

Oct. 31, 1944.

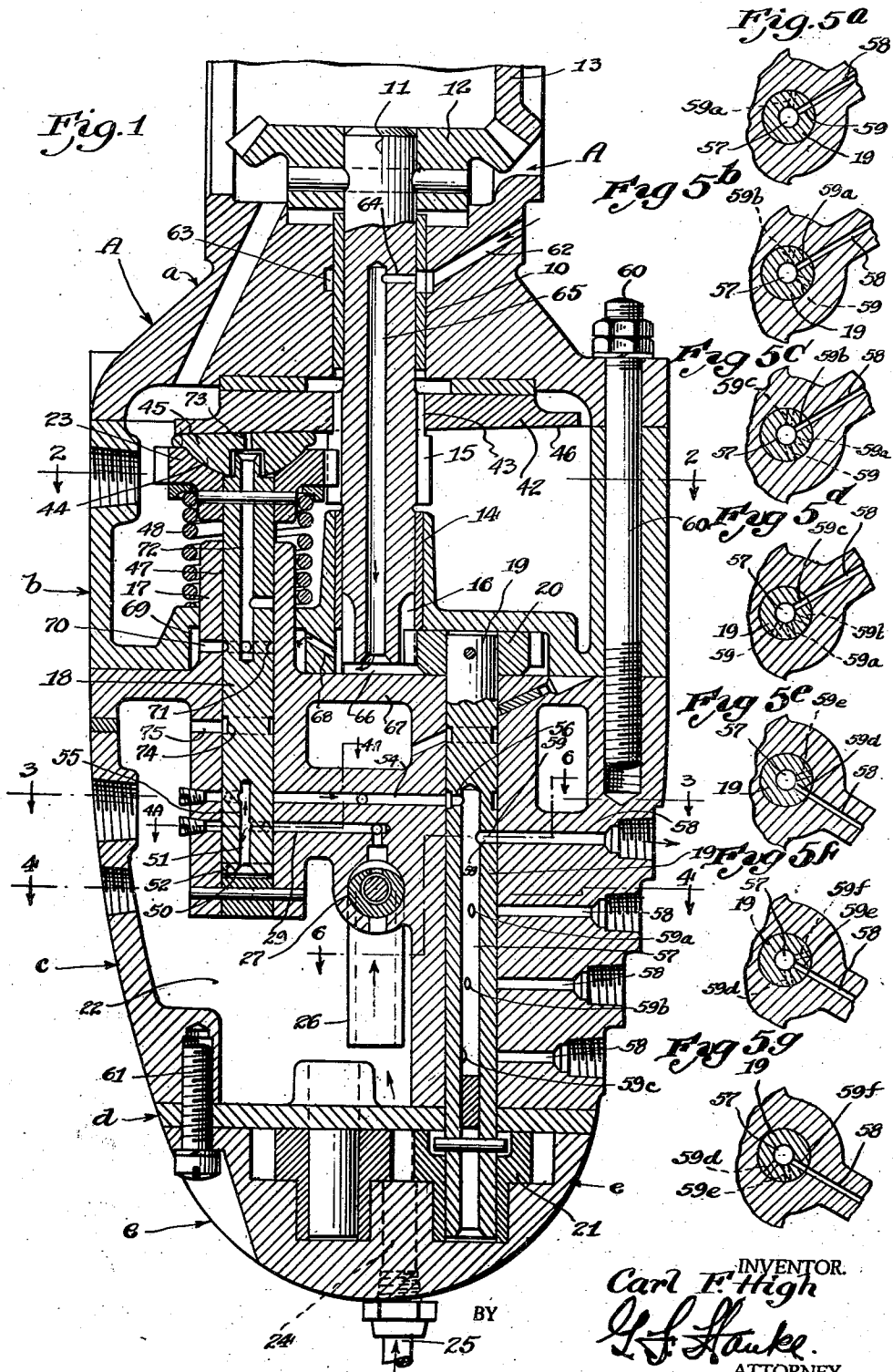
C. F. HIGH

2,361,399

FUEL PUMPING AND DISTRIBUTING DEVICE

Filed April 4, 1940

6 Sheets-Sheet 1



Oct. 31, 1944.

C. F. HIGH

2,361,399

FUEL PUMPING AND DISTRIBUTING DEVICE

Filed April 4, 1940

6 Sheets-Sheet 2

Fig. 3

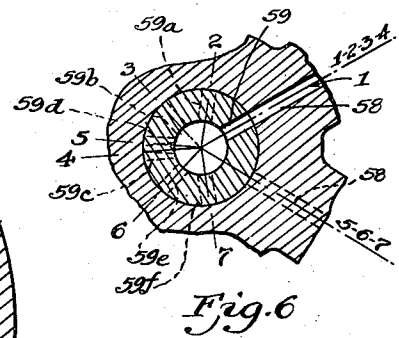
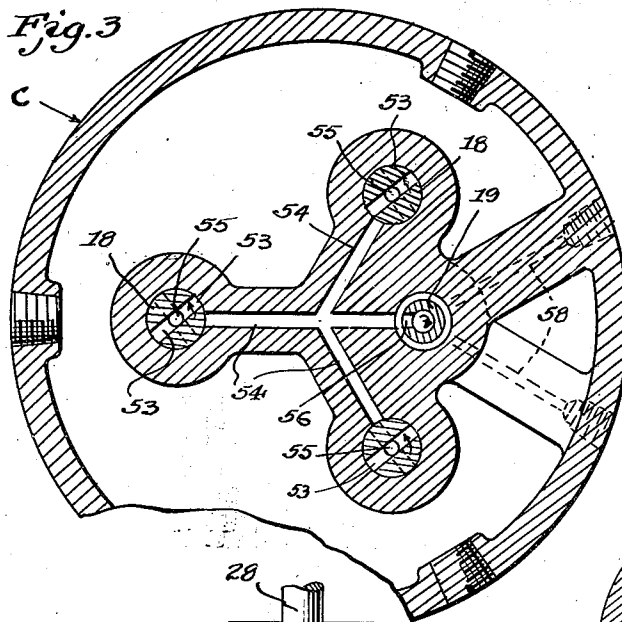


Fig. 6

Fig. 2

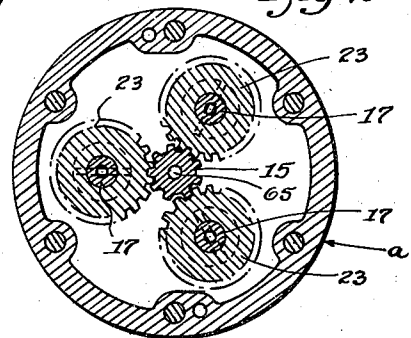


Fig. 4

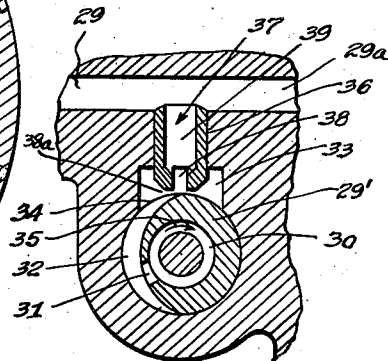
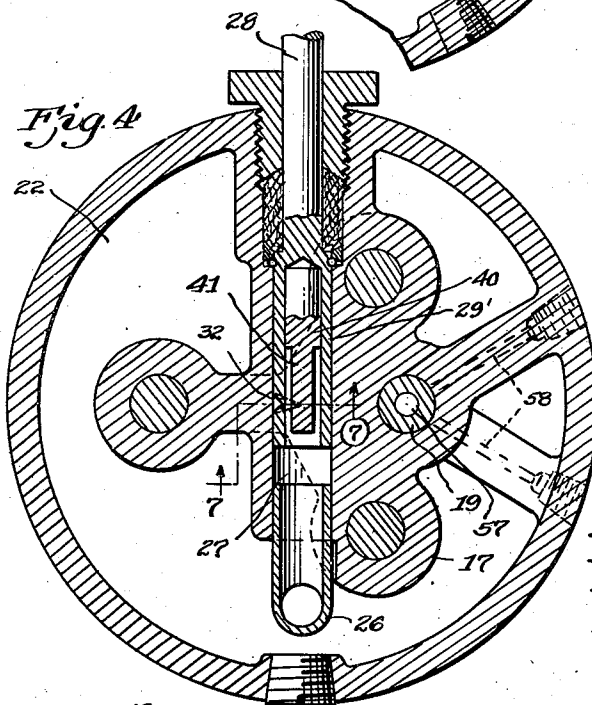


Fig. 7

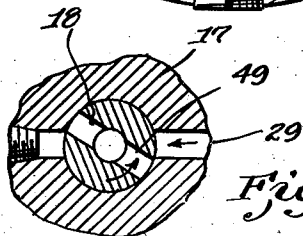


Fig. 4A

BY

INVENTOR.
Carl F. High
G. J. Hawks.
ATTORNEY.

