 61 of said tappet guide sleeve.

Mechanism is provided for continuously rotating the pump plunger 33 during the reciprocating movement thereof, said plunger making one complete rotation while six complete reciprocating cycles are being imparted thereto by one complete rotation of the cam shaft 46. As shown in the drawings, the plunger rotating mechanism comprises a spur gear 68 driven from the cam shaft 46 and having an axially slidable but non-rotary connection with the pump plunger 33. This connection preferably comprises a series of circumferentially spaced longitudinal splines 69 on the plunger that slidably engage a similar series of longitudinal grooves 70 in the hub 68*a* of the gear 68. This gear is located in the vertical bore 60 of the housing 45 on a circular supporting plate 71 supported in said bore on the flanged upper end of the tappet guide sleeve 59. The supporting plate 71 has a central circular opening through which the plunger 33 extends; and the gear 68 has its hub portion 68*a* extended upwardly far enough to abut against the bottom of the injection pump housing 26, whereby said gear is held against vertical movement between the underside of said housing and the upper surface of said supporting plate.

The plunger rotating gear 68 is rotated from the continuously driven horizontal cam shaft 46 through an upright shaft 72 mounted for rotary and axial sliding movement in a vertical bore 73 provided therefor in the housing 45 at one side of said cam shaft. As shown in the drawings, the cam shaft 46 has a helical gear 74 thereon intermeshing with a helical gear 75 on the shaft 72. The vertical shaft 72 also has a spur pinion 76 on the upper end thereof that intermeshes with the spur gear 68 on the plunger 33. The upper end of the supporting bore 73 for the pinion shaft 72 is counterbored, as at 77, to accommodate the spur pinion 76 on the upper end of said shaft; and the upper end of this counterbore is closed by a removable cover plate 78, said counterbore being deep enough to permit limited vertical movement of pinion 76 therein between the bottom thereof and the underside of said cover plate. The lower end of the bore 73 has a bushing 79 press-fitted therein flush with the bottom of the housing 45; and the pinion shaft 72 has a lower end portion 72*a* that is rotatably and slidably journaled in said bushing.

The pinion shaft 72 has a series of spaced annular peripheral grooves therein between the helical gear 75 and spur pinion 76 thereon, which grooves cooperate with the annular spaces therebetween to form a rack 80 on said pinion shaft. Intermeshing with the rack 80 on the vertical pinion shaft 72 is a sector pinion 81 that is supported on a horizontal control shaft 82 journaled in the housing 45, whereby said pinion shaft may

be raised or lowered relative to the spur gear 68 on the plunger 33 and the helical gears 74 on the cam shaft 46 by rocking said control shaft. As stated above, the driving connection between the horizontal cam shaft 46 and the vertical pinion shaft 72 comprises the intermeshing helical gears 74 and 75 so that, when the pinion shaft is raised or lowered by means of the sector pinion 81, slight rotary movement is imparted to the pinion shaft and the plunger 33 driven thereby due to the oblique angle of the teeth of said intermeshing helical gears, thus changing the positions of the longitudinal pressure relief grooves 43 in the pump plunger 33 relative to the overflow or by-pass port 38 to thereby vary the volume of fuel delivered to the engine.

In order to initially adjust the pump injection to the requirements of the particular engine supplied thereby use is made of the vernier effect between the number of teeth on the plunger gear 68 and the number of teeth on the pinion 75 on the pinion shaft 72. In the present case, the pinion 75 has five teeth and the plunger gear 68 driven thereby has twenty-six teeth, so that a seventy-two degree change in angular adjustment of the plunger 33 relative to the cam shaft 46 is obtained by moving said pinion relative to said cam shaft a distance corresponding to one tooth space. However if, at the same time, the plunger gear 68 is rotated in the opposite direction a distance corresponding to five tooth spaces, which is equivalent to about sixty-nine degrees, an adjustment of less than three degrees on the cam shaft can be obtained, which amounts to one and one-half degrees on the crank shaft of the engine.

