March 29, 1960 R. W. HALBERG 2,930,369

FUEL INJECTION APPARATUS

Filed Oct. 7, 1957 2 Sheets-Sheet 1

Fig. 1

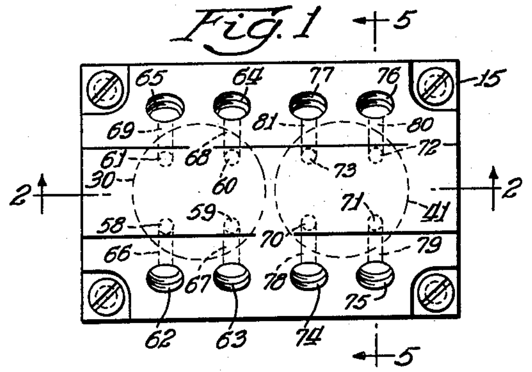

Fig. 5

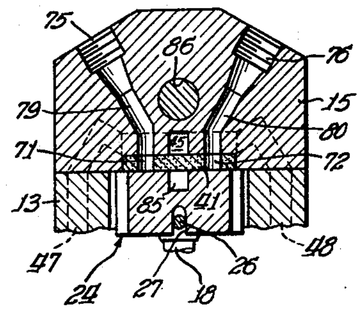

Fig. 2

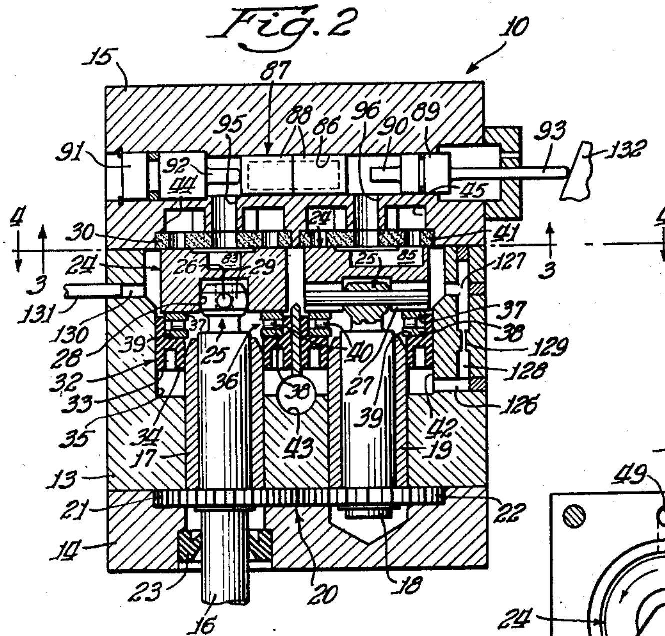

Fig. 4

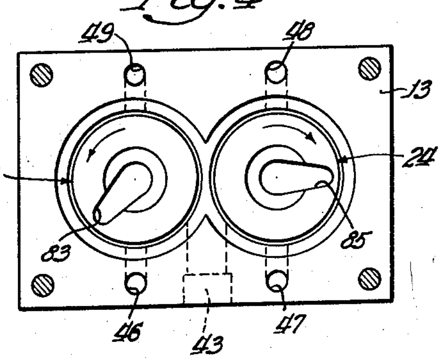

Fig. 3

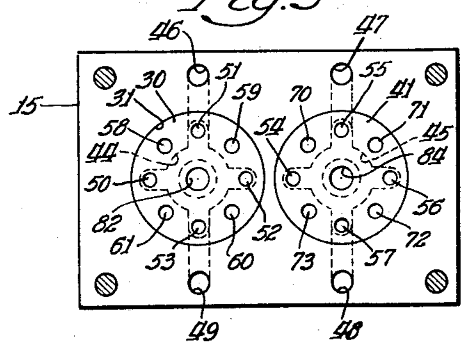

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Fig. 6

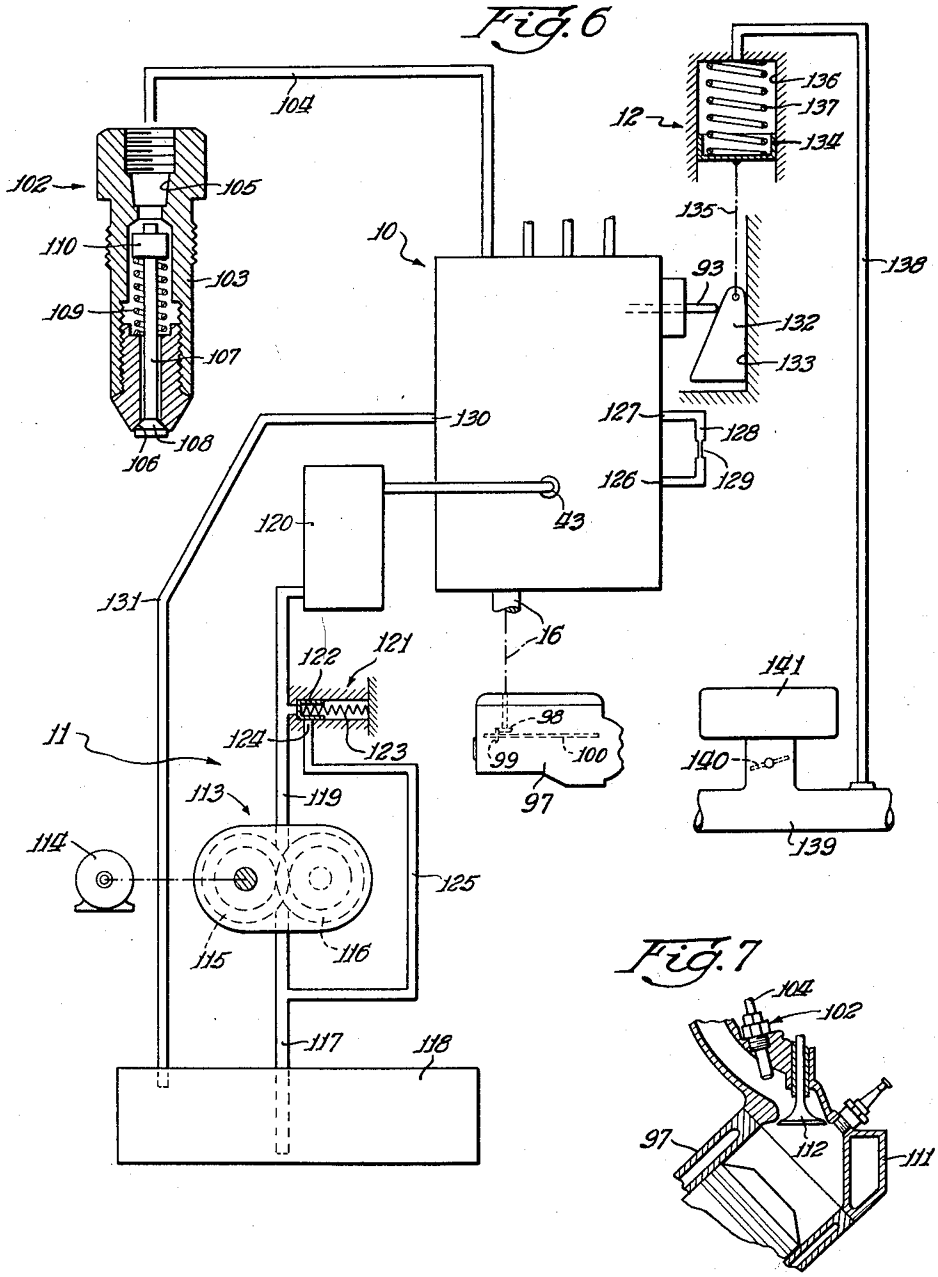

Fig. 7

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United States Patent Office

2,930,369

Patented Mar. 29, 1960

2,930,369

FUEL INJECTION APPARATUS

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Application October 7, 1957, Serial No. 688,554

7 Claims. (Cl. 123—139)

My invention relates to fuel injection apparatus for internal combustion engines and, more particularly, to such apparatus utilizing a reciprocable plunger moved by the application of fuel under pressure to the plunger so as to pump fuel to the engine.

It is an object of the present invention to provide an improved fuel injection apparatus of this type utilizing a pair of valves for alternately connecting opposite ends of the above mentioned plunger with the fuel source under pressure and with different fuel injector nozzles adapted to supply fuel to different cylinders of the engine. More particularly, it is an object to construct these valves to be of the rotary type comprising rotors in face-to-face contact with flat plates, the plates being so ported to accomplish this result.

It is also an object to so construct the injection apparatus that the pressure of the fuel source is impressed behind the rotors to hold them firmly in contact with their corresponding plates.