Oct. 31, 1944.

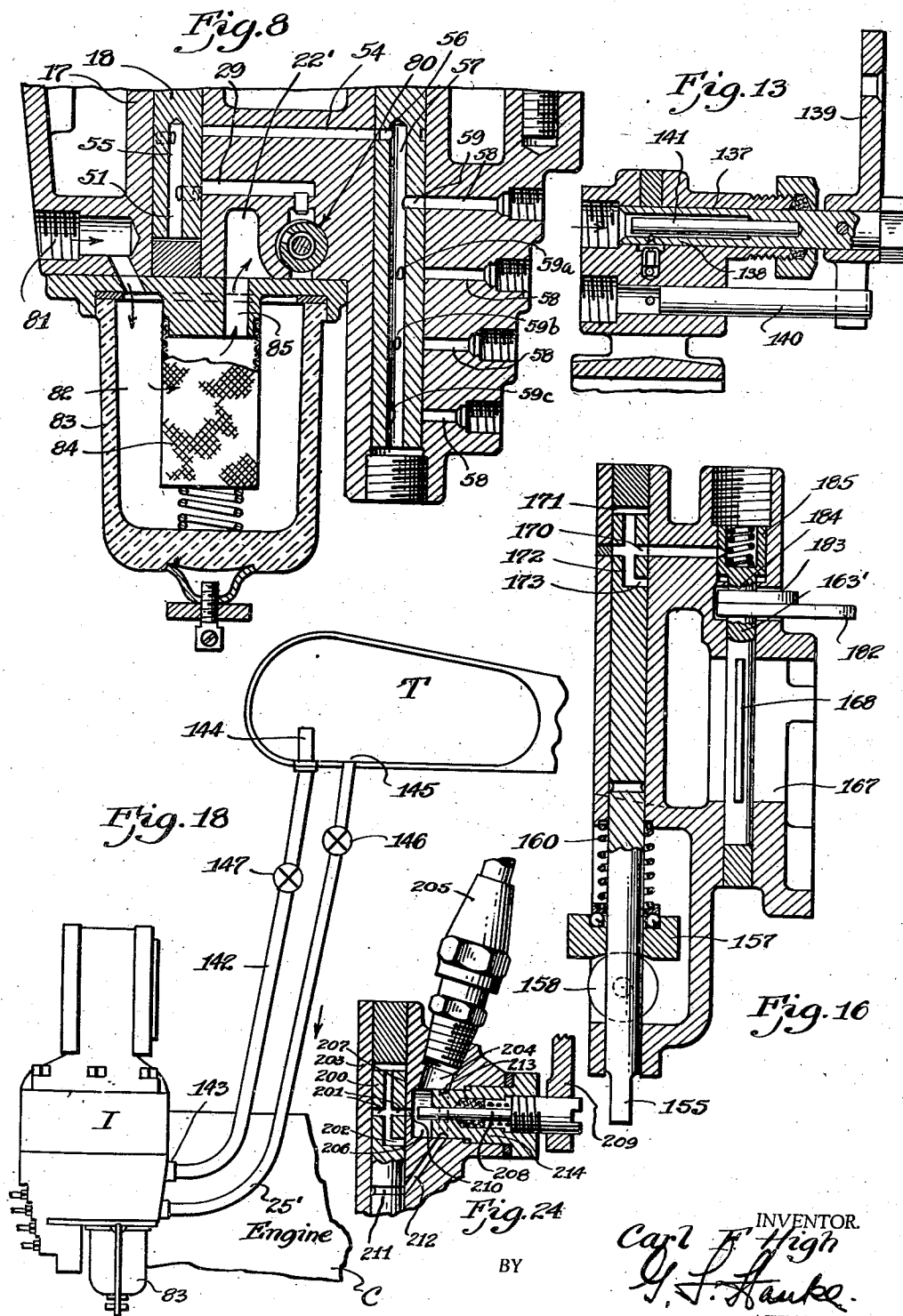
C. F. HIGH

2,361,399

FUEL PUMPING AND DISTRIBUTING DEVICE

Filed April 4, 1940

6 Sheets-Sheet 3



Oct. 31, 1944.

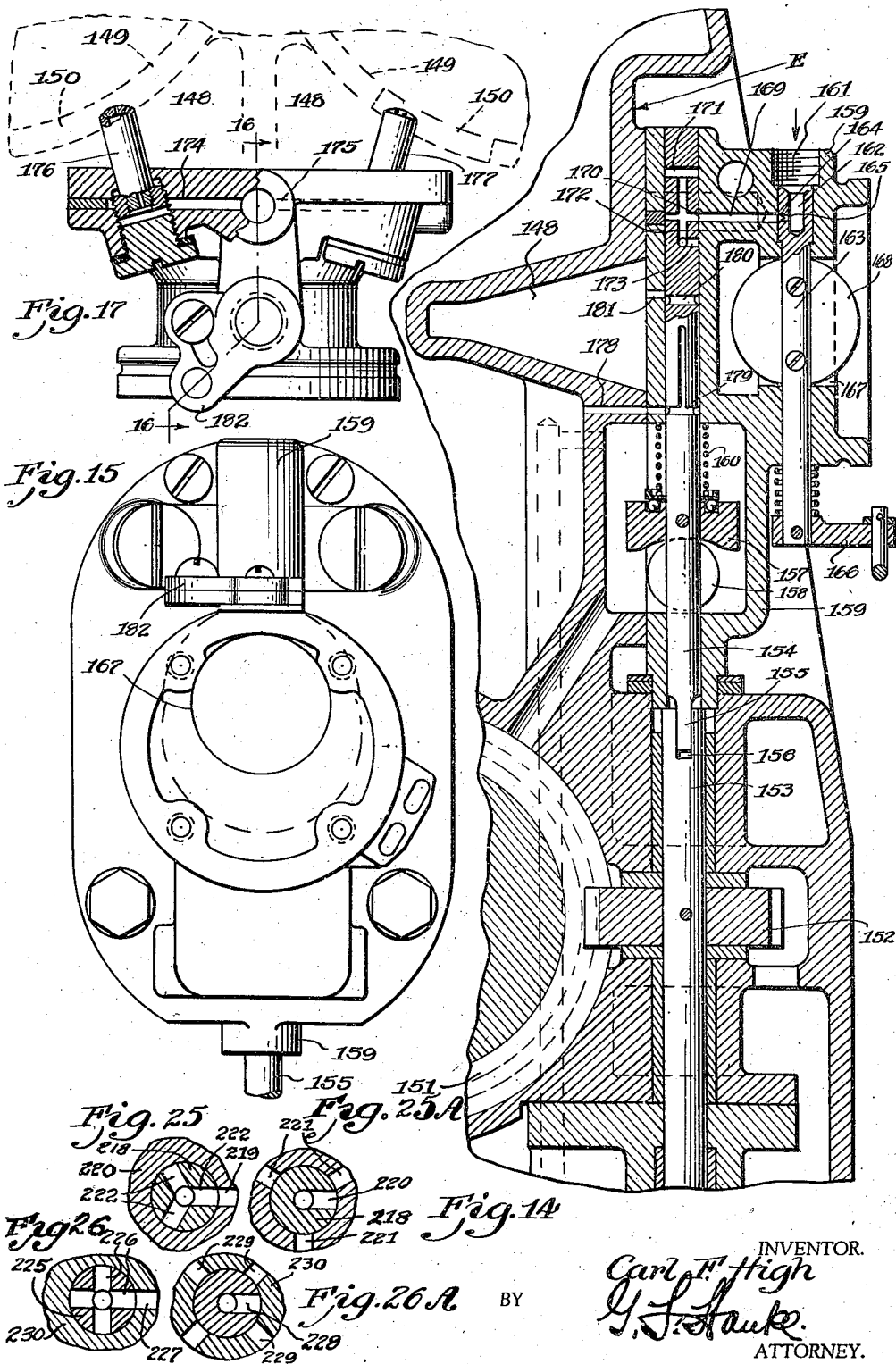
C. F. HIGH

2,361,399

FUEL PUMPING AND DISTRIBUTING DEVICE

Filed April 4, 1940

6 Sheets-Sheet 5



Oct. 31, 1944.