As shown in Fig. 13 of the drawings, the housing 45 has a passageway 38*d* opening through the outer end thereof whose inner end opens through the top of said housing in line with the outlet end of the branch 38*c* of the by-pass passageway 38 in the injection pump cylinder or housing 26 and is connected to said outlet end of said branch of said by-pass by means of a ferrule 84 that seats within registering ends of said passageways. The outer end of the passageway 38*d* in the housing 45, which passageway communicates with and constitutes a part of the by-pass passageway 38, 38*a*, 38*b*, 38*c* leading from the plunger receiving bore 28 in said housing, communicates with a conduit 38*e* which leads to the fuel supply tank (not shown) or to a suitable hydraulic governor (not shown) such as the governor shown in my copending application Serial No. 397,714, filed June 12, 1941.

If desired, the supply pump A may be used for hydraulically operating an angularly adjustable coupling (not shown) between the cam shaft and the driving shaft (not shown) therefor, for advancing or retarding the timing of the fuel injection. Such a timing coupling is shown in my copending application Serial No. 397,715, filed June 12, 1941. As shown in Fig. 12 of the drawings, the connection between the supply pump and the angularly adjustable shaft coupling comprises a passageway 22*a* leading from one of the discharge passageways 22 in the supply pump housing 1 into an annular clearance space or chamber 85 between the lower end portion 25 of said housing and the counterbored upper end portion 29 of the plunger bore 28 in the housing 26 and a passageway 85*a* leading downwardly from the chamber 85 through the housing 26 to the lower end thereof where it is connected by a ferrule 86 to a passageway 85*b*, which opens through the side of the housing 45 and communicates with a conduit 85*c* leading to said shaft coupling.

As shown in Figs. 6 and 7 of the drawings, the horizontal control shaft 82 is journaled in bushings 87 located in alined openings provided therefor in opposite walls of an outwardly opening pocket or recess 88 in one end of the housing 45 just above the cam shaft 46 therein. The hub of the sector pinion 81 is sleeved on the control shaft 82 between the bushings 87; and said shaft has a pin 89 projecting radially therefrom adapted, when the shaft is turned, to abut against a lug 90 on the adjacent end of said hub and thus force said sector pinion to rotate with said shaft. The pin 89 is normally held out of contact with the lug 90 on the hub of the sector pinion 81 by means of a coiled torsional retraction spring 91 having one end anchored to an adjacent bushing 87 and the other end anchored to said pin. One end of the shaft 82 has a retaining collar 92 pinned thereon and the opposite end has the hub of a manually operable control lever 93 pinned thereon. The control shaft supporting bushings 87 have flanged outer ends 87*a* that overlap and are clamped to the outer face of the housing 45 by means of cap screws 94. The main body portions of the bushings 87 have a loose fit in the openings provided therefor in said housing so that said bushings, together with the control pinion journaled therein, may be shifted transversely in said openings to take up excessive back lash between the sector pinion 81 and the rack 80 on the pinion shaft 72 and the bushings are then clamped to said housing by means of the cap screws 94. As stated above, the control shaft 82 may be manually operated by means of the control lever 93 to adjust the quantity of fuel delivery. The quantity of fuel delivery may also be automatically controlled according to the speed and load conditions of the engine by the hydraulic governor hereinbefore referred to, such governor being operated by the varying pressure transmitted thereto through the by-pass passageway 38 of the pump and the hub of the sector pinion 81 being provided with a forked extension 95 which provides means for mechanically connecting said pinion with said governor for operation thereby.

The operation of the hereinbefore described pump is as follows:

When the injection pump plunger 33 is pulled downwardly in its cylinder 26 by the plunger retracting spring 67, the down or suction stroke is imparted to the supply pump piston 10 by the coil tension spring 19, thereby opening the inlet valve 6 and drawing fluid fuel from the supply pipe 5 into the upper end of the supply pump cylinder 1. When the supply pump piston 10 moves upwardly in its cylinder 1 against the tension of the retraction spring 19 during the up or pressure stroke of the injection pump plunger 33, the inlet valve 6 closes and cuts off communication between said cylinder and the supply pipe 5, and the inlet valve 14 in the upper end of said piston is forced off its seat by the pressure of the fuel trapped in said cylinder above said piston and this fuel is transferred from the space above said piston to the space therebelow and fills the passageways 17 in the piston plug 12 and the passageways 22 and the annular groove 23 in the lower end of said cylinder; and when the injection pump plunger 33 again moves downwardly during its suction stroke, the valve 31, which closes said annular groove, is opened and the

fuel in the supply pump cylinder between the valves 14 and 31 is transferred to the pressure chamber 30 of the injection pump cylinder 26 by the pressure produced by said piston as it is pulled downward by the extended spring 19.