It is also an object to construct the plates of graphite and imbed them in suitable cavities within a fuel injector casing so as to provide a good seal for the rotors whereby suitable fuel supply cavities behind the plates may be provided by casting methods, with fuel ports in the plates being subsequently drilled accurately after the plates have been mounted within the casing.

It is also an object to provide universal joints between rotor drive shafts and the rotors to assure a flat face to face sealing contact of the rotors with their respective plates, while still maintaining accurate concentricity of the rotor.

It is a further object of the invention to so construct the plunger that it has a minimum weight to reduce its inertia and a minimum fuel cavity ahead of it so as to minimize the inertia effects on the fuel pumped by the plunger and to limit the reciprocation of the plunger by stops located at opposite ends of it, the separation between which is adjustable.

The invention consists of the novel constructions, arrangements and devices to be hereinafter described and claimed for carrying out the above stated objects and such other objects as will be apparent from the following description of a preferred form of the invention illustrated with reference to the accompany drawings, wherein:

Fig. 1 is a top view of a fuel injection mechanism embodying the principles of the invention;

Fig. 2 is a sectional view of the mechanism taken on line 2—2 of Fig. 1 in the direction indicated;

Figs. 3 and 4 are sectional views taken on lines 3—3 and 4—4 respectively of Fig. 2 in the directions indicated;

Fig. 5 is a sectional view taken on line 5—5 of Fig. 1 in the direction indicated;

Fig. 6 is a schematic illustration of a fuel injection system including the mechanism illustrated in Figs. 1 to 5; and

Fig. 7 is a fragmentary cross-sectional view of an internal combustion engine with which the illustrated fuel injection system may be used.

Like characters of reference designate like parts in the several views.

Referring now to the drawings, the illustrated fuel injection mechanism comprises, in general, a fuel injector pump 10, a fuel supply system 11 for the pump 10 and a mixture control system 12.

The pump 10 comprises a central casing portion 13 having a lower casing portion 14 and an upper casing portion 15 fixed thereto. A shaft 16 extends into the central casing portion 13 and through the casing portion 14, as shown. The shaft 16 is driven at one-half the speed of rotation of the crank shaft of the four cycle internal combustion engine with which the fuel injection mechanism is used, the driving mechanism between the engine and shaft 16 consisting of any suitable gearing (not shown). The shaft 16 is rotatably supported with respect to the casing portion 13 by means of a bushing 17 about the shaft 16.

A second shaft 18 is rotatably disposed in the casing portion 13; and a bushing 19, similar to the bushing 17, is provided about the shaft 18. The shaft 18 is driven from the shaft 16 by means of gearing 20. The gearing 20 comprises a gear 21 fixed on the shaft 16 and a gear 22 of the same size as the gear 21 fixed on the shaft 18 and in mesh with the gear 21. A lip type seal 23 of rubberlike material is provided within a cavity surrounding the shaft 16.

A rotor 24 is driven from the shaft 16 and is connected with the shaft by means of a universal joint 25. The joint 25 comprises a pin 26 fixed in the end of the shaft 16 and extending loosely into a slot 27 formed in the rotor 24. The rotor 24 is provided with a central cavity 28, and the end of the shaft 16 is provided with rounded sides 29 adapted to bear on the sides of the cavity 28 to pilot the rotor 24 with respect to the shaft 16.

The rotor 24 is in contact with a carbon or graphite rotor plate 30 disposed in a cavity 31 provided in the upper casing portion 15. The rotor 24 is held in contact under pressure with the rotor plate 30 by means of an annular piston 32 of rubber-like material having lips 33 and 34 respectively in contact with the sides of an annular cavity 35 formed in the casing portion 13 and the outer surface of the bushing 17. A bearing 36 is provided between the piston 32 and the rotor 24 and comprises a race 37 beneath the rotor 24, a rice 38 disposed on a shoulder 39 of the piston 32 and a plurality of rollers 40 between the races 37 and 38.

A rotor 24 is also disposed on the shaft 18, being connected with the shaft by means of a universal joint 25. The rotor 24 on the shaft 18 is in contact with a carbon or graphite plate 41 which is identical with the plate 30 and is held in such contact under pressure by means of a piston 32 and a bearing 36. The piston 32 for the shaft 18 is disposed within a cavity 42 formed in the casing portion 13 and is in contact with the outer surface of the sleeve 19.

