Aug. 11, 1936. A. M. STARR 2,050,392

FUEL INJECTOR

Filed July 18, 1933 3 Sheets-Sheet 1

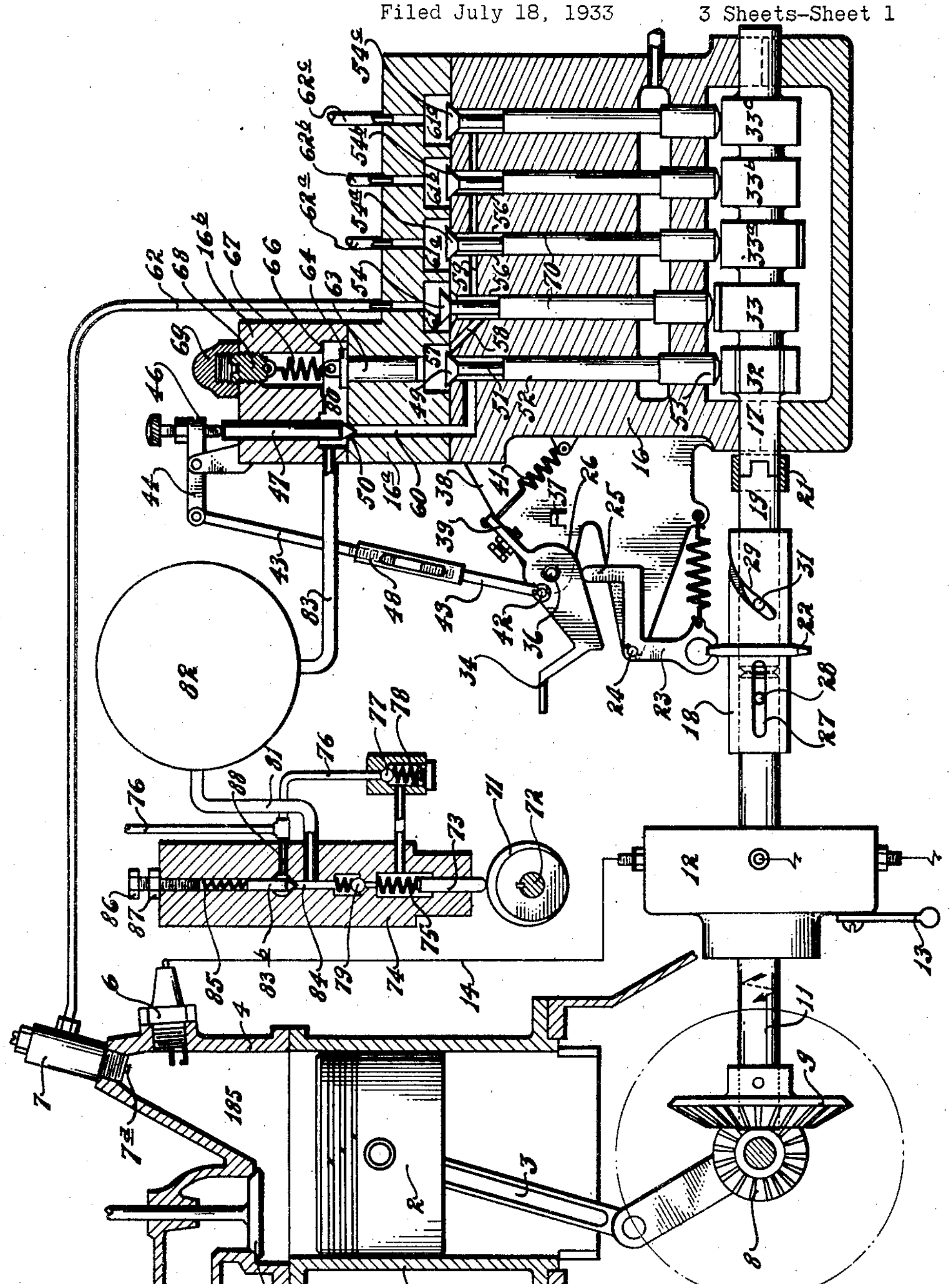


Fig. 1.

INVENTOR.
Allan M. Starr

BY Ernest [illegible]
ATTORNEY

Aug. 11, 1936. A. M. STARR 2,050,392

FUEL INJECTOR

Filed July 18, 1933 3 Sheets-Sheet 2

Fig. 3.