During the first part of the up-stroke of the injection pump plunger 33, the valved supply pump piston 10 is forced upwardly in its cylinder by the pressure of the fluid fuel on the portion of the push rod 24 located in the pressure chamber 30. After the supply pump piston 10 has reached the limit of its upstroke, the longitudinal distributing or indexing groove 44 in the pump plunger 33 is in register with one of the discharge passageways 34 and the discharge therethrough begins. Therefore, the discharge through the passageways 34 occurs while the supply pump piston 10 is held stationary at the limit of its upward stroke by the hydraulic pressure on the push rod 24. Thus, the entire area of the injection plunger 33 is effective throughout the entire injection stroke, different injection speeds being obtained by the use of cams with slightly different speeds. The injection plunger 33 makes one complete reciprocating cycle for each injection and it makes one complete rotation for each complete engine cycle. There are, however, six cam lobes 47 on the cam shaft 46, whereby the injection plunger 33 is given six reciprocating cycles for each rotation that it makes.

During the pressure stroke of the pump plunger 33, pressure rise begins when the lower edge of the annular groove 42 in said plunger closes the by-pass passageway 38 and ceases when one of the six longitudinal pressure relief grooves 43 located in said plunger below said annular groove registers with said by-pass. The quantity of fuel delivered through each of the discharge passageways 34 may be varied by manipulating the control lever 93 to rock the sector pinion 81 which shifts the pinion shaft 72 vertically and thus rotates the plunger 33 relative to the cam shaft 46. Thus, if one of the pressure relief grooves 43 of the plunger 33 is in register with the by-pass passageway 38 during the entire working stroke of said plunger, the fuel is discharged through said by-pass passageway instead of the discharge passageway 34 and there is no discharge of fuel through said discharge passageways. When, however, the sector pinion is operated to locate a pressure relief groove 43 a maximum circumferentially distance from the discharge passageway 34 at the time the by-pass passageway 38 is covered, the time of opening of said by-pass is delayed thus bringing about the delivery of a maximum quantity of fuel through the discharge passageway. As stated above, the plunger 33 is constantly rotated and reciprocated in phase relation to the cam shaft 46; but this phase relationship between said plunger and cam may be changed to vary the volume of fuel delivered to the engine cylinders by operating the control lever 93. At each discharge or up stroke of the plunger 33, the distributing groove 44 therein registers with a different discharge passageway 34 and each pumping stroke is identical with any other and delivers the same quantity of fuel to a different engine cylinder. In this way, it is easy to obtain equal discharges to all cylinders without very great accuracy in the manufacture of the pump plunger and cylinder, the accuracy of the start of injection depending only upon the squareness of the lower edge of the annular groove 42 in the plunger 33 and the uniformity of the quantity of fuel delivered depending only upon the spacing of the six vertical grooves 44 below said annular groove.

It is noted that, when the supply pump piston 10 is at the end of its upward stroke, there is a very small clearance between the top of said piston and the annular valve spring supporting plate 8, whereby a high degree of vacuum is obtained when the pump is in operation. As shown in the drawings, the supply pump C is provided with three valves, 6, 14 and 31. While the upper valve 6 may be omitted, this valve insures adequate filling of the space above the piston 10 with fuel under all conditions of operation and also tends to dampen out hydraulic surges within the fuel supply line or conduit 5. Retraction of the fuel in the delivery lines 37 leading to the injection nozzles may be regulated to prevent dribble from said nozzles by varying the pressure of the closing spring 41 for the check valve 40 in the by-pass passageway 38. The non-rotary but axial sliding connection between the injection pump plunger 33 and the driving gear 68 therefor at the lower end thereof is simple and inexpensive and greatly reduces the weight of the reciprocating parts.