The casing portion 13 is provided with a fuel inlet opening 43, in communication with the cavities 35 and 42, and the casing portion 15 is provided with star-shaped cavities 44 and 45 disposed respectively above the rotor plates 30 and 41 which are connected to the cavities 35 and 42 by means of passages 46, 47, 48 and 49 extending through the casing portions 13 and 15.

The plate 30 is provided with openings 50, 51, 52, and 53 therethrough which are in communication with the cavity 44; and the plate 41 is provided with openings 54, 55, 56, and 57 which are in communication with the cavity 45; the openings 50, 51, 52, 53, 54, 55, 56 and 57 being thereby provided with fuel from the inlet opening

43. The plate 30 is provided with holes 58, 59, 60 and 61 therethrough which are respectively connected with ports 62, 63, 64, and 65 in the upper casing portion 15 by means of passages 66, 67, 68, and 69. The plate 41 is provided with holes 70, 71, 72 and 73 therethrough which are respectively connected with ports 74, 75, 76, and 77 by means of passages 78, 79, 80 and 81. A central opening 82 is provided in the plate 30, and a passage 83 is provided in the upper face of the rotor 24 for connecting the opening 82 with any of the other openings in the plate 30 depending on the rotative position of the rotor on the plate. The plate 41 is provided with a central opening 84 therethrough, and the rotor 24 resting on the plate 41 is provided with a passage 85 in its upper face for connecting the opening 84 with any of the other openings in the plate 41.

The upper casing portion 15 is provided with a cylindrical cavity 86 therein in which a shuttle plunger 87 is slidably disposed. The shuttle plunger 87 is made up of two hollow thimbles 88 fixed together at their open ends. A movable stop 89 is disposed at one end of the plunger 87 and has a small diameter stem or boss 90 adapted to abut the plunger 87. A fixed stop 91 is positioned on the other end of the shuttle plunger 87 and has a stem or boss 92 adapted to abut the plunger 87. A control rod 93 is fixed to the movable stop 89 for controlling its position. A passage 95 is provided in the casing portion 15 and is in communication with the opening 82 in the plate 30 and the cavity 86 about the boss 92. A similar passage 96 is in communication with the opening 84 in the plate 41 and with the cavity 86 about the boss 90.

The shaft 16 may be driven from the vehicle engine 97 by any suitable gearing such as bevel gears 98 and 99 (see Fig. 6). The gear 98 is fixed on the shaft 16 and the gear 99 is fixed to the cam shaft 100 of the engine.

Each of the ports 62, 63, 64, 65, 74, 75, 76 and 77 is connected to a fuel injection nozzle 102 directing fuel into the engine 97. Each of the nozzles 102 comprises a nozzle body 103 connected by means of a fluid conduit 104 with one of these ports. The nozzle body 103 is provided with an internal passage 105 therein having an outwardly flared seat 106 at its outer end. A valve plunger 107 is disposed in the nozzle body 103 and is provided with an outwardly flared end 108 adapted to rest and seat on the seat 106. A spring 109 is disposed between a shoulder in the nozzle body 103 and a sleeve 110 fixed on the plunger 107 for yieldably holding the plunger 107 on the seat 106.

Each of the nozzles 102 is disposed in the head 111 of the engine 97 and is adapted to spray fuel into the air stream to a fuel air mixture intake valve 112. It will, of course, be understood that the nozzles 102 can instead be directed to spray fuel directly into the explosion cavities in the cylinders. There are eight of the ports 62, 63, 64, 65, 74, 75, 76 and 77 corresponding to the eight cylinders in the engine 97, and one of the nozzles 102 is positioned adjacent each of the eight cylinders of the engine 97.

It necessarily follows that this type of rotary valve operation is not limited to eight cylinder engines but is applicable by suitable design modifications to any engine having an even number of cylinders.

The supply system for the injector pump 10 comprises a pump 113 driven by any suitable prime mover, such as an electric motor 114. The pump 113 may be of any suitable type such as a gear pump comprising a pair of gears 115 and 116. The inlet end of the pump 113 is connected by means of a fluid conduit 117 to draw fuel out of a fuel tank 118.

The outlet end of the pump 113 is connected through a conduit 119 with the inlet port 43 of the pump 10. A filter 120 of any suitable type is disposed in the conduit 119, and a relief valve 121 is also provided in the conduit 119. The relief valve 121 comprises a plunger 122 acted on by a compression spring 123. On a certain movement of the plunger 122 against the spring 123, it uncovers a port 124 with respect to the conduit 119 bypassing the pump 113 by means of a bypass conduit 125.