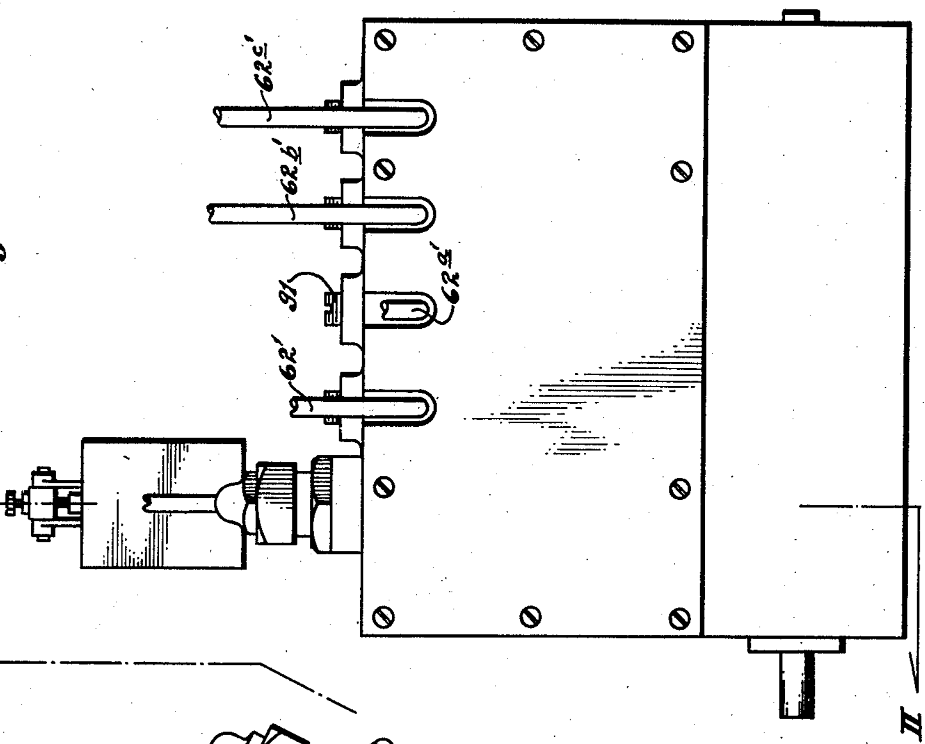
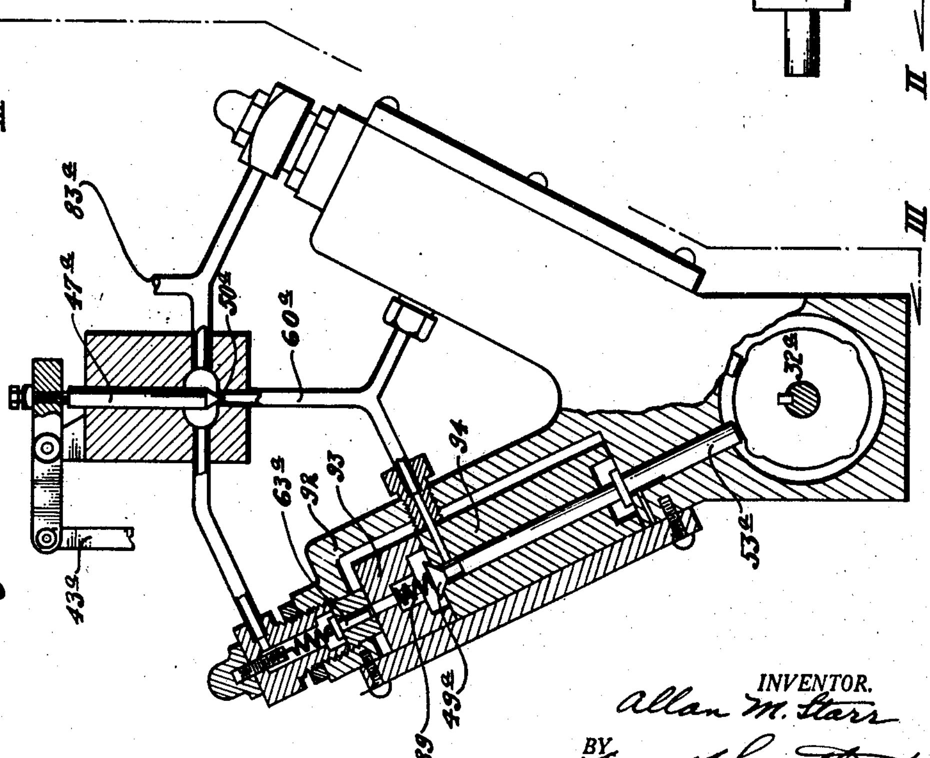


Fig. 2.



INVENTOR.
Allan M. Starr
BY Ernest J. Sweetland
ATTORNEY

Aug. 11, 1936. A. M. STARR 2,050,392

FUEL INJECTOR

Filed July 18, 1933 3 Sheets-Sheet 3

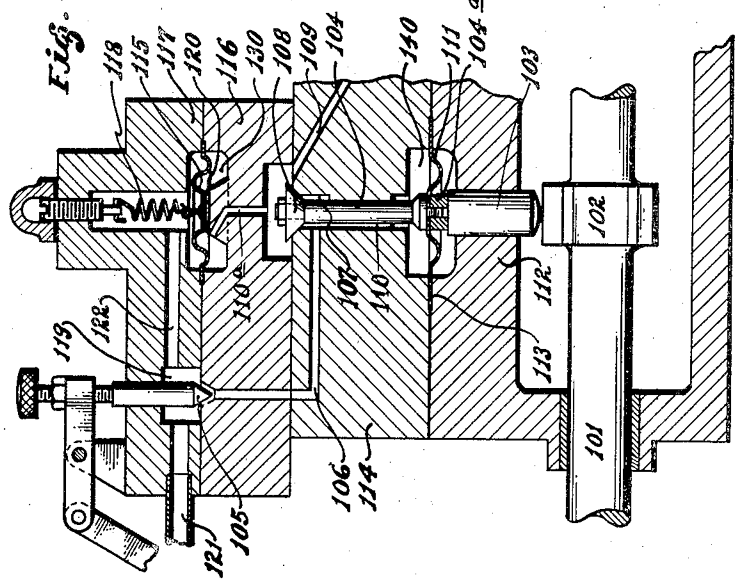


Fig. 4.