In the modified pump construction shown in Figs. 19 to 21, inclusive, the supply pump comprises the housing 1 hereinbefore referred to and a member 96 threaded into the upper end of said housing and having an axial bore extending therethrough, whose upper end portion is threaded to receive the inlet fitting 4 that is connected to the fuel inlet line 5, and whose lower end portion is enlarged and constitutes a cylinder 9a for a cup-shaped piston 10a that is moved downwardly in said cylinder by a coil compression spring 19a. The lower end of the spring 19a seats in the cup-shaped piston 10a and the upper end of said piston seats against the under side of an annular spring seat 20b and forces the same upwardly against an annular shoulder provided therefor in said cylinder.

Located in the axial bore of the member 96 above the spring seat 20b is a downwardly opening upper valve 6a and an upwardly opening lower valve 14a. The upper valve 6a seats against a downwardly facing annular valve seat provided therefor in the axial bore of the member 96 and the lower valve 14a seats on top of the annular spring seat 19a and covers the central opening therethrough. The valves 6a and 14a are yieldably held against their respective seats by means of a single coil compression spring 97 interposed between said valves. The cylinder portion 9a of the member 96 terminates short of the upper ends of the vertical discharge passageways 22 in the lower portion of the housing 1 and a clearance space is provided between the side walls of said cylinder and housing to form an annular passageway 98 therebetween. The space between the vertically spaced valves 6a and 14a is in continuous communication with the annular passageway 98 through radial ports 98a in the cylinder 9a opposite said space, while said annular passageway is in continuous communication at its lower end with the upper ends of the passageways 22.

The piston 10a is forced upwardly in its cylinder 9a by a push rod 24a that is reciprocable in the axial bore 21 in the lower end portion of the supply pump housing. In this construction, the upper end of the push rod 24a bears against the lower end of the piston 10a; the lower end of said push rod is positively connected to the upper end of the injection pump plunger 33a for mechanical operation thereby instead of being hy-

draulically operated as in the case of the push rod **24** hereinbefore described. The direct mechanical connection between the push rod **24a** and the plunger **33a** comprises a diametral T-head on the upper end of said plunger that slidably fits within a diametral T-groove in the lower end of said push rod, such connection permitting the plunger and push rod to be connected and disconnected by relative movement crosswise of their axes.

In the operation of the modified supply pump, fuel is drawn into the supply pump through the upper valve **6a** by the suction of the piston **10a** when the latter is forced upwardly against the pressure of the spring **19a** by the upward pressure transmitted to said piston by the plunger **33a** through the push rod **24a** secured thereto. The fuel fills the space between the valves **6a** and **14a**, the annular passageway **98** and all of the space beneath the piston **10a** down to the closed valve **31**. This upward movement of the piston **10a** in the cylinder also prevents fuel that leaks into said cylinder from accumulating therein in sufficient quantity to interfere with such movement of said piston, excess fuel in said cylinder being forced out through the valve **14a** by the positive up-stroke of said piston. When the push rod **24a** is pulled downwardly by the downward travel of the plunger **33a**, the supply pump piston **10a** is forced downwardly in its cylinder **9a** by the expansive action of the spring **19a** which is strong enough to overcome any vacuum in said cylinder and the fuel trapped in the supply pump by the closing of the valves **6a** and **14a** is forced downwardly through the passageways **22** and the annular groove in the housing, thus forcing the valve **31** off its seat and permitting the fuel to flow into the pressure chamber **30** of the injection pump, which operates in the manner hereinbefore described to force the fuel through the discharge passageways **34**.