The fuel is used for cooling the rotors 24 and the plates 30 and 41, and for this purpose the casing portion 13 is provided with passages 126 and 127 therein. The passage 126 is in communication with the cavity 42 below the seal 32 therein, and the passage 127 is in communication with the cavity 42 above the seal 32. A fluid conduit 128 connects the passages 126 and 127, and a restriction 129 is provided in the conduit 128. A passage 130 is provided in the casing portion 13 opposite the passage 127, and a fuel return line 131 connects the passage 130 with the tank 118.

The control system 12 for the pump 10 comprises a control wedge 132 positioned at the end of the stem 93 and movably disposed on a stationary flat surface 133. A piston 134 is connected by any suitable link 135 with the wedge 132, and the piston 134 is slidably disposed in a cylinder 136. A spring 137 yieldably moves the wedge 132 downwardly as seen in the figure, and the cylinder 136 is connected by means of a conduit 138 with the fuel intake manifold 139 of the engine 97. The usual throttle valve 140 and air cleaner 141 are connected with the manifold 139 as shown.

In operation, the pump 113 draws fuel, such as gasoline, through the conduit 117 from the tank 118 and discharges it into the conduit 119. The piston 122 of the relief valve 121 opens the port 124 against the action of the spring 123 when a predetermined pressure, such as, for example, 150 pounds per square inch, is reached; and the relief valve maintains the pressure at this value in the conduit 119. The fuel passes through the filter 120 to the fuel intake port 43 of the pump 10, and the fuel flows through the passages 46, 47, 48 and 49 to the star-shaped cavities 44 and 45.

The shaft 16 is driven at half the speed of the engine crankshaft by means of the gears 98 and 99, and the shaft 18 is driven at the same speed in the opposite direction by means of the gears 21 and 22 which are equal in size. The shaft 16 may be driven in either direction, but for the purpose of this description is assumed to be driven in the counterclockwise direction as seen in Fig. 4. The rotors 24 are driven from the shafts 16 and 18 through the universal joints 25, and the rotors respectively rotate on the carbon or graphite plates 30 and 41. The rotors 24 are maintained in forceful contact with the plates 30 and 41 by means of the annular seals 32 disposed in the cavities 35 and 42. The fuel under pressure is present in these cavities from the inlet port 43, and the fuel under pressure acts against the lower faces of the seals 32 forcing the seals upwardly and providing the same force on the rotors 24 through the bearings 36.

The slots 83 and 85 in the rotors 24, at one particular point in the rotation of the shaft 16, are at 135 degrees with respect to each other as shown in Fig. 4. At this time the slot 85 is disposed over and is in communication with the hole 56 in the plate 41, and the slot 83 is disposed over and is in communication with the hole 58 in the plate 30. Under these conditions, fuel under pressure flows from the star-shaped cavity 45 through the opening 56, the slot 85, the opening 84, and the passage 96 into the cavity 86 between the shuttle plunger 87 and the movable stop 89. This causes the shuttle plunger 87 to move to the left until it contacts the boss 92 on the fixed stop 91. During such movement of the shuttle plunger 87, it forces fuel within the cavity 86 between the shuttle plunger 87 and the fixed stop 91 through the passage 95, the opening 82, the slot 83, the opening 58 to the port 62 and therethrough the particular conduit 104 nozzles 102 connected to the port 62. The particular engine cylinder adjacent this nozzle 102 is thus furnished with a charge of fuel, the plunger

107 of the nozzle 102 being moved off the seat 106 to spray fuel out of the end of this nozzle 102.

The shaft 16 and the rotor 24 driven from the shaft 16 continue to rotate in the counterclockwise direction as seen in Fig. 4, and the rotor 24 driven from the shaft 18 continues to rotate in the opposite direction, so that the slot 83 moves off the opening 58 and the slot 85 moves off the opening 56. Such rotation brings the slot 83 in communication with the opening 51, and at the same time the slot 85 is brought into communication with the opening 71 in the plates 30 and 41 respectively. The opening 51 is in communication with the star-shaped cavity 44 supplied with fuel under pressure, and fuel thus flows through the opening 51, the slot 83, the opening 82 and the passage 95 into the cavity 86 between the shuttle plunger and the body portion of the fixed stop 91. The fuel under pressure in this portion of the cavity 86 moves the shuttle plunger 87 to the limit of its movement to the right against the stem 90 of the movable stop 89, and fuel is forced from between the shuttle plunger 87 and the movable stop 89 through the passage 96, the opening 84, the slot 85 and the opening 71 to the port 75 and from thence through the particular conduit 104 and nozzle 102 connected to the port 75. A charge of fuel is thus supplied to the particular engine cylinder adjacent to this particular nozzle 102.