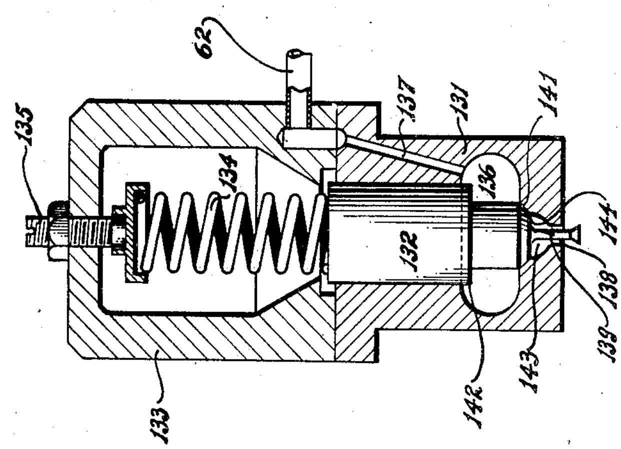


Fig. 5.

INVENTOR.
Allan M. Starr
BY Ernest J. Sweetland
ATTORNEY

Patented Aug. 11, 1936 2,050,392

UNITED STATES PATENT OFFICE

2,050,392

FUEL INJECTOR

Allan M. Starr, Piedmont, Calif., assignor, by direct and mesne assignments, to Starr Sweetland Corporation, Piedmont, Calif., a corporation of California

Application July 13, 1933, Serial No. 680,953

5 Claims. (Cl. 123—137)

This invention is a continuation in part of patent application Serial No. 638,866 filed October 21, 1932.

This invention relates to a novel means of injecting fuel into the cylinders or combustion chambers of internal combustion engines and to the correlation of the quantity of fuel injected with the timing of fuel injection.

A further object is to provide a fuel system whereby at slow speeds of the engine injection occurs substantially simultaneously with the spark but wherein as the engine speed is increased the fuel injection is advanced and the degree to which the injection is advanced is dependent upon the speed of the engine as well as the amount of fuel in each injection.

Another object of my invention is to provide the combination of a fuel throttle and fuel injection timing mechanism with a cylinder head of such construction as to permit of the efficient combustion of the fuel charges.

Further objects of my invention will be apparent from the following specification and the appended drawings.

There are many advantages to be gained by the injection of fuel directly into the combustion chamber of internal combustion engines, as compared with engines wherein the fuel is supplied by means of carburetors, but to gain the full advantages of injected fuel it is necessary to provide fuel injection means which is compact and simple, and which possesses the ability to meter the minute quantities of fuel required for each charge in the various engine cylinders in an exceedingly accurate and reliable manner. Where such engines are adapted to automotive uses it is of great importance that the metering be reliable and accurate through a wide range of engine speeds and varying loads and one of the essential features of novelty in my invention resides in a metering means which is well adapted to these varying conditions and which will be fully understood by reference to the following specification and drawings.

Figure 1 is a schematic drawing which illustrates a portion of an internal combustion engine in section in combination with my fuel injecting system and means for regulating the amount of fuel supplied in combination with means of advancing or retarding the time of fuel injection.

Figure 2 shows an end elevation partially in section along the lines II—II of Figure 3 of a modified form of my invention and is particularly intended to illustrate a V-type or radial construction of fuel injecting system whereby a single needle valve may serve to regulate the fuel supplied to an engine having a large number of cylinders.

Figure 3 is a side elevation of the mechanism shown in Figure 2. This view is taken along the plane of the lines III—III to simplify the illustration.

Figure 4 is a modified form of my invention wherein diaphragms are employed in lieu of lapped fits in certain portions of the mechanism.

Figure 5 is an enlarged view of a type of fuel injector nozzle which may be employed in conjunction with my invention. Invention is not claimed in connection with the construction of this particular nozzle and it is illustrated to facilitate description of the features of my invention which are correlated with it.

Referring particularly to Figure 1, 1 designates an internal combustion engine cylinder with piston 2 and connecting rod 3. The cylinder head is so constructed as to be particularly adapted to operation by fuel injection methods and is in accordance with my patent application heretofore referred to. This cylinder head includes connection 4a for intake manifold, valve 5, spark plug 6 and injection nozzle mechanism 7, an enlarged view of which is shown in detail in Figure 5. The exhaust valve is not shown. Timing gears are conventionally represented by the numerals 8 and 9 which are made in two to one ratio so that the shaft 11 is revolved by the engine in the direction indicated by the arrow at one-half the speed of the crank shaft.