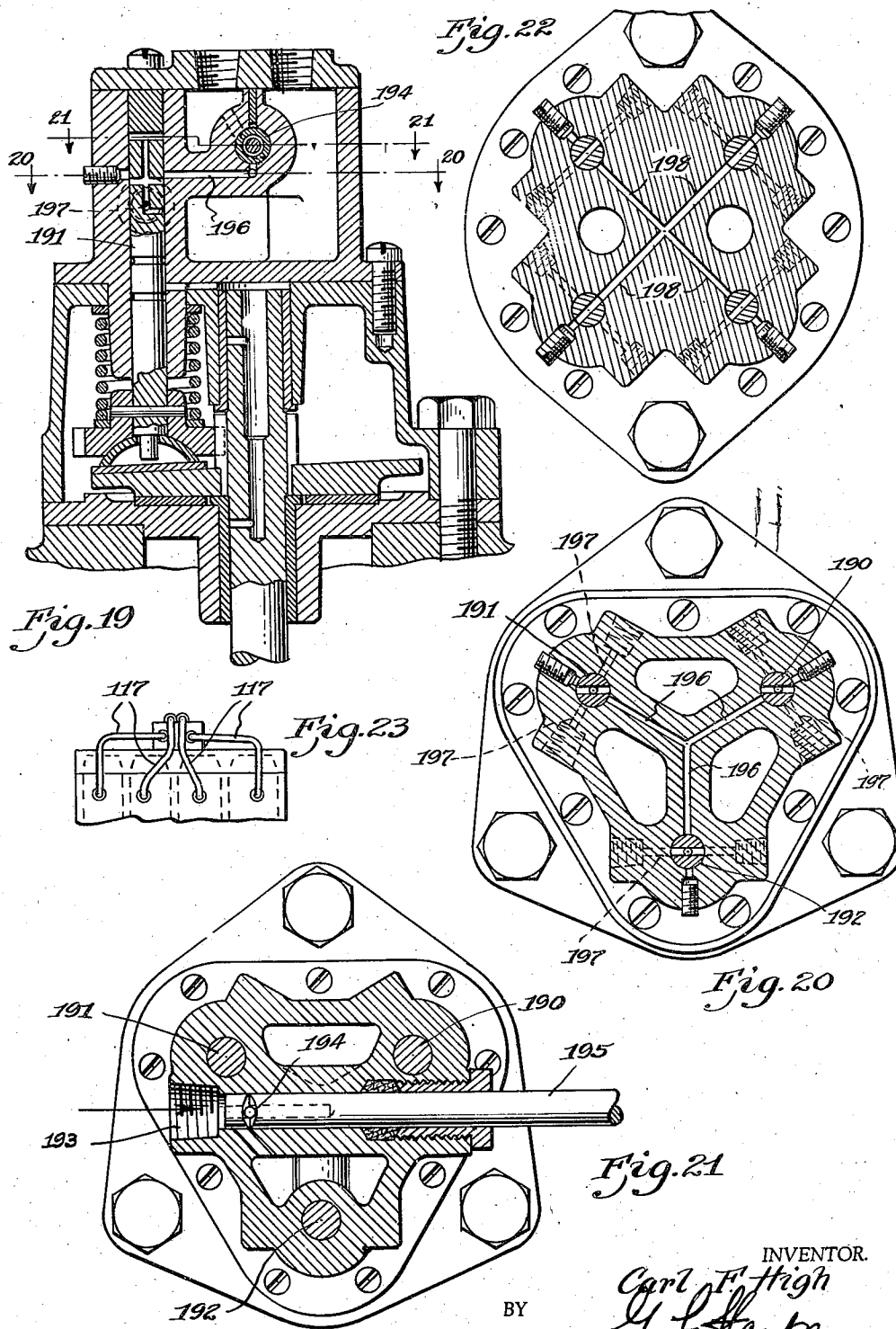
C. F. HIGH

2,361,399

FUEL PUMPING AND DISTRIBUTING DEVICE

Filed April 4, 1940

6 Sheets-Sheet 6



BY

INVENTOR.
Carl F. High
BY *G. L. Hauke*
ATTORNEY.

UNITED STATES PATENT OFFICE

2,361,399

FUEL PUMPING AND DISTRIBUTING
DEVICE

Carl F. High, Muskegon, Mich., assignor, by mesne assignments, to Ex-Cell-O Corporation, Detroit, Mich., a corporation of Michigan

Application April 4, 1940, Serial No. 327,834

13 Claims. (Cl. 123—139)

My invention relates to liquid fuel injectors and more particularly to one embodying a fuel pump and means for measuring and pumping liquid fuel to a plurality of engine cylinders.

More particularly the present fuel pump is constructed and arranged to include fuel metering means on the suction side of the pump and a pump plunger operable in timed relation with the engine which drives same to pump liquid fuel and to distribute same to a plurality of fuel outlet means. More particularly my invention embodies a pump plunger driven with a combined reciprocating and rotating motion.

In some embodiments of my invention, the pump plunger which is operable to distribute the fuel is constructed to discharge fuel from one or more discharge passages which may register at predetermined periods with separate and distinct discharge passages in the pump housing or with a single discharge passage leading to a liquid fuel distributing device.

Another object of my present invention is to facilitate engine operation by providing a fuel pumping, metering and distributing unit of compact design and of economical construction which makes possible the assembly of the pumping unit with an aircraft engine power plant.

Other objects of my invention relate to various features of construction and operation embodying improved controlling and operating devices and improved means for lubricating the moving parts of the unit.

For a more detailed understanding of my invention, reference may be had to the accompanying drawings illustrating various preferred embodiments of my invention and improvements as hereinafter described, and in which like parts are identified by like reference characters throughout the several views, and in which:

Fig. 1 is a longitudinal sectional view through my fuel injector pump embodying a rotating and reciprocating pump plunger and a distributing device all of which are operated from a single driving element driven by the engine associated therewith, this fuel injector device being particularly constructed for assembly with a seven cylinder radial engine and timed to provide a fuel injection to each cylinder of the engine once for each two revolutions of the engine crankshaft,

Fig. 2 is a transverse sectional view on the line 2—2, Fig. 1, reduced in scale and illustrating means for driving the plurality of pumping instrumentalities,

Fig. 3 is a transverse sectional view taken on the line 3—3 of Fig. 1, and illustrating in detail the pump unit and its relation with the fuel discharge passages in the pump housing,

Fig. 4 is a transverse sectional view on the line 4—4 of Fig. 1, illustrating in detail the fuel intake

metering means incorporated with the fuel injector unit as illustrated in Fig. 1,

Fig. 4A is a detail transverse sectional view of the pump inlet taken on the line 4A—4A of Fig. 1,

Figs. 5A to 5G inclusive are views showing a series of positions assumed by the distributor valve in distributing the fuel to the ultimate place of consumption, this view particularly illustrating the series of positions assumed by the distributor valve in distributing the liquid fuel to the conduits leading to the engine cylinders,