Continued rotation of the rotor 24 driven by the shaft 16 brings its groove 83 consecutively into communication with the output port 59, the fuel supply port 52, the output port 60, the supply port 53, the output port 61, the supply port 50, and finally back with the output port 58 in the plate 30. Simultaneous continued rotation of the rotor 24 driven from the shaft 18 brings its slot 85 into communication with the supply port 55, the output port 70, the supply port 54, the output port 73, the supply port 57, the output port 72, and finally back with the supply port 56. The slot 83 passes over each of the openings in the plate 30 at the same time that the slot 85 passes respectively over the openings in the plate 41. The ports 59, 60 and 61 in the plate 30 are connected to the ports 63, 64 and 65 and the respective nozzles 102, so that fuel charges are supplied through these nozzles from the portion of the cavity 86 between the shuttle plunger 87 and the fixed stop 91 by movement of the shuttle plunger 87 to the left. This movement of the shuttle plunger 87 is due to the supplying fuel under pressure into the portion of the cavity 86 between the shuttle 87 and the movable stop 89 respectively from the supply ports 55, 54, and 57 in the plate 41. The ports 70, 73 and 72 are connected with the ports 74, 77 and 76 and supply fuel to the respective nozzles 102 connected to the latter ports from the portion of the cavity 86 between the shuttle 87 and the movable stop 89 due to a movement of the shuttle 87 toward the right to the limit of its movement against the movable stop 89, and this movement of the shuttle 87 from left to right is due to the supply of fuel under pressure into the cavity 86 between the shuttle plunger 87 and the fixed stop from the supply ports 52, 53 and 50 in the plate 30.

Thus it is apparent that the rotor 24 driven from the shaft 16 alternately supplies fuel under pressure to the left end of the shuttle plunger 87 to move it to the right and connects consecutively the output ports 62, 63, 64 and 65 with this end of the shuttle plunger, and the rotor 24 driven from the shaft 18 has this same function with respect to the right end of the shuttle 87 and the output ports 75, 74, 77 and 76. Thus the shuttle plunger 87 is caused to reciprocate, and in its movements from left to right it pumps fluid consecutively through the ports 75, 74, 77 and 76 to the connected nozzle 102, and in its movements from right to left it consecutively pumps fuel through the ports 62, 63, 64 and 65 and the nozzles 102 connected to these ports.

As will be apparent, the amount of fuel that is pumped through the ports 62, 63, 64, 65, 74, 75, 76 and 77 is

determined by the length of the reciprocatory stroke of the shuttle plunger 87, and the stroke is determined by the separation between the stops 89 and 91. As the stop 89 is moved to the right as seen in Fig. 2, the plunger stroke becomes larger, and the amount of fuel pumped through these ports by the plunger is increased. The position of the wedge 132 determines the location of the movable stop 89, and the wedge 132 is changed in position by means of the piston 134. The piston 134 is subject to the vacuum in the engine intake manifold 139, and this varies generally with the opening of the throttle valve 140, the vacuum being relatively high at a closed throttle position and being relatively low at an open throttle position. When the vacuum is relatively high at closed throttle position of the throttle valve 140, atmospheric pressure moves the piston 134 upwardly within the cylinder 136 against the action of the spring 137 and causes a corresponding upward movement of the wedge 132 by means of the link 135. The wedge 132 when moved upwardly moves the movable stop 89 to the left and shortens the stroke of the shuttle plunger 87, so that the amount of fuel supplied to the ports 62, 63, 64, 65, 74, 75, 76 and 77 and to the nozzles 102 connected therewith is at a minimum corresponding to closed throttle position. When the throttle is opened, the vacuum in the manifold 139 decreases, and the spring 137 moves the wedge 132 downwardly so that the movable stop 89 may move to the right as seen in Fig. 2 and lengthen the stroke of the shuttle plunger 87. The amount of fuel supplied to these ports and to the injector nozzles 102 is thus increased with increased throttle openings.