The electric ignition distributor 12 is of the conventional type and connected with the spark plugs of the engine in the usual manner. This distributor is assumed to be equipped with the well known fly ball regulating mechanism (not shown) which automatically advances the timing of the spark with increased speed of the engine. 13 is a control lever whereby the spark may be manually advanced or retarded independent of other controls of the engine. 14 represents one of the lead wires from the timing mechanism connected with the spark plug 6.

16 designates the block or housing which contains the injection control valves and 17 a cam shaft by means of which the valves are actuated. Interposed between the shaft 11 and the cam shaft 17 is a collar 18 which is a sliding fit upon the end of shaft 11 and also a sliding fit upon the shaft 19, which connects to the shaft 17 by means of the conventional coupling 21. The collar 18 is provided with flange 22 which rotates freely between the forked or open lower end of the lever

23 which is pivoted at the point 24 and is provided with the upstanding arm 25 which bears against the cam surface 26. It will be noted that the collar 18 is provided with slot 27 which receives the pin 28 which is firmly secured near the end of the shaft 11 so that the collar 18 must rotate at the same speed as the shaft 11. In the opposite end of collar 18 is the spiral groove 29 which receives the pin 31, this pin being firmly secured in the shaft 19. Since the pin 31 is a sliding fit in the groove 29 and since the collar 18 may be caused to slide backward or forward on the shafts it is obvious that when this collar is moved along the axis of shafts 11 and 19 it causes the cams 32, 33, 33*a*, 33*b* and 33*c* carried by shaft 17 to change their angular position with relation to the shaft 11 and thus change the injection timing of the engine.

34 is the pedal of the throttle mechanism by means of which the cam 26 is caused to revolve about the axis 36, and 37 is a lug on the face of the plate 38 which limits the motion of cam 26 when the lower end of the screw 39 strikes the lug 37. 41 is a tension spring which tends to urge the cam toward the idling position. When it is desired to speed up the engine the pedal 34 is pressed downward. The pin 42 is carried by the casting upon which the cam surface 26 is formed and this connects through rod 43 with the lever 44 which in turn carries the adjusting screw 46 by means of which the needle valve 47 is adjusted. 48 is a turn buckle connection in rod 43 by means of which it may be shortened or lengthened to effect suitable adjustments. The block 16*a* is rigidly secured to the block 16 by any suitable means (not shown) and the block 16*b* is secured firmly to the block 16*a* so that the three blocks 16, 16*a* and 16*b* form the complete housing for the valves and other parts of the fuel injecting mechanism. These blocks are preferably fitted together with a ground joint to withstand a high pressure of fuel. 49 is a metering valve which is provided with stem 52 which is reduced in diameter at the point 51 and is actuated by the follower 53, the hardened surface of which bears against the cam 32, which it should be noted is a four lobe cam whereas the cams 33, 33*a*, 33*b* and 33*c* each have but a single lobe. The valves 54, 54*a*, etc. and their stems are substantially duplicates of the valve 49 and its attendant parts although their function is quite different. It will be noted that there is a chamber surrounding the upper reduced portions of the valve stems as indicated by the numeral 56 and that each of these chambers is in open communication with chamber 57 by means of conduits 58 and 59. Also that there are chambers such as 61 and 61*a* each of which communicates with an injector 7 through the tubes 62, 62*a*, etc.

An important element of my invention is the metering plunger 63 which is a lapped sliding fit in the hole through block 16*a* in which it is located. This plunger is provided with the flange 64 which limits its downward motion by contact with the upper surface of the block 16*a* and its upward motion by contact with the shoulder 66 that is formed within the block 16*b*. A spiral tension spring 67 produces an upward pull on the metering plunger 63 and this spring is connected to the lower end of the screw 68 which provides means of adjusting the tension. 69 is a cap which serves the double purpose of lock nut for screw 68 and prevents leakage of fuel. I have found by experience that when the metering plunger 63 has a cross sectional area of 1/20th square inch, a tension of about 8 lbs. on the spring 67 produces a satisfactory result although I do not limit myself in this regard. 71 is an eccentric cam which may be operated through shaft 72 by any suitable connection to the engine mechanism. 73 is a pump plunger which is a lapped fit in its opening in the block 74. The upward motion of this plunger is caused by revolving cam 71 while it is returned to the downward position by the spring 75. The pump thus formed is supplied with fuel from any suitable tank through the conduit 76 which preferably delivers the fuel by gravity to the inlet ball valve 77 which is held against its seat by the spring 78. The pump delivers the fuel past the discharge valve 79 and delivers the fuel through conduit 81 into the pressure tank 82. This tank is capable of sustaining a high pressure and in normal operation I prefer to maintain a pressure of approximately 2000 lbs. per square inch, although this may be varied through wide limits. 83*b* is a plunger which is seated at its lower end with a ground fit to form a valve at the upper end of conduit 84. The valve plunger 83*b* is held in position by the compression spring 85 and cap screw 86 which provides means of adjustment and may be held in locked position by means of the nut 87.