Fig. 6 is a fragmentary enlarged transverse sectional view through the distributor valve taken substantially on the line 6—6 of Fig. 1,

Fig. 7 is an enlarged detail sectional view of the liquid fuel throttle valve showing how the fuel is metered as the same is introduced into the intake passage leading to the suction side of the pump and taken substantially on the line 7—7 of Fig. 4,

Fig. 8 is a fragmentary sectional view of a fuel injector unit constructed similar to Fig. 1 by showing a modified fuel intake construction embodying a filtering device,

Fig. 9 is a plan view of another type of fuel injector device particularly constructed for assembly with a four cylinder engine, and having a pair of pump units and a pair of fuel outlets associated with each pump unit,

Fig. 10 is a side elevational view of a fuel injector device illustrated in Fig. 9,

Fig. 11 is a longitudinal sectional view through this device taken on the line 11—11 of Fig. 9,

Fig. 11A is a detailed transverse sectional view of the pump discharge taken on the line 11A—11A of Fig. 11,

Fig. 11B is a detail transverse sectional view of the pump inlet passages taken substantially on the line 11B—11B of Fig. 11,

Fig. 12 is a transverse sectional view of the injector taken substantially on the line 12—12 of Fig. 9 and showing the intake fuel metering valve which embodies an eccentric throttle valve operable to shut off the flow of fuel,

Fig. 13 is a fragmentary sectional view showing a modified fuel metering valve construction,

Fig. 14 is a longitudinal sectional view of another type of fuel injector mounted directly on an engine and incorporating additional structural features as will be hereinafter described in detail,

Fig. 15 is an elevational view of an injector of modified construction,

Fig. 16 is a detailed sectional view of the modified construction shown in Fig. 15 in which the interconnected air and fuel throttle means are relatively adjustable, said view being taken substantially on the line 16—16 of Fig. 17,

Fig. 17 is a plan view of the construction shown in Fig. 16 and illustrating in detail the adjust-

able feature of the air and fuel control means.

Fig. 18 is a detail diagrammatic view showing the installation of the aforesaid unit with an engine and the connection and relationship to a fuel tank.

Fig. 19 is a longitudinal sectional view of another type of fuel injector and particularly one constructed for assembly with a six cylinder engine.

Fig. 20 is a transverse sectional view showing the fuel intake and discharge passages and the plurality of pump units incorporated with the structure shown in Fig. 19 and taken substantially on the line 20—20 of Fig. 19.

Fig. 21 is a transverse sectional view taken on the line 21—21 of Fig. 19 and illustrating in detail the liquid fuel metering valve.

Fig. 22 is a transverse sectional view of another type of fuel injector in general similar to sectional view Fig. 20 and showing the fuel intake and discharge passages particularly constructed for an injector adapted for assembly with an eight cylinder engine.

Fig. 23 is a detail elevational view showing a fuel injector assembled with a multi-cylinder engine and illustrating particularly the fuel conduits or lines connecting the injector with the several engine cylinders.

Fig. 24 is a fragmentary sectional view of an injector of modified construction adapted for assembly direct on an engine similarly as the injector illustrated in Fig. 14.

Fig. 25 is a sectional detail view of a multiple outlet injector pump plunger showing the inlet port.

Fig. 25A is a similar sectional view showing the outlet ports.

Fig. 26 is a sectional detail view of another form of multiple outlet injector pump plunger showing the inlet port, and

Fig. 26A is a similar sectional view showing the outlet ports.

Referring more particularly to the injector illustrated in Figs. 1 to 8 inclusive, it will be noted that this construction is particularly designed for application with an engine having an odd number of cylinders and more particularly the injector proper is provided with an odd number of liquid fuel outlets. This particular construction is especially designed for assembly with a seven cylinder radial engine and is constructed particularly compact and light in weight so as to be applicable to an aircraft engine.

The fuel injector comprises a composite housing structure A consisting of complementary housing sections or portions a, b, c, d and e. The housing portion a carries a bearing 10 for supporting a central driving shaft 11 to which is pinned a beveled gear 12 meshing with a beveled gear 13 driven in any suitable manner from an engine driven element. It will be noted that the driving shaft 11 is preferably driven at a speed which is $2\frac{1}{2}$:2 of engine crankshaft speed. The inner end of the driving shaft 11 is supported in a bearing 14 carried by the housing portion b and carries an intermediate pinion 15 and a second pinion 16 located adjacent the inner end thereof.

Housing portion c is cast with a plurality of pump cylinders 17 in which the rotating and reciprocating pump units 18 are operable. The pump cylinders (three in number) are nested about the central drive shaft 11 and are preferably equally angularly spaced from each other and are located substantially equidistant from

the drive shaft 11. Said casing c also supports the rotating distributor valve 19 which valve is provided with a gear or pinion 20 at one end meshing with the gear 16 carried by the drive shaft and a pinion 21 at the other end, this pinion or gear 21 forming the driving element of a pump for pumping liquid fuel into the receiving chamber 22 carried by housing portion c. The ratio between the gear 20 and pinion 16 is such as to drive the distributor rotor 19 at a speed so that the same will rotate one complete revolution for each two revolutions of the engine crankshaft, in other words, at one half engine crankshaft speed. The ratio between gear 20 and pinion 16 is $2\frac{1}{2}$:1. The ratio of the pinion 15 with the gear 23 pinned or otherwise secured to the pump plunger 18 is 1:2 so that these pump plungers are rotated at a speed which is one-half the speed of the driving shaft 11.

The liquid fuel enters into the intake duct 24 in housing portion e from the feed line 25 and is pumped into chamber 22. Referring particularly to Figs. 1 and 4 it will be observed that the fuel is introduced into the depending intake pipe 26 and then into the intake passage 27 formed by the drilled hole in the housing structure which extends substantially transverse thereof, substantially normal to the axis of the pump plunger 18. A liquid fuel metering valve is fitted into this drilled hole 27 and consists of a stem 28 which may be angularly adjusted manually to control the amount of fuel admitted into the intake passage 29 leading to the liquid fuel pump. This valve is constructed to provide a sleeve-like cylinder extension 29' (see Fig. 7) which has an internal bore 30 and a transverse port 31 which communicates with a segmental crescent shaped groove or slot 32. The fuel which is introduced into chamber 27 enters the bore 30 thence flowing through the port 31, crescent groove 32, and into the pocket 33. It will be noted that as the valve is angularly adjusted the opening into the pocket 33 at 34 is adjusted in area, and it may be observed that as this valve is adjusted in the direction as indicated by the arrow 35 (Fig. 7) that the area of the opening at 34 will be increased to permit the flow of a greater volume of fuel into the pocket 33. This pocket 33 communicates with the intake passage 29 through a port 36, and preferably I assemble a fuel pressure equalizer fixture or fuel distributing control device 37 in this port 36 which fixture is slotted at one end as at 38 and provides an internal passage 39 through which the liquid fuel flows on its way to the fuel pump. The slot 38 is preferably arranged to extend at substantially right angles to the flow of fuel. This insert is located to provide a restricted opening at 38a so that substantially all the fuel must enter into the fixture 37 through the ends of the slot 38. The internal bore of fixture 37 is substantially uniform in cross section throughout its entire length and the fuel, either in a liquid form or semi-gaseous state attains a degree of equilibrium as it flows through this fixture and will be substantially uniformly distributed to passages 29 and 29a. A plug 40 is fitted within the bore 30 of the valve and carries an extension 41 of reduced diameter which extends across the port 31 and serves to reduce the volume of the intake passage 30 to reduce the effect of liquid fuel surge to facilitate the normal flow of liquid fuel through the port 31.