The purpose of the conduit 128 is to permit a flow of liquid fuel through the passages 126 and 127 about the rotors 24 for cooling the rotors. The fuel flows from the cavity 42 through the passage 126, the conduit 128 and the passage 127 to the rotors 24. After passing about the rotors 24, the fuel flows back to the fuel tank 118 through the passage 130 and the conduit 131. The flow of fuel about the rotors is limited to a small amount by the restriction 129.

The carbon or graphite plates 30 and 41 are cemented into the round cavities 31 by any suitable bonding agent as, for example, an "epoxy" resin. The star-shaped cavities 44 and 45 may simply be cast in the upper casing portion 15 and need not be formed within close tolerances. The openings 51, etc., in the plate 30 and the openings 55, etc., in the plate 41 are preferably drilled into these plates after the plates have been secured in position in the casing portion 15, and the openings may thus be precisely located, permitting rather wide tolerances to be used in casting the cavities 44 and 45 but yet providing the accuracy necessary in locating the fuel inlet and outlet openings with respect to the grooves 83 and 85 in the rotors 24.

My fuel injection pump advantageously utilizes the two rotors 24, each of which acts to supply fuel under pressure to one end of the shuttle plunger 87 and each of which receives fuel pumped by the plunger 87 and distributes it to half of the engine cylinders. The passages 95 and 96 are quite short, so that there is a minimum of fuel between the ends of the plunger 87 and the ports 58, 59, 60, 61, 70, 71, 72 and 73 through which fuel is pumped by the plunger. Cavitation between the plunger 87 and the ports listed above is thus minimized and resulting over-discharge through the nozzles due to inertia effect of the fuel between the ends of the plunger 87 and the nozzles is minimized. The plunger 87 is advantageously hollow in this connection, so that the forces of inertia due to the plunger are at a minimum. It has been noted that the plunger 87 is formed by the two thimblelike members 88 fixed together at their open ends, so that no fuel is present within the plunger likewise minimizing in this manner the amount of fuel within the cavity 86 and cavitation of fuel between the plunger 87 and the nozzles 102.

The carbon or graphite plates 30 and 41 on which the rotors 25 rest and rotate provide bearing faces with a minimum of friction for the rotors 24 and on which the rotors will not seize. The carbon or graphite plates 30 and 41 furthermore provide good sealing with respect to the rotors 24. The universal joints 25 driving the rotors 24 assure that the rotors 24 rest flatly in face to face fluid sealing contact with the carbon or graphite plates 30 and 41, and the rotors may pivot slightly on the rounded surfaces 29 and are driven by the pins 26 about which the rotors may also slightly pivot.

Due to the fact that cavitation of the fuel is minimized as just mentioned, the fuel injection pump 10 may operate satisfactorily at high engine speeds and maintains the output of fuel substantially the same with unchanged position of the movable stop 89, regardless of changes in speed of the rotors 24.

I wish it to be understood that the invention is not to be limited to the specific constructions and arrangements shown and described, except only insofar as the claims may be so limited, as it will be understood to those skilled in the art that changes may be made without departing from the principles of the invention.

I claim:

1. In a fuel injection apparatus for an internal combustion engine; the combination of a source of fuel under pressure; a reciprocable plunger; a first valve for connecting one end of said plunger alternately with said pressure source and with the engine; a second valve for connecting the other end of said plunger alternately with said pressure source and with the engine; each of said valves comprising a rotatable rotor and a flat plate in face-to-face contact, said plate having a plurality of ports therethrough and said rotor having a groove in its face for connecting various of the ports; and gearing for moving said rotors in unison so that one valve connects said pressure source to one end of said plunger to move the plunger and the other valve at the same time connects the other end of said plunger to the engine so that said plunger as it moves pumps fuel from its last named end to the engine.

2. In a fuel injection apparatus for an internal combustion engine; the combination of a source of fuel under pressure; a reciprocable plunger; a first valve for connecting one end of said plunger alternately with said pressure source and with the engine; a second valve for connecting the other end of said plunger alternately with said pressure source and with the engine; each of said valves comprising a rotatable rotor having a flat face in face to face contact with a carbon or graphite plate, said plate having a plurality of ports therethrough and said rotor having a groove in its face for connecting various ones of said ports as the rotor is rotated; and gearing for moving said rotors in unison so that one valve connects said pressure source to one end of said plunger to move the plunger and the other valve at the same time connects the other end of said plunger to the engine so that said plunger as it moves pumps fuel from its last named end to the engine.