The pump which is made up of the parts just described is always designed of sufficient size to provide a greater volume of fuel than is actually required by the engine and the excess capacity of the pump is provided for by overflow past the valve 83*b* which permits the surplus fuel to escape through the conduit 88 back into the supply line 76. By means of the screw 86 the valve stem is adjusted to maintain the desired pressure in the tank 82.

Tank 82 is made large enough to provide a cushioning effect which cushions the pulsations of the pump and thus provides a steady pressure against the needle valve seat 50. When a large number of cylinders are to be supplied the construction illustrated in Figure 2 may be used to advantage as the mechanism is more compact in this V-type construction and the same cam shaft and cams and the same needle valve mechanism may be utilized for operating two or more blocks of injectors. It will be obvious from a study of Figures 2 and 3 that the construction of the injector may readily be modified to use any number of injector valves radially disposed about the central shaft and each block so arranged may conveniently contain from one to six or eight injectors.

Referring to the parts of Figure 2, 32*a* represents the metering cam, 53*a* a hardened follower, 49*a* the metering valve and 63*a* the metering plunger. The needle valve is designated by the numeral 47*a* and the needle valve seat by 50*a*. 83*a* is the supply line from pressure tank 82. These parts are similar in construction and function to the parts bearing the same numeral without the appended letter "*a*" in Figure 1. In this modified form of the invention I have illustrated the compression spring 89 which may be used if desired to supplement the forces of the liquid pressure in seating any of the valves such as the valve 49*a* although in my preferred form of the invention this spring is omitted. The conduit 60*a* serves the purpose of the conduit 60 in Figure 1.

The side elevation shown in Figure 3 requires no special explanation and is used merely to illustrate the general form of the apparatus when designed with four injection outlets on each side. In this view the tubes 62′, 62*a*′, 62*b*′ and 62*c*′

represent the tubes which lead from the injection valve mechanisms to the various injector nozzles of the engine. The screws 91 lead through the top of the casing 92 (Figure 2) and serve the purpose of holding the blocks 93 and 94 firmly in place, the surface of these blocks being ground and lapped to form a tight joint when they are clamped closely together.

Referring to the modified construction shown in Figure 4 this shows a fragmentary view of a metering valve and metering oscillating mechanism which may be substituted for the construction shown in Figure 1.

In the construction shown in Figure 1 the valve stems 70 and metering plunger 63 are carefully ground and lapped to form substantially leak proof sliding fits in the blocks wherein they are located and the construction shown in Figure 4 is an alternate method that may be used if it is desired to avoid making these carefully fitted joints. This will be understood by reference to Figure 4 wherein 101 is the cam shaft and 102 the four lobe metering cam, 103 the follower and 104 the valve stem. 105 is the needle valve which feeds the fuel through conduit 106 into the chamber 107 from which it passes by the valve 108 and out through conduit 109 and on to the injection valve 111 is a diaphragm to which the valve stem 104 is secured by the nut 104*a*. As this diaphragm is sealed to the block 112 at the point 113 and since the surfaces between the blocks 112 and 114 are ground and lapped the diaphragm 111 prevents leakage around the stem of the valve and an accurate fit is therefore not required between stem 104 and the opening through which it passes. Another diaphragm 115 is sealed at its edges between the blocks 116 and 117 and is provided with tension spring 118 which exerts an upward pull against the diaphragm. Fuel comes to the needle valve chamber 119 through conduit 121 and the fluid pressure in chamber 119 is communicated to the space on the upper side of diaphragm 115 through conduit 122. The functions of these parts will be made clear further on.

Referring to Figure 5 which is an enlarged view of the injector nozzle 7 of Figure 1, 131 is a casing member provided with plunger 132 which forms a fluid tight sliding fit within the casing. The upper casing member 133 contains compression spring 134 which may be adjusted to any desired pressure by means of screw 135. Conduit 62 which leads from an injector valve in the mechanism shown in Figure 1, forms connection with the chamber 136 through the conduit 137. At the lower end of casing 131 is the nozzle aperture 138 through which passes the pintle 139 which is integral with the plunger 132. The construction of this valve is such that its opening pressure is considerably higher than its closing pressure for the reason that the beveled portion of the plunger 141 is ground to form a valve which is seated against the casing 131. Therefore when pressure is admitted through conduit 62 and 137 into chamber 136 the fluid pressure bears only against the area of the annular shoulder 142 whereas when this pressure is sufficient to overcome the compression of spring 134 the plunger 132 raises, thus admitting fluid pressure into the chamber 143. Because opening 138 is restricted pressure exists in chamber 143 as well as in chamber 136 and pressure is exerted not only against the annular shoulder 142 but also against the annular surface 144 including the beveled surface. Consequently the pressure is exerted against a larger surface when the valve is open than when it is closed with the result that a lower pressure will sustain the valve in open position than is required to effect the initial opening. I have found valves which have an opening pressure of approximately 1300 lbs. per square inch and a closing pressure of from 800 to 900 lbs. per square inch to fulfill all requirements satisfactorily. It will thus be seen from the construction of the spray nozzle illustrated in Figure 5 that the pressure is never allowed to escape entirely from conduit 62 and the chamber 61 of Figure 1 to which it is connected. Therefore there is always a pressure at the top of the injection valves 54, 54*a* etc. of Figure 1 which automatically seats them without the use of springs.