The position of the pump plunger 18 in Fig. 1 is at the beginning of intake or at the end of dis-

charge. This plunger is reciprocated by means of a wobble plate cam 42 which is splined with a reduced diameter portion 43 of the pinion 15. The gears 23 are provided with a spherical recessed portion 44 in which is seated the convex cam follower 45 having a flat face engaging the cam surface 46 of the cam 42. As this cam is rotated the plunger is forced inwardly of the pump cylinder 47 against the resistance of spring 48, this spring 48 exerting a force outwardly so as to maintain the cam follower 45 constantly in contact with the cam surface 46. In the position illustrated in Fig. 1 and Fig. 4A, it will be noted that the intake passage 49 of the pump plunger is moving into registration with the passage 29 as the pump plunger is beginning its outward movement. The liquid fuel is thus introduced into the pump chamber 50 as indicated by arrow 51, said fuel filling the chamber 50 which in its spaced position will have a length as indicated at 52. The intake cycle will take place substantially for about a 90 degree angular travel of the plunger 18, and, as the intake closes the outlet passage 53 is brought into registration with the outlet passage 54 in the housing portion c. At this time the plunger 18 is at the upper end of its stroke and is beginning the pumping stroke, said plunger now beginning to displace the fuel and force same through the internal passage 55 in said pump plunger through said discharge passage 53 into passage 54 and thence through the intake 56 in the distributor valve 19 and into the internally drilled hole or passage 57, from which passage the liquid fuel is caused to flow through the passages 58 to the various fuel outlets. It will be observed that in the position shown in Fig. 1, the passage outlet 58 connected with cylinder 1, is in registration with the uppermost port 59 in the distributor valve body. The timing of the distributor valve and the pump plunger is such that the various ports 59 are held in registration with the various outlet passages 58 concurrently with the registration of pump outlet passages 53 with passages 54 and thus a column of fuel is successively moved through the said passage to the various discharge passages 58. In Figs. 5A to 5G inclusive I have illustrated diagrammatically how these discharge passages 58, which lead to the various engine cylinders are successively brought into registration with the discharge ports 59, 59a, 59b, 59c, 59d, 59e and 59f of the distributor valve 19.

Fig. 6 is a diagrammatic time diagram showing the relationship of each of the distributor valve discharge ports with the discharge passages 58. In order to conserve length it will be noted that the discharge passages 58 leading to cylinders 1, 2, 3 and 4 are aligned one above the other in one plane while the passages 58 leading to cylinders 5, 6, and 7 are aligned one above the other in another plane.

It will be noted that the pump plunger 18 is continuously rotating and carries a pair of oppositely extending discharge passages 53 angularly spaced 180 degrees apart. The pump has two discharges for each revolution and each discharge enters the common discharge passage 54. The construction of the three pump plungers shown in detail in Fig. 3 is such that for every $\frac{1}{4}$ rotation of the distributor valve, one of these pump plungers discharge passages 53 is brought into registration with the passage 54 and a predetermined volume of liquid fuel is moved through the system and discharged into an engine cylinder. This is accomplished by

properly proportioning the gears which drive the distributor valve 19 and the pump plungers 18.

It will be noted that the parts a, b, c, d and e of the pump housing are secured together by suitable bolts, the bolts 60 securing parts a, b and c together while the bolts 61 secure the parts d and e to portion c.

The various moving parts of the above described mechanism are lubricated as will hereinafter be described. The lubricating oil is introduced into the passage 62 in housing portion a and thence fed into the circular groove 63 then through the transverse passage or duct 64 into the central or axial drilled passage or hole 65 in the driving shaft 11. The lubricating oil enters the chamber 66 formed by spacing the inner end of shaft 11 from the wall 67 of the housing and is then fed through the passage 68 into the annular chamber 69 about the pump cylinder 17, and through the transverse duct 70 into an annular groove 71 on the pump plunger. Some of this lubricating oil is thus allowed to spread in a film on the surface of the pump cylinder to lubricate same and some is fed outwardly of the pump plunger through the central axial passage 72 to the upper end thereof and through the passage 73 to lubricate the cam surface 46. The pump plunger is provided with an annular groove 74 intermediate the groove 71 and the fuel outlet passages 53. The cylindrical portion of the pump plunger cylinder intermediate port 70 and port 75, which latter port communicates with the annular groove 74 has a very close fit with the plunger in order to minimize leakage of the lubricating oil into the annular groove 74. I preferably provide a system in which the oil pressure forcing the lubricating oil to the various elements to be lubricated is greater than the fuel pressure and therefore if there is any leakage resulting in intermingling of the fuel and lubricating oil, the lubricating oil leaks into the fuel instead of the fuel leaking into the lubricating oil. The drain passage 75 obviously drains any leakage of fuel and oil along the surface of the pump plunger back into the intake chamber 22, and any minute portion of the lubricating oil which may find its way into the chamber 22 is readily carried along with the fuel and burned in the engine.

In Fig. 8 I have illustrated a modified construction and have shown a portion of an injector substantially similar in construction and operation to that illustrated in Fig. 1. This modified construction is more compact and is provided with an intake valve structure 80 and includes an intake passage 81 connected with a chamber 82 formed by a glass bell 83 secured to the under side of the injector housing. The liquid fuel is caused to flow from chamber 82 through a filter screen 84, thence into passage 85 and into an intake chamber 22' similar in purpose of the intake chamber 22.

In Figs. 9 to 13 inclusive, I have illustrated an injector now being commercially used for injecting fuel into the intake chambers or cylinders of a four cylinder aircraft engine. This injector consists generally of a housing structure B preferably constructed of sectional portions bolted together by a plurality of bolts 90 and cap screws 91. This injector includes a driving shaft 92 driven in timed relation with the engine with which the injector is associated, this driving shaft 92 functioning the same as driving shaft 11 as described in connection with the injector illustrated in Figs. 1 to 8 inclusive. In view of the

fact that this injector is designed for application for a four cylinder engine the timing of the pump plunger is different than the timing of the pump plungers 18 shown in Fig. 1. The drive shaft 92 carries an intermediate gear 93 which drives gears 94 pinned or otherwise secured to the two pump plungers 95. A cam 96 having a cam face 97 is splined to the gear teeth 93 as at 98 and it will be noted that in this case the gear ratio between the gear 94 and gear 93 is 2:1 while the cam 96 is rotated at the same speed as the drive shaft 92. It will therefore be observed that the plungers 95 are moved up and down two complete strokes for each complete rotation.

The liquid fuel is introduced to the injector pump from the fuel line 99 into the intake port 100 (see Fig. 12). A fuel metering valve structure 101 is supported by the boss 102 of the housing and comprises a tubular sleeve 103 preferably angularly adjusted manually by the arm 104, this sleeve 103 being provided with a segmental crescent shaped V-groove 105 and transverse port 106 similar in construction and operation to the valve 29 shown in Fig. 7. The fuel is metered by adjustably positioning this valve sleeve 103 and controls the column of fuel admitted into the fuel intake passages 107. Preferably a fuel pressure equalizer fixture 108 is assembled in the fuel intake passage in the same manner as in the injector constructed for seven cylinder engine operation and illustrated in Fig. 1. In addition this fuel metering valve carries an eccentric shut-off valve 109 manually actuated by arm 110 and serving as a manual fuel mixture control. In the position shown in Fig. 12, the eccentric shut-off valve is in open position but it will be readily seen that same can be moved to vary the size of the port 106.

The port 106 is made of a size to take care of maximum fuel demands of the engine at ground level and the flow of fuel through this orifice or port is dependent on the atmospheric pressure at the altitude at which the aircraft is flown. It will be understood that the atmosphere pressure forces both the fuel through port 106 and the air into the engine, therefore when the valve is adjusted for correct proportioning of fuel and air at ground it is correctly adjusted for any altitude where reduced atmospheric pressure is effective.

It will be observed that the fuel introduced into the passage 107 may flow in either direction toward either of the pump plungers 95. The pump plunger is provided with a central drilled hole 111 and communicating therewith are the transverse passages 112, which are successively and periodically brought into registration with the intake passage 107. In fact it will be noted that there are two intake periods for each rotation of the pump plunger as first one of the passages 112 is brought into registration with passage 107 and then when the plunger has rotated through an angle of 180 degrees the other intake passage 112 is brought into registration with passage 107 (see Fig. 11B). The pump plunger 95 is provided with an outlet or discharge passage 113 communicating with the center passage 111. It will be noted that on rotation of the plunger this discharge passage 113 is successively brought into registration with the fuel outlet passages 114 and 115. These passages 114 and 115 are located 180 degrees apart around the pump plunger and therefore there is a time interval of substantially 180 degrees in rotation of the pump plunger between the intake opening point for these passages 114 and 115.