In the modified construction, each of the discharge passageways **34** of the injection pump has an outwardly opening piston valve **99** slidably mounted in the inner end portion thereof. This valve has a peripheral collar **99a** thereon near the outer end thereof, and the outer end portion of the discharge passageway **34** is enlarged to form an outwardly facing annular seat **99b** for said collar. The collar **99a** is yieldably held against the seat **99b** by means of a coil compression spring **100** mounted in the enlarged outer end of the passageway **34** between said collar and the cap **35** for the outer end of said passageway. The discharge valve **99** has a diametral passageway **99c** extending therethrough inwardly of the collar **99a** and an axial passageway **99d** leading from said diametral passageway and opening through the inner end of said valve. By this arrangement, the pressure of the fuel against the inner end of the piston valve **99** forces the same outwardly against the pressure of the spring **100** far enough to move the diametral passageway **99c** of said valve past the seat **99b** for the collar **99a** of said valve into the enlarged outer end portion of the discharge passageway **34**, thus permitting flow of the fuel through said passageways, said outer end portion of said valve and thence through the branch **34a** of said discharge passageway to the injection nozzle. When the pressure in the injection pump chamber **30** is relieved by establishing communication between said chamber and the by-pass passageway **38**, the discharge or delivery valve **99** is forced inwardly by the closing spring **100** thereof until the collar **99a** abuts against the shoulder or seat **99b** provided therefor in the discharge passageway **34**, thus cutting off communication between the pressure chamber and the discharge passageway. The diametral passageway **99c** of the discharge valve **99** enters the smaller valve supporting portion of the discharge passageway **34** and cuts off flow of the fuel through said valve before it reaches the end of its closing movement. Continued movement of the valve to closed position serves to relieve the pressure that still exists in the discharge line between said valve and the hydraulically opened injection nozzle and thus permitting said nozzle to close rapidly without leakage or after dribble of the fuel therefrom into the combustion chamber of the engine.

In the modified construction, the spur gear **68b** for rotating the injection pump plunger **33a** during the reciprocating movement of the latter is rigidly secured to the lower end of said plunger for axial movement therewith and is thus movable vertically relative to the spur driving pinion **73** therefor on the upper end of the upright pinion shaft **72**. The connection between the gear **68b** and the plunger **33a** comprises a pair of clamping screws **101** that extend through a split hub portion **68c** of said gear on opposite sides of said plunger. These screws firmly clamp the split hub portion **68c** of the gear **68b** to the plunger **33a** and seat in an annular groove **33b** provided therefor in the plunger, thus preventing relative axial and rotary movement of said gear and plunger. With this constructed proper phase relation between the metering grooves **44** and the plunger **33a** and the cam shaft **46** is obtained by rotating the plunger relative to the gear **68b** and then clamping said gear to the plunger in the desired position of rotary adjustment.

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 precise arrangements shown and described.

What I claim is:

1. A unit fuel injection and supply pump assembly for an internal combustion engine comprising a fuel injection piston and a fuel supply piston in axial alinement with said fuel injection piston for feeding fuel thereto, and means interposed entirely between the adjacent ends of said fuel injection and fuel supply pistons, whereby said fuel injection piston is adapted during its movement in the direction of said fuel supply piston to exert an end thrust on said fuel supply piston to thus operate the latter in the same direction.

2. A unit fuel injection and supply pump assembly for an internal combustion engine comprising an injection pump section and a supply pump section for feeding fuel to said injection pump section, said injection pump section including a reciprocable plunger, and said supply pump section including a reciprocable piston disposed in axial alinement with said plunger without being positively secured thereto, and means interposed directly between the adjacent ends of said plunger and piston, whereby said plunger is adapted during its movement in the direction of said piston to exert an end thrust on said piston and thus operate said piston in the same direction.

3. A fuel pump construction for an internal combustion engine comprising a fuel injection pump and a second pump operated by said first

mentioned pump for feeding fuel thereto, said first mentioned pump including a reciprocable plunger and said second pump including a reciprocable piston disposed in axial alinement with said plunger, means whereby said plunger is adapted during its movement in the direction of said piston to exert an end thrust on said piston and thus operates said piston in the same direction, and separate springs cooperating with said plunger and said piston for operating them in the opposite direction.

4. A fuel pump construction for an internal combustion engine comprising a fuel injection pump and a second pump operated by said first mentioned pump for feeding fuel thereto, said first mentioned pump including a reciprocable plunger and said second pump including a reciprocable piston disposed in axial alignment with said plunger, and means whereby said plunger is adapted during its movement in the direction of said piston to exert an end thrust on said piston and thus operate said piston in the same direction.

5. A fuel pump construction for an internal combustion engine comprising a fuel injection pump and a second pump operated by said first mentioned pump for feeding fuel thereto, said first mentioned pump including a reciprocable plunger and said second pump including a reciprocable piston disposed in axial alignment with said plunger, means whereby said plunger is adapted during its movement in the direction of said piston to exert an end thrust on said piston and thus operate said piston in the same direction, and separate means cooperating with said plunger and said piston for operating them in the opposite direction.