In the operation of my invention I may use a low grade oil such as Diesel oil or fuel oil or I may under certain circumstances use a volatile fuel such as gasoline to which I prefer to add a sufficient amount of oil to provide lubrication for the parts of the fuel injector. The operation is as follows: Fuel is pumped into the pressure tank 82 by methods heretofore explained and I prefer to maintain a pressure of approximately 2,000 pounds per square inch within this tank, although I do not limit myself to any particular pressure range. Fuel under pressure is conveyed from tank 82 to chamber 80. The pressure within the chamber 80 maintains a constant upward urge against the needle valve 47 so that downward movement of the lever 44 through its connections with the pedal 36 causes the valve to open and discharge fuel into conduit 60 and the annular chamber surrounding the lower surface of the valve 49.

It should be noted in this connection that the cam 32 is a four lobe cam whereas the cams 33, 33*a*, 33*b* and 33*c* each have but a single lobe. The lobes of the four last mentioned cams are arranged in accordance with the order of firing of the engine cylinders and the four lobes on cam 32 are spaced intermediate of the lobes on the cams 33, 33*a* etc. so that the valve 49 is opened and closed to admit a charge of fuel just before each of the valves 54, 54*a* etc. are opened. The chamber 57 into which fuel is admitted when valve 49 opens is in open communication through conduits 58 and 59 with the annular space underneath each of the valves 54, 54*a*, 54*b* and 54*c*. It has previously been explained that the injection nozzle 7 is so constructed that it closes while there is still a pressure of several hundred pounds per square inch in conduit 62. It is this back pressure which returns the valves 54, 54*a* etc. back to the closed position without the assistance of springs or other mechanical parts.

While no springs are required to close valves 54, 54*a* etc. when the type nozzle shown in Figure 5 is used, I may use compression springs above these valves, (such as is shown at 89 in Figure 2) in the event that open type nozzles, or nozzles which do not close at high pressure, are used.

Needle valve 47 being open slightly there can be no flow of fuel until valve 49 opens and since all of the valves 54, 54*a*, etc. are closed when valve 49 opens, there tends to be momentarily an equalization of fluid pressure between chamber 80 and chamber 57 since the two chambers are in open communication through conduit 60 while the valve 49 is open. During this instant the pressure is balanced at the two ends of plunger 63 and during this instant the spring pulls the plunger upward by a distance sufficient to accommodate the small charge of fuel admitted through valve 49 during the instant it was held open by the cam 32. This distance may vary from a few thousandths of an inch up to the full stroke which is limited by the flange 64 contacting with the surface 66. Valve 49 having opened and admitted a metered charge of fuel and closed again the next step in the cycle is the opening of one of the valves of the 54 series, let us say the first one, as indicated in the drawings. When this valve opens the pressure in chamber 57 tends to equalize with the pressure in chamber 61 thus disturbing the balance of pressure which existed against the opposite ends of metering plunger 63. The result of this is that the superior pressure at the top of plunger 63 immediately forces the plunger downward which discharges out of chamber 57 exactly the quantity of fuel that was admitted during the opening of valve 49. This discharge produces a similar discharge through the injection nozzle 7*a*. Valve 54 now closes and the next lobe of cam 32 opens valve 49 admitting another charge into chamber 57 and again raising the plunger 63. Then the next valve, say 54*a* opens and the plunger 63 is again forced downward expelling another charge through conduit 58 and out through valve 54*a* and so the operation is repeated until each cylinder has been supplied after which the first cylinder again takes its turn. It should be understood that the flange or shoulder 64 at the top of plunger 63 has nothing to do with the balance of fluid pressure on the plunger, because the fluid pressure on the upper and lower sides of the flange are balanced, there being at least a film of fluid surrounding the flange at all times and it therefore operates so far as fluid pressure balance is concerned the same as though the plunger were made without the flange 64; but for practical purposes this flange serves the important purpose of acting as a stop to limit the upward and downward motions of the plunger.

If the construction and operation of the mechanism illustrated in Figure 1 is understood, the operation of the modification illustrated in Figure 4 will be obvious. In this modification the flexible diaphragm 115 which may be made of corrugated metal or other suitable material takes the place of the metering plunger 63 of Figure 1. It will be noted that the upper side of this diaphragm is given an upward pull by the spring 118 and the downward movement is limited by the spot 128. This diaphragm moves upwardly due to the tension of spring 118 when the pressure in chamber 130 is equalized with the pressure in the chamber above the diaphragm. But when the pressure in chamber 130 is reduced by the opening of an injection valve (not shown) which is in communication with conduit 109 the superior pressure at the top of the diaphragm forces it down on stop 128 to discharge the fuel through the conduit 118*a* on to the injection valve in a manner similar to that explained in connection with Figure 1. In connection with Figure 4 it should be understood that the valve stem 104 is a sufficiently loose or fluted fit in the block through which it passes so that the oil in chamber 140 may leak back and forth through groove 110 past the stem to permit free movement of the diaphragm 111 as the valve stem moves upwardly or downwardly.