The timing of the pump plunger is such as to provide an intake period for filling the pump chamber 116 with liquid fuel and then as the plunger is moved to displace the fuel in this chamber 116 the discharge port or passage 113 is brought into registration with either the passage 114 or 115 to discharge the fuel into one of the fuel lines 117 leading to the engine cylinders.

The fundamental principle of operation of the pumping unit shown in Figs. 9 to 13 inclusive is substantially the same as the pumping unit illustrated in Figs. 1 to 7 inclusive. In the pumping unit, first described, the pump plunger had two discharge passages 53 which were successively brought into registration with the passage 54 of the pump housing. In the latterly described injector, the pump unit includes a plunger having an outlet or discharge passage or port 113 which is successively brought into registration with angularly spaced outlet passages 114 and 115 in the housing. Therefore, it is readily apparent that the pump plunger in both instances serves as a pumping instrumentality and as a liquid fuel distributing means for controlling successive injections of liquid fuel to different engine cylinders, in other words the pump plunger not only pumps the fuel but serves to distribute fuel in a predetermined sequence to outlet passages under pressure for conduction to separate engine cylinders where the fuel is burned.

The injector particularly illustrated in Fig. 11 is constructed to provide for lubrication of the moving parts, the lubricating oil being introduced from the oil passage 118 in the engine block 119, into a passage 120 in the injector housing. The oil is fed under pressure through the duct 121 into the axially drilled hole 122 in the drive shaft 92. Lubricating oil is fed to the bearing 123 carried by the housing for supporting the drive shaft 92 and is fed upwardly through the drilled hole 122 into the oil chamber 124 formed at the upper end of the drive shaft 92 which is spaced from the wall 125 of the injector housing. Oil is fed from the drilled hole 122 through oil ducts 126 to lubricate the bearings 127 which support the inner end of the drive shaft 92. The injector housing is provided with laterally extending oil grooves 128 conducting the lubricating oil from chamber 124 to the external cylindrical surface of the pump plungers 125, said lubricating oil being fed to the annular grooves 129 carried by the pump plungers and fed downwardly through the longitudinal grooves 130 to lubricate the pump cylinder surface 131. That portion of the pump plunger indicated by the reference character 132 preferably has a tight fit within the pump cylinder to minimize leakage of the lubricating oil toward the fuel pumping portion of the plunger. Such lubricating oil as may leak by this portion 132 is collected in the annular groove 133 and conducted away through the passage 134 into the return line 135. As is the case with the construction illustrated in Fig. 7, the lubricating oil introduced into this injector is under a pressure greater than the fuel pressure and therefore if any leakage occurs the lubricating oil will leak into the fuel reservoir instead of the fuel leaking into the lubricating oil system. The return line 135 may be connected with the intake side of the pump by a duct 136 (see Fig. 12). A stop pin 137 is mounted or secured to the housing to limit travel of arm 110 and 104.

The modified construction illustrated in Fig. 13 shows a modified type of fuel metering valve which is substantially similar to the fuel meter-

ing valve illustrated in Fig. 4. This valve consists of a valve stem 137 having a segmental crescent shaped metering groove 138 and is adjustable by manually moving the arm 139. The adjustment of the valve is limited by the stop pin 140. A pin 141 is carried by the valve stem and is similar in construction and operation to the pin 41 shown in Fig. 4.

In Fig. 18 I have illustrated an installation of a fuel injector in conjunction with an engine C and a fuel tank T. The injector designated as a whole by reference character I is similar in construction to that illustrated by Fig. 8, the fuel line 25' connecting the fuel tank with the inlet 81. The vent fuel line 142 connects with the fuel intake reservoir or chamber of the injector as at 143 and is extended into the fuel tank as at 144 to a height in the tank at a point above the tank fuel outlet opening 145. Suitable shut-off valves 146 and 147 may be included in these lines 25' and 142 respectively. It will be noted that the present installation provides a gravity feed and the fuel from the tank to the injector, this system being preferred in many instances although it will be understood that the injector may be fed from a low pressure fuel pump if so desired instead of by gravity from an elevated fuel tank. The low pressure fuel pump 21 as illustrated in Fig. 1 may serve to initially feed fuel into the injector intake chamber.

The principle of my invention may be, if desired, incorporated in a fuel injector applicable to installation or mounting directly on the side of the cylinder block and constructed to operate together with an air controlled means. This particular application is illustrated in Figs. 14 to 17 inclusive. The engine herein illustrated comprises an engine structure E which has an intake chamber 148, connected in open communication with the engine cylinders 149 through ports 150. A driving worm gear 151 driven by the engine, and preferably carried by the engine cam shaft, drives a worm gear 152 at a 1:1 ratio, said worm gear 152 being pinned or otherwise secured to a drive shaft 153. The pump plunger 154 is provided with a tongue 155 fitted into a slot 156 carried by the drive shaft 153, and it will be thus noted that the pump plunger is rotated at a speed which is one-half crankshaft speed, or in other words the pump plunger has one complete revolution for every two revolutions of the crankshaft. The pump plunger carries a cam 157 which rotates with the plunger and engages the roller 158 supported by the injector housing 159. This cam 157 has two high and two low points and thus the plunger is caused to be reciprocated as the same rotates by reason of this cam action, the spring 160 urging the plunger downwardly and holding the cam 157 in engagement at all times with the roller 158.

The injector housing 159 is provided with a fuel intake 161, said fuel entering the drilled passage 162 carried by the valve stem 163. The valve stem is provided with a segmental crescent shaped V-groove 164, the groove communicating with the passage 162 by a port 165. The construction of this fuel metering valve is substantially like that illustrated in Fig. 7 and said valve is adjustable manually by means of an arm 166 secured to the valve stem. The injector housing is provided with an intake air passage 167 and said valve stem carries a butterfly valve 168 for controlling the flow of air through said intake passage 167. Thus the control of air intake to

the engine is controlled together with the fuel metering control, and is preferably constructed to permit the flow of greater volumes of air into the engine when the valve is adjusted to increase the flow of fuel to the engine.

The fuel entering the injector is metered into the fuel intake passage 169 which conducts the fuel to the fuel intake port 170 carried by the pump plunger 154. The fuel will fill the pump chamber 171 on the suction stroke of the pump plunger and when said pump plunger is moved to displace the fuel in said chamber 171 said fuel is caused to flow into passage 172 under pressure and to be discharged through the discharge passage 173. This discharge passage 173 of the pump plunger is successively brought into registration with the discharge the passages 174 and 175 leading respectively to the fuel spray nozzles 176 and 177 (see Fig. 17).

The construction and operation of the pump unit illustrated in detail in Figs. 14 to 17 inclusive is identical in construction and operation with the fuel pump units illustrated in detail in Figs. 11, 11A and 11B. In this construction the lubricating oil for lubricating the plunger is introduced into the pump cylinder through the oil passage 178 which periodically communicates with the annular groove 179 carried by the pump plunger. Any leakage of lubricating oil or fuel along the surface of the pump plunger is collected in the annular groove 180 and same then escapes through the port 181 into the intake chamber 148 of the engine. Figs. 16 and 17 illustrate a modified form of construction, which consists in providing an adjustable connection between the fuel metering valve and the air throttle valve. The valve stem 163' is moved by manual operation of the arm 182, the arm having an adjustable connection by means of the slot and pin connection with an arm 183 secured to valve stem 184. The valve stem 163' is connected to operate the butterfly valve 168 controlling the air supply to the engine while the valve stem 184 is integrally formed or otherwise suitably connected with the fuel metering valve 185. It will be thus noted that I have provided an adjustment between the fuel metering and air flow controlling valves.