6. A fuel pump construction for an internal combustion engine comprising a fuel injection pump and a second pump operated by said first mentioned pump for feeding fuel thereto, said first mentioned pump including a reciprocable plunger and said second pump including a reciprocable piston disposed in axial alinement with said plunger, and a push rod interposed between but non-mechanically connected to the opposing ends of said plunger and piston and operable by the pressure of fuel in said first mentioned pump on the plunger opposing end of said push rod during the movement of said plunger in fuel feed direction to force said piston in a corresponding direction.

7. A fuel pump construction for an internal combustion engine comprising a fuel injection pump and a second pump operated by said first mentioned pump for feeding fuel thereto, said first mentioned pump including a plunger and said second pump including a piston disposed in axial alinement with said plunger, and a push rod interposed between the opposing ends of said plunger and piston with one end positively connected to said plunger and the other end disposed in endwise abutting relation to said piston whereby said plunger is adapted in one direction of its sliding movement to force said piston in a corresponding direction of its sliding movement.

8. A fuel pump construction for an internal combustion engine comprising a fuel injection pump and a second pump operated by said first mentioned pump for feeding fuel thereto, said first mentioned pump including a plunger and said second pump including a piston disposed in axial alinement with said plunger, and a push rod interposed between the opposing ends of said plunger and piston with one end positively connected to said plunger and the other end disposed in endwise abutting relation to said piston, whereby said plunger is adapted in one direction of its sliding movement to force said piston in a corresponding direction of its sliding movement, and separate springs for operating said plunger and said piston, respectively, in the opposite direction.

9. A fuel pump construction for an internal combustion engine comprising a fuel injection pump, a second pump operated by said first mentioned pump for feeding fuel thereto, said first mentioned pump comprising a cylinder and a plunger reciprocable therein, said second pump comprising a cylinder and a piston reciprocable therein in axial alinement with said plunger, said second cylinder having an outlet communicating at one end with said first cylinder and having an inlet at its opposite end, a valve in said inlet adapted to be opened by the suction produced by said piston in one direction of its movement, a valve in said outlet adapted to be opened by the pressure produced by such movement of said piston, said piston having a passageway extending therethrough adapted to establish communication between said inlet and outlet, a valve in said passageway adapted to be opened by the pressure produced by said piston in the other direction of its movement, a push rod disposed between and in abutting relation to said plunger and piston, and a spring for urging said piston in the direction of said plunger.

10. A fuel pump construction for an internal combustion engine comprising a fuel injection pump, a second pump operated by said first mentioned pump for feeding fuel thereto, said first mentioned pump comprising a cylinder and a plunger reciprocable therein, said second pump comprising a cylinder fixed to said first mentioned cylinder and a piston reciprocable in said second cylinder in axial alinement with said plunger, said second cylinder having an inlet at one end thereof and an outlet at the other end thereof communicating with said first mentioned cylinder, an inwardly opening check valve in said inlet, a check valve for said outlet adapted to be opened by the suction produced by said plunger, a push rod disposed in axial alinement with said plunger and said piston with one end rigid with said plunger and with the opposite end in abutting relation to said piston, and a spring for urging said piston in the direction of said plunger.

11. A fuel injection pump for a multi-cylinder injection engine comprising a cylinder having an inlet passageway, a plurality of discharge passageways, and a by-pass passageway, a plunger working in said cylinder, means for simultaneously reciprocating and rotating said plunger in said cylinder, means formed on said plunger for successively placing said discharge passageways in communication with the pressure space of said cylinder in intermittently successive positions of the rotary and reciprocating movement of said plunger, and means formed on said plunger for placing said pressure space in communication with said by-pass passageway when any one of said discharge passageways is in communication with said pressure space.