In carrying out the purposes of my invention it is important that the timing of injection be correlated with the quantity of fuel injected and the speed of the engine. In order to effect this purpose and simplify the mechanism so that it may be readily controlled by the average operator, I provide the mechanism as shown in Figure 1 wherein the single control pedal or lever 34 provides the necessary control for all operating conditions. This operates as follows: When the pedal 34 is pressed downward this raises the screw 46 and the needle valve opens. At the same time the cam surface 26 which bears upon the lever 25 communicates movement to the slotted collar 18 which through the action of the spiral groove advances injection timing, and when the pedal is released the opposite occurs and injection timing is retarded. The lug 37 furnishes the stop for the idling position of the throttle and the screw 39 can be adjusted to give the engine proper idling speed. I prefer to design the cam 26 in such a manner that its surface during the first very short part of the movement of pedal 34 is practically the arc of a circle so that when the needle valve is first opened injection timing is not advanced. The outline of the cam is designed to give the proper timing of injection for different positions of the needle valve.

It will be understood that the distance through which the plunger 63 travels governs the amount of fuel contained in each injection and that each cylinder will receive the same amount of fuel.

The maximum quantity of fuel that can be injected is limited by the stop 66. The distance between the upper surface of flange 64 and stop 66 is preferably made so that the volume displaced by plunger 63 in moving this distance is equal to the volume of fuel required to burn with all the air that can be drawn into each engine cylinder. Consequently the larger the cylinder of the engine the greater must be the volume displaced by the complete stroke of plunger 63.

It is apparent from Figure 1 that the opening or closing of valve 49 or a valve of the 54 series causes a displacement within the fuel system. The volume displaced by the opening or closing of valve 49 is absorbed by a slight motion of plunger 63. The volume displaced by the opening and closing of a valve of the 54 series is absorbed by the elasticity of a conduit of the 62 series and its contents. Opening a valve of the 54 series increases the pressure in conduits of the 62 series which assists the system in promptly discharging each fuel charge from nozzle 7*a*. Closing a valve of the 54 series reduces the pressure in a conduit of the 62 series which lessens the tendency of the spray valves 7*a* to drip fuel into the combustion chambers.

From the description of the operation of the fuel system it is apparent that the quantity of fuel contained in an injection is controlled by the opening of needle valve 47 as well as by the time the valve 49 remains open. The time valve 49 remains open depends on the speed of the engine. The slower the engine turns over the longer time the metering valve 49 is held open for each charge and vice versa. Consequently the amount of fuel in each injection automatically increases as the engine slows down and decreases as the engine speeds up with the throttle in a fixed position. It is this self-governing characteristic of the fuel system which makes it possible to operate the engine efficiently under rapidly varying speeds and loads by directly connecting the variable timing mechanism 18 with the throttle lever 34. For example while the engine is operating at a constant speed and the load increases it is desirable to start injecting the larger quantities of fuel further in advance of ignition than smaller fuel quantities which were sufficient for the lighter load, and my injection system carries out this requirement. When the quantity of fuel in each injection is constant it is desirable to start injecting that fuel further in advance of ignition at higher engine speeds than at lower engine speeds, and my fuel system accomplishes this because as the engine speed increases the throttle must be pressed down if the quantity of fuel injected is to remain constant. This arrangement makes possible engine control under varying conditions without the necessity of a fly ball governor on the fuel system.

The timing of the injections of various quantities of fuel at various engine speeds, at it is accomplished by the above described system, fully meets the requirements for fuel injecting into the cylinder head arrangement shown in Figure 1 and enables me to attain responsive flexibility and efficient operation at all loads and speeds.

The cylinder arrangement shown in Figure 1 is the subject matter of my patent application heretofore referred to, of which this is a continuation in part. This cylinder head is arranged with chamber 185 so that adjacent to the injector nozzle 7*a* and spark plug 6 there is a cavity or pocket which is remote from turbulence and from gaseous currents produced by the motion of the piston and the travel of gases through the valves. The arrangement of this chamber in conjunction with my fuel injection system as herein described constitutes an important combination particularly where great flexibility and ease of control are desired. The chamber 185 makes possible ordinary spark ignition even where a low grade fuel oil is used. This is because chamber 185 entraps some of the heated gases of explosion which tend to volatilize the atomized spray ejected from nozzle 7*a* and at the same time the freedom from turbulence and gaseous currents in the upper end of this chamber provide a condition favorable for the ignition of various quantities of injected fuel through a wide range of speeds and loads. Under these conditions the minute volume of fuel discharged from the nozzle when the engine is lightly loaded ignites readily when the timing of ignition is substantially simultaneous with the injection, and larger fuel quantities injected in advance of the spark are also readily ignited; whereas ordinary spark ignition of various fuel quantities so injected would be uncertain with low grade fuel in the engine cylinder head of ordinary construction.