3. In a fuel injection apparatus for an internal combustion engine; the combination of a source of fuel under pressure; a reciprocable plunger; a first valve for connecting one end of said plunger alternately with said pressure source and with the engine; a second valve for connecting the other end of said plunger alternately with said pressure source and with the engine; each of said valves comprising a rotatable rotor having a flat face in face to face contact with a flat plate portion, means for applying the pressure of said source on said rotors for holding them in forceful contact with said plate portions, and gearing for connecting said rotors so that they move in unison whereby one valve connects said pressure source to one end of said plunger to move the plunger and the other valve at the same time connects the other end of said plunger to the engine and said plunger as it moves pumps fuel from its last named end to the engine.

4. In a fuel injection apparatus for an internal combustion engine, the combination of a source of fuel under pressure, a reciprocable plunger, a first valve for connecting one end of said plunger alternately with said pressure source and with the engine, a second valve for connecting the other end of said plunger alternately with said pressure source and with the engine, each of said valves comprising a rotatable rotor in face to face contact with a flat plate portion, means for forcefully holding said rotors and plate portions in contact, a shaft for driving each of said rotors, gearing for causing said rotors to move in unison so that one of said valves connects said pressure source to one end of said plunger to move the plunger and the other of said valves at the same time connects the other end of said plunger to the engine and said plunger as it moves pumps fuel from its last named end to the engine, and a universal joint between each of said shafts and the respective rotor for assuring proper radial location and a fluid tight contact of the rotor on its respective plate portion.

5. In a fuel injection apparatus for an internal combustion engine having a plurality of combustion cylinders; the combination of a fuel injection nozzle for each of said cylinders; a source of fuel under pressure, a reciprocable plunger, a first valve for connecting one end of said plunger alternately with said pressure source and with different ones of said nozzles, a second valve for connecting the other end of said plunger alternately with said pressure source and with other different ones of said nozzles, each of said valves comprising a rotatable rotor in face-to-face contact with a plate portion, each of said plate portions having a central port connected with one end of said reciprocable plunger and having a plurality of peripheral ports alternate ones of which are connected with said pressure source and with different ones of said nozzles, each of said rotors being provided with a groove in its face for connecting the central port of the corresponding plate portion with the peripheral ports in sequence, and gearing for driving said rotors in unison so that one rotor connects a port in the associated plate portion supplied from said pressure source to one end of said plunger to move the plunger and the other valve at the same time connects the other end of said plunger through the central port in the associated plate portion to one of said fuel nozzles and said plunger as it moves pumps fuel from its last named end to said last named nozzle.

6. In a fuel injector pump for an internal combustion engine, the combination of a pump casing having a cylindrical cavity therein, a reciprocable plunger in said cavity, said casing being provided with an inlet port connectible to a source of fuel under pressure and a plurality of outlet ports connectible to fuel injector nozzles, a first valve for connecting one end of said plunger alternately with said inlet port and with different ones of said outlet ports, a second valve for connecting the other end of said plunger alternately with said inlet port and with different other ones of said outlet ports, each of said valves comprising a rotatable rotor in face-to-face contact with a plate portion, said plate portions each having a center port therein connected to one end of said plunger and peripherally located ports alternately connected to said inlet port and to different ones of said outlet ports and each of said rotors having a groove in its face for connecting the center port of the corresponding plate portion consecutively with the peripheral ports in said plate portion, and gearing for connecting said rotors to rotate in unison whereby one of said valves connects said inlet port to one end of said plunger so that the pressure of the fuel may move the plunger and the other valve at the same time connects the other end of said plunger to one of said outlet ports so that said plunger

as it moves may pump fuel from its last named end to the outlet port.

7. In a fuel injection apparatus for an internal combustion engine, the combination of a source of fuel under pressure, a reciprocable plunger, a first valve for connecting one end of said plunger alternately with said pressure source and with said engine, a second valve for connecting the other end of said plunger alternately with said pressure source and with said engine, each of said valves comprising a rotatable rotor in face-to-face contact with a plate portion, each of said plate portions having a plurality of ports connected with said pressure source and a plurality of ports adapted to be connected to said engine and also a port connected to one end of said plunger, gearing for moving said valves in unison so that one valve connects said pressure source to one

end of said plunger to move the plunger and the other valve at the same time connects the other end of said plunger to said engine so that said plunger as it moves pumps fuel from its last named end to the engine, and means for limiting the reciprocation of said plunger and including a fixed stop on one end of the plunger and a movable stop on the other end of the plunger.

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