The pump units described in detail in connection with the description pertaining to Figs. 9 to 13 inclusive may be employed with other types of injectors. My injector is constructed for application with multi-cylinder engines of most any type. Figs. 19, 20 and 21 illustrate a construction adapted for assembly with a six cylinder engine. In this construction it will be noted that I have provided an injector having three pumping units designated 190, 191 and 192 respectively. In this construction as in the other constructions described above the fuel is arranged to be fed to the injector through the inlet port 193, metered by means of a segmental crescent shaped V-groove 194 in the valve stem 195 which may be manually adjusted. The fuel is thus metered and introduced into the intake passages 196 leading to the pump intakes. Each pumping unit is constructed to successively discharge fuel into the discharge passages 197, each of which is preferably individually connected with an engine cylinder. The means for reciprocating and rotating each of these units is constructed substantially similar to the means illustrated and described in connection with Fig. 11, and are properly timed with the engine crankshaft.

In Fig. 22 I have illustrated an injector struc-

ture which embodies four pumping units, each of which are preferably operable to successively inject fuel into a pair of engine cylinders. The construction of the eight cylinder injector is fundamentally the same as that shown in Figs. 19 to 21 inclusive except that the intake system comprises four intake passages 198 instead of three as illustrated in Fig. 20 or two as illustrated in Fig. 11.

It will be noted that in all instances the fuel pumps are nested about a common drive element, equally angularly spaced from each other and positioned equidistant from said driving element.

Fig. 23 is diagrammatically illustrative of how these individual fuel lines 117 may be arranged for connection with separate engine cylinders. Very obviously the injectors illustrated herein will be adaptable for assembly with various types of multi-cylinder engines. The fundamental principles of my invention embodied in all such structures, as are illustrated and described herein, is the construction of a pumping unit having a pump plunger which is given a combined rotating and reciprocating motion and which is operable to pump fuel and to discharge the fuel through a plurality of fuel discharge passages for separate conduction to separate engine cylinders. Obviously there are many details of construction, which are common to all forms of injectors described herein, and some details are specific to one or more of the injectors only. It will be noted however that in all injectors described herein that the same is very compactly arranged, and the parts may be manufactured and assembled with a minimum of cost. All parts are readily accessible for minimizing service or maintenance expenses.

In Fig. 24, I have illustrated a modified injector construction embodying a pump plunger 200 similar in construction to plunger 154 of Fig. 14, this plunger having fuel inlet passages 201 and fuel outlet passages 202. The injector body 203 is provided with a fuel intake 204 connected with the fuel line 205 and with the fuel chamber 206 located in close proximity to the pump cylinder 207 in which said plunger 200 is operated. An adjustable metering valve 208 is supported by the injector body 203 and is preferably manually actuated by means of a lever 209 to vary the amount of fuel allowed to flow through the port 210 connecting the fuel chamber 206 and the pump intake passage 201.

Any vaporization of fuel in chamber 206 may readily pass out through the fuel intake 204 and fuel line 205 so as to insure the intake of liquid fuel into the pump. Also the port 210 is relatively short or of minimum length to minimize the tendency of any fuel vapor to form and collect in the port 210. Any fuel which may escape along the pump barrel is collected in the annular groove 211 and returned to the intake 204 through the passage 212, and the annular groove 213 constructed about the metering valve guide 214.

The principles of my invention may be readily incorporated in the modified constructions as illustrated in Figs. 25 and 26. An injector pump may be constructed with more than two outlets and still come within the scope of my present invention.

In Fig. 25 the injector body 220 is provided with a single fuel inlet 219 and three outlets 221 and the pump plunger 218 has three fuel inlets 222 and is operated to reciprocate three times for each revolution thereof. Therefore,

the pump has a discharge at each 120 degree angular travel of the pump plunger.

In Fig. 26, the same principles of construction are embodied as in other forms illustrated herein. The pump plunger 225 has four fuel inlets 226 which are successively brought into registration with the fuel inlet 227. The pump plunger is reciprocated four times per revolution and has a fuel outlet 228 which is successively moved into registration with the fuel outlets 229 in the injector body 230.

In these modified constructions the proper gearing must be selected to impart the desired reciprocation and rotation to the pump plunger.

It will be apparent to those skilled in the art to which my invention pertains that various modifications and changes may be made therein without departing from the spirit of my invention or from the scope of the appended claims.

I claim:

1. A fuel injector for a six cylinder internal combustion engine comprising a housing structure, driving means driven by said engine and supported centrally of said housing, three fuel pumps nested about said driving means and equally spaced about and located equidistant from said driving means, each fuel pump including a pump plunger having a single discharge port and supported for combined rotation and reciprocation about axes extending substantially parallel to the axis of the driving means, each of said fuel pumps having a pair of discharge outlets, means connecting each of said outlets with an engine cylinder, means supported by said housing structure for drivingly connecting each of said pump plungers to said driving means, and a common fuel inlet means for all said fuel pumps.

2. A fuel injector for an eight cylinder internal combustion engine comprising a housing structure, driving means driven by said engine and supported centrally of said housing, four fuel pumps nested about said driving means and equally spaced about and located equidistant from said driving means, each fuel pump including a pump plunger having a single discharge port and supported for combined rotation and reciprocation about axes extending substantially parallel to the axis of the driving means, each of said fuel pumps having a pair of discharge outlets, means connecting each of said outlets with an engine cylinder, means supported by said housing structure for drivingly connecting each of said pump plungers to said driving means, and a common fuel inlet means for all said fuel pumps.

3. A fuel injector for an even number multi-cylinder internal combustion engine comprising a housing structure, driving means driven by said engine and supported centrally of said housing, fuel pumps nested about said driving means and equally spaced about and located equidistant from said driving means, said injector being provided with half the number of fuel pumps as there are engine cylinders, each fuel pump including a pump plunger having a single discharge part and supported for combined rotation and reciprocation about a fixed axis extending substantially parallel to the axis of the driving means, each of said fuel pumps having a pair of discharge outlets, said driving means operable to rotate said pump plungers to successively distribute the fuel to said pair of discharge outlets, means connecting each of said outlets with an engine cylinder, means supported

by said housing structure for drivingly connecting each of said pump plungers to said driving means, a common fuel inlet means for all said fuel pumps, and fuel metering means associated with said fuel inlet means.

4. A fuel injector for a four cylinder internal combustion engine having a crankshaft and including a housing structure, a common driving means driven by said engine and supported centrally of said housing, a pair of fuel pumps operable about fixed axes and positioned substantially diametrically opposite to each other with respect to said driving means and substantially equi-distant therefrom, each fuel pump including a cylinder having outlet ports positioned substantially diametrically opposite to each other and a pump plunger having a single discharge port and operable in said cylinder, means drivingly connecting each of said pump plungers to said driving means and consisting of means imparting a combined rotating and reciprocating motion to said pump plungers in which same is reciprocated twice for each revolution thereof whereby to successively distribute the fuel to said cylinder outlet ports, the operation of said driving means and said pump plungers being timed to the engine operation to effect four discharges of fuel from said fuel pumps, two discharges from each pump, for each two revolutions of said engine crankshaft.

5. A fuel injector for a multi-cylinder internal combustion engine comprising a housing structure, engine driven means supported substantially centrally of said housing, a plurality of fuel pumps operable about fixed axes and compactly grouped about said engine driven means, each pump including a cylinder having diametrically opposed outlet ports and a pump plunger having a single discharge port, and a plurality of intermediate driving means drivingly connecting said pump plungers with said engine driven means and including a common drive gear, said intermediate driving means consisting of cam means and spur gearing operable to reciprocate and rotate said plungers relative to their own fixed axes in timed relation with said gearing, whereby to operate said pump plungers in timed relation to each other and to said engine operation.