12. A fuel injection pump for a multi-cylinder injection engine comprising a cylinder having an inlet passageway, a single by-pass passageway and radially disposed discharge passageways located in a plane intermediate between said inlet and by-pass passageways, a spring loaded outwardly opening check valve in said by-pass pas-

sageway, a plunger working in said pump cylinder, and means for continuously reciprocating and rotating said plunger in said cylinder, said plunger having an annular peripheral groove therein adapted to communicate directly with said by-pass passageway when said plunger nears the end of its suction stroke, a single longitudinal peripheral groove extending from said annular groove through the working end of said plunger and adapted to successively register with said discharge passageways in intermittently successive positions of the reciprocating movement of said plunger, and a series of circumferentially spaced longitudinal peripheral grooves of a number corresponding to the number of said discharge passageways extending from said annular groove far enough to establish communication between said annular groove and said by-pass passageway in all positions of the reciprocating movement of said plunger.

13. The combination as set forth in claim 12, in which means are provided for rotatably adjusting said plunger relative to the driving means therefor to thereby change the positions of said series of longitudinal grooves relative to said by-pass port and thus vary the fuel amounts delivered by said pump.

14. A fuel injection pump for a multi-cylinder injection engine comprising a cylinder having an inlet passageway, a plurality of discharge passageways, and a by-pass passageway, a plunger working in said cylinder, means for simultaneously reciprocating and rotating said plunger in said cylinder, means formed on said plunger for successively placing said discharge passageways in communication with the pressure space of said cylinder in intermittently successive positions of the rotary and reciprocating movement of said plunger, and means formed on said plunger for placing said pressure space in communication with said by-pass passageway when any one of said discharge passageways is in communication with said pressure space, said plunger reciprocating and rotating means comprising a cam shaft for reciprocating said plunger and a connection between said cam shaft and plunger for rotating the latter, and means for adjusting said connection to change the phase relationship between said cam shaft and said plunger.

15. A fuel injection pump for a multi-cylinder injection engine comprising a cylinder having an inlet passageway, a plurality of discharge passageways, and a by-pass passageway, a plunger working in said cylinder, means for simultaneously reciprocating and rotating said plunger in said cylinder, means formed on said plunger for successively placing said discharge passageways in communication with the pressure space of said cylinder in intermittently successive positions of the rotary and reciprocating movement of said plunger, and means formed on said plunger for placing said pressure space in communication with said by-pass passageway when any one of said discharge passageways is in communication with said pressure space, said plunger rotating means comprising a drive shaft having a helical gear thereon, a pinion shaft having a helical pinion intermeshing with and driven by said helical gear and a spur pinion, a spur gear on said plunger and intermeshing with and driven by said spur gear, and means for shifting said pinion shaft endwise whereby movement is imparted to said pinion shaft and the plunger driven thereby are rotated relative to said drive shaft due to the oblique angle of the teeth of said intermeshing helical gears to thereby change the phase relationship between said plunger and drive shaft and thus vary the volume of fuel delivery.

16. A fuel injection pump for a multi-cylinder injection engine comprising a cylinder having an inlet passageway, a plurality of discharge passageways, and a by-pass passageway, a plunger working in said cylinder, means for simultaneously reciprocating and rotating said plunger, means for successively placing said discharge passageways in communication with the pressure space of said cylinder in intermittently successive positions of the rotary and reciprocating movement of said plunger, and means for placing said pressure space in communication with said by-pass passageway when any one of said discharge passageways is in communication with said pressure space, said plunger reciprocating and rotating means comprising a drive shaft having a cam thereon for reciprocating said plunger, a pinion shaft disposed transverse to said drive shaft and having a helical pinion intermeshing with and driven by a helical gear on said drive shaft and a spur pinion intermeshing with a spur gear on said plunger, and means for shifting said pinion shaft endwise whereby said pinion shaft and said plunger are rotated relative to said drive shaft due to the oblique angle of the teeth of said intermeshing helical gears to thereby change the phase relationship between said drive shaft and said plunger, said means comprising a rock shaft disposed transversely of said pinion shaft, and a pinion mounted on said rock shaft and intermeshing with a rack provided therefor on said pinion shaft.

17. A fuel injection pump for a multi-cylinder injection engine comprising a cylinder having an inlet passageway, a plurality of discharge passageways, and a by-pass passageway, a plunger working in said cylinder, means for simultaneously reciprocating and rotating said plunger in said cylinder, means formed on said plunger for successively placing said discharge passageways in communication with the pressure space of said cylinder in intermittently successive positions of the rotary and reciprocating movement of said plunger, and means formed on said plunger for placing said pressure space in communication with said by-pass passageway when any one of said discharge passageways is in communication with said pressure space, said plunger reciprocating and rotating means comprising a tappet roller carried by said plunger, a drive shaft having a series of cams thereon adapted to successively engage said tappet roller, a spring for retracting said plunger and for holding the tappet roller thereon in engagement with said cam, a gear on said plunger and a driving connection between said drive shaft and said gear.