6. A fuel injector for a multi-cylinder internal combustion engine comprising a housing structure, driving means driven by said engine and supported centrally of said housing, a plurality of fuel pumps nested about and drivingly connected with said driving means and equally spaced about and located equi-distant from said driving means, said fuel pumps each having a plurality of discharge outlets connected with said engine cylinders, said injector being provided with a plurality of fuel pumps, less in number than the total number of engine cylinders, said total number of engine cylinders being a multiple of the total number of fuel pumps, each fuel pump including a pump plunger driven with a combined rotating and reciprocating motion about a fixed axis extending substantially parallel to the axis of the driving means for successively distributing the fuel through said plurality of discharge outlets and thence to said engine cylinders, each of said fuel pumps having the same number of discharge outlets, the discharge outlets of all said fuel pumps being equal to the total number of engine cylinders, means connecting each of said outlets with an engine cylinder, means supported by said housing structure for

drivingly connecting each of said pump plungers to said driving means, and a common fuel inlet means for all said fuel pumps.

7. A fuel metering and pumping assembly for a multi-cylinder fuel injection engine comprising, a housing provided with a plurality of pumping cylinders each having a fuel inlet port and annularly spaced outlet ports, a central source of fuel supply connected with all said inlet ports and including a regulable fuel metering means operable to meter the fuel as same is supplied to all said pump cylinder inlet ports, a pump plunger operable in each of said pump cylinders and provided with fuel inlet and outlet passages cooperating with said pump cylinder inlet and outlet ports, and a common central pump driving mechanism actuating all of said pump plungers with a combined rotating and reciprocating motion to pump said metered volume of fuel and successively distribute same to said pump cylinder outlet ports, said pump driving mechanism being timed with engine operation to successively discharge a metered volume of fuel from all said pumps for distribution to the engine cylinders in a predetermined sequence.

8. A fuel metering and pumping assembly for a multi-cylinder fuel injection engine comprising, a housing provided with a plurality of pumping cylinders each having a fuel inlet port and annularly spaced outlet ports, a central source of fuel supply connected with all said inlet ports and including a manually controlled regulable fuel metering valve associated with said source of fuel supply and operable to meter the fuel as same is supplied to all said pump cylinder inlet ports, a pump plunger operable in each of said pump cylinders and provided with fuel inlet and outlet passages cooperating with said pump cylinder inlet and outlet ports, and a common central pump driving mechanism actuating all of said pump plungers with a combined rotating and reciprocating motion to pump said metered volume of fuel and successively distribute same to said pump cylinder outlet ports, said pump driving mechanism being timed with engine operation to successively discharge a metered volume of fuel from all said pumps for distribution to the engine cylinders in a predetermined sequence.

9. A fuel metering and pumping assembly for a multi-cylinder fuel injection engine comprising, a housing provided with a plurality of pumping cylinders each having a fuel inlet port and annularly spaced outlet ports, a central source of fuel supply connected with all said inlet ports and including a regulable fuel metering means operable to meter the fuel as same is supplied to all said pump cylinder inlet ports, a pump plunger operable in each of said pump cylinders and provided with fuel inlet and outlet passages cooperating with said pump cylinder inlet and outlet ports, and a common central pump driving mechanism actuating all of said pump plungers with a combined rotating and reciprocating motion to pump said metered volume of fuel and successively distribute same to said pump cylinder outlet ports, said pump driving mechanism being timed with engine operation to successively discharge a metered volume of fuel from all said pumps for distribution to the engine cylinders in a predetermined sequence, the pump plungers operable to have two reciprocating cycles for each complete rotation thereof to bring said plunger outlet port into successive registration with said two cylinder outlet ports, said

pump plunger having fuel inlet means constructed and arranged to register twice for each complete rotation of the plunger with the cylinder intake port, said pump plunger further constructed and arranged for operation with said pump cylinder to register said inlet ports of said pump plunger and cylinder only when the outlet ports of said pump plunger and cylinder are out of register.

10. A fuel metering and pumping assembly for a multi-cylinder fuel injection engine comprising, a housing provided with a plurality of pumping cylinders each having a fuel inlet port and annularly spaced outlet ports, a central source of fuel supply connected with all said inlet ports and including a regulable fuel metering means operable to meter the fuel as same is supplied to all said pump cylinder inlet ports, a pump plunger operable in each of said pump cylinders and provided with fuel inlet and outlet passages cooperating with said pump cylinder inlet and outlet ports, and a common central pump driving mechanism actuating all of said pump plungers with a combined rotating and reciprocating motion to pump said metered volume of fuel and successively distribute same to said pump cylinder outlet ports, said pump driving mechanism being timed with engine operation to successively discharge a metered volume of fuel from all said pumps for distribution to the engine cylinders in a predetermined sequence, said plurality of pump plungers and cylinder assemblies nested about said pump plunger driving mechanism and substantially equally radially spaced therefrom, said pump plungers each having two or more reciprocations per each complete rotation thereof, said group of pump plungers and cylinder assemblies being identically constructed and operatively timed with the associated engine to inject fuel successively to all said engine cylinders, the total number of engine cylinders being a whole number multiple of the total number of pump plunger and cylinder assemblies.

11. A fuel metering and pumping assembly for a multi-cylinder fuel injection engine comprising, a housing provided with a plurality of pumping cylinders each having a fuel inlet port and annularly spaced outlet ports, a central source of fuel supply connected with all said inlet ports and including a regulable fuel metering means operable to meter the fuel as same is supplied to all said pump cylinder inlet ports, a pump plunger operable in each of said pump cylinders and provided with fuel inlet and outlet passages cooperating with said pump cylinder inlet and outlet ports, and a common central pump driving mechanism actuating all of said pump plungers with a combined rotating and reciprocating motion to pump said metered volume of fuel and successively distribute same to said pump cylinder outlet ports, said pump driving mechanism being timed with engine operation to successively discharge a metered volume of fuel from all said pumps for distribution to the engine cylinders in a predetermined sequence, said pump driving mechanism comprising cam means and spur gearing operatively connected with said pump plungers to reciprocate and rotate said pump plungers relative to a fixed axis, said cam means being constructed and arranged to impart the same number of reciprocating cycles to each

of said pump plungers for each complete rotation thereof as there are outlet ports in the associated pump cylinder.

12. A fuel injector for an even numbered multi-cylinder internal combustion engine comprising a housing structure, driving means driven by said engine and supported centrally of said housing, fuel pumps nested about said driving means, said injector being provided with a plurality of fuel pumps less in number than the number of engine cylinders, the number of cylinders of the said engine being an integer multiple of the pumps, each fuel pump including a pump plunger having a single discharge port and supported for combined rotation and reciprocation about a fixed axis extending substantially parallel to the axis of the driving means, each of said fuel pumps having a plurality of discharge outlets which is the same as the said integer multiple, said driving means being operable to rotate said pump plungers to deliver separate discharges of fuel from the several fuel pumps successively and respectively to the pump discharge outlets, means for connecting each of said outlets respectively to supply fuel to an engine cylinder, means supported by said housing structure for drivingly connecting each of said pump plungers to said driving means, a common fuel inlet means for all said fuel pumps, and fuel metering means associated with said fuel inlet means.

13. A fuel metering and pumping assembly for a multi-cylinder fuel injection engine comprising, a housing provided with a plurality of pumping cylinders equal in number to the number of engine cylinders divided by a whole number integer greater than one, each pumping cylinder having a fuel inlet port and annularly spaced outlet ports, a central source of fuel supply connected with all said inlet ports and including a regulable fuel metering means operable to meter the fuel as same is supplied to all said pump cylinder inlet ports, a pump plunger operable in each of said pump cylinders and provided with fuel inlet and outlet passages cooperating with said pump cylinder inlet and outlet ports, and a common central pump driving mechanism actuating all of said pump plungers with a combined rotating and reciprocating motion to pump said metered volume of fuel and successively distribute same to said pump cylinder outlet ports, said pump driving mechanism being timed with engine operation to successively discharge a metered volume of fuel from all said pumps for distribution to the engine cylinders in a predetermined sequence, said pump plungers being operable to have a number of cycles of reciprocation per revolution thereof, which is equal to the said integer to bring said plunger outlet port into successive registration with said cylinder outlet ports, said pump plunger having fuel inlet means constructed and arranged to register with said cylinder intake port during the suction movement of the plunger, said pump plunger being further constructed and arranged for the outlet passage thereof to register successively with the several outlet ports of the associated pump cylinder during successive discharge movements of said plunger.

CARL F. HIGH.