18. A fuel injection pump for a multi-cylinder injection engine comprising a cylinder having an inlet passageway, a plurality of discharge passageways, and a by-pass passageway, a plunger working in said cylinder, means for simultaneously reciprocating and rotating said plunger in said cylinder, means formed on said plunger for successively placing said discharge passageways in communication with the pressure space of said cylinder in intermittently successive positions of the rotary and reciprocating movement of said plunger, and means formed on said plunger for placing said pressure space in communication with said by-pass passageway when any one of said discharge passageways is in communication with said pressure space, said plunger reciprocating and rotating means comprising a tappet

roller carried by said plunger, a drive shaft having a series of cams thereon adapted to successively engage said tappet roller, a spring for retracting said plunger and for holding the tappet roller thereon in engagement with said cams, a gear on said plunger and a driving connection between said drive shaft and said gear, said gear being held against axial movement in said pump and said plunger having an axially sliding but non-rotary connection with said gear.

19. A fuel injection pump for a multi-cylinder injection engine comprising a cylinder having an inlet passageway, a plurality of discharge passageways, and by-pass passageway, a plunger working in said cylinder, means for simultaneously reciprocating and rotating said plunger in said cylinder, means for successively placing said discharge passageways in communication with the pressure space of said cylinder in intermittently successive positions of the rotary and reciprocating movement of said plunger, and means for placing said pressure space in communication with said by-pass passageway when any one of said discharge passageways is in communication with said pressure space, said plunger reciprocating means comprising a tappet roller carried by said plunger, a drive shaft having a series of cams thereon adapted to successively engage said tappet roller and a spring for retracting said plunger and for holding the tappet roller thereon in engagement with said cam, comprising a gear on said plunger and a driving connection between said drive shaft and said gear, and means for rigidly securing said gear to said plunger for sliding movement therewith, said securing means permitting relative rotary adjustment of said gear and plunger.

HERBERT C. EDWARDS.

CERTIFICATE OF CORRECTION.

Patent No. 2,372,559. March 27, 1945.

HERBERT C. EDWARDS.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 8, second column, lines 10 and 14, page 9, first column, line 17, and second column, line 2, after "means" insert the words --formed on said plunger--; page 9, first column, line 14, before "by-pass" insert --a--; and second column, line 7, before "means" insert --and rotating--; line 10, strike out "and" and insert instead a comma; line 12, strike out "comprising"; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 25th day of September, A. D. 1945.

Leslie Frazer

(Seal) First Assistant Commissioner of Patents.

roller carried by said plunger, a drive shaft having a series of cams thereon adapted to successively engage said tappet roller, a spring for retracting said plunger and for holding the tappet roller thereon in engagement with said cams, a gear on said plunger and a driving connection between said drive shaft and said gear, said gear being held against axial movement in said pump and said plunger having an axially sliding but non-rotary connection with said gear.

19. A fuel injection pump for a multi-cylinder injection engine comprising a cylinder having an inlet passageway, a plurality of discharge passageways, and by-pass passageway, a plunger working in said cylinder, means for simultaneously reciprocating and rotating said plunger in said cylinder, means for successively placing said discharge passageways in communication with the pressure space of said cylinder in intermittently successive positions of the rotary and reciprocating movement of said plunger, and means for placing said pressure space in communication with said by-pass passageway when any one of said discharge passageways is in communication with said pressure space, said plunger reciprocating means comprising a tappet roller carried by said plunger, a drive shaft having a series of cams thereon adapted to successively engage said tappet roller and a spring for retracting said plunger and for holding the tappet roller thereon in engagement with said cam, comprising a gear on said plunger and a driving connection between said drive shaft and said gear, and means for rigidly securing said gear to said plunger for sliding movement therewith, said securing means permitting relative rotary adjustment of said gear and plunger.

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