From the foregoing it will be understood that when the engine is operated under light load and at low speed the injection occurs when the piston is near the top of the compression stroke and with the cylinder head arrangement shown, the small quantity of fuel under these conditions is very little diluted and is readily ignited whereas when operating at high speed or under heavy load, the injection may commence in the early part of the compression stroke in the engine thereby permitting a thorough mixture of the fuel with the air during compression and at the same time permitting of satisfactory ignition. These features of advantage are made possible by the cylinder head arrangement heretofore described, in combination with the throttle control which is correlated with the timing of injection.

Where the term "reciprocating valve" may be employed in the following claims I refer to a valve such as valve 69 or valves of the 56 series which are caused to reciprocate by the movement of a cam or similar device as distinguished from a throttle valve such as 47, which is not given a regular reciprocating movement but is moved only by manual or pedal adjustment. In certain of the claims the valves 54, 54*a* etc. may be referred to as fuel injection control valves.

The plunger 63, or the diaphragm 111, may be referred to as a movable partition. The element 63 may also be referred to as a metering piston.

For convenience, in some of the claims the chamber 80 is referred to as the primary chamber and chamber 57 as the secondary chamber. It should be understood that the respective sizes of these chambers may vary through wide limits without departing from the spirit of my invention. The chamber 80 may, if desired, be greatly enlarged, even to such a degree that the pressure tank 82 may be dispensed with if desired. The chamber 57 is preferably of small size and may be reduced to a point where it merely serves as a clearance space for the valve 69 when in open position. For the sake of clarity in defining the structure in the claims the chamber 57 may be referred to as a receiving chamber.

In certain of the claims the needle valve 47 is referred to as a "throttle valve" or "throttle means".

While I have described the construction and operation of a preferred form of my invention it should be understood that the principles herein set forth are subject to a variety of modifications without departing from the spirit of my invention and I do not limit myself to the specific constructions shown and described but only to the scope of the following claims as limited by the prior art.

Having this described my invention what I claim is:

1. The combination with a fuel injection system of an internal combustion engine of a primary fuel chamber having communication with a fuel pump and with a secondary chamber, a conduit between said chambers and a mechanically operated engine-timed reciprocating valve and a throttle valve in said conduit whereby fuel may be intermittently transferred through said throttle valve and said reciprocating valve from said primary chamber to said secondary chamber, a movable partition member between said chambers, a conduit from said secondary chamber leading to one side of an engine-timed reciprocating fuel control valve which is intermittently opened and closed by an engine-timed cam to admit fuel to flow from said secondary chamber through a nozzle into a combustion chamber in said engine.

2. A mechanism for metering and distributing fuel for internal combustion engines consisting of means of imparting pressure to said fuel, a primary and a secondary chamber, a conduit leading from said means to said primary chamber, a conduit having a throttle valve in communication with said means of imparting pressure and said secondary chamber, a metering valve opened and closed in timed relation with said engine to permit intermittent surges of fuel to flow through said throttle valve to said secondary chamber, a movable partition between said primary and said secondary chamber, means to bias said partition toward said primary chamber, a conduit leading from said secondary chamber to a plurality of distributing valves each of which is operated in timed relation with said engine and each of which controls the flow of fuel to a cylinder thereof, said distributing valves being

timed to open successively following each opening of said metering valve, and said movable partition being forced by fuel pressure against the resistance of said bias means to inject a charge of fuel into an engine cylinder when each distributing valve is opened.

3. A mechanism for metering fuel for internal combustion engines comprising a primary and a secondary fuel chamber, means of forcing fuel under pressure into said primary chamber, a conduit leading from said primary chamber to said secondary chamber, a throttle valve in said conduit and a metering valve in said conduit between said throttle valve and said secondary chamber, mechanically operated means for opening and closing said metering valve in timed relation with said engine, a second conduit between said primary and secondary chambers, a movable partition in said conduit one surface of which is exposed to the fuel pressure in said primary chamber and the opposite surface of which is exposed to the fuel pressure in said secondary chamber whereby said movable partition is caused to reciprocate in accordance with the pressure differential in said chambers, a conduit leading from said secondary chamber to a plurality of valves each of which is operated in timed relation with said engine and communicates with an injector nozzle therein.

4. A mechanism for metering fuel for internal combustion engines comprising a primary and a secondary fuel chamber, means of forcing fuel under pressure into said primary chamber, a conduit leading from said primary chamber to said secondary chamber, a metering valve on said conduit between said primary and said secondary chambers, mechanically operated means for opening and closing said metering valve in timed relation with said engine, a second conduit between said primary and secondary chambers, a movable partition in said conduit one surface of which is exposed to the fuel pressure in said primary chamber and the opposite surface of which is exposed to the fuel pressure in said secondary chamber whereby said movable partition is caused to reciprocate in accordance with the pressure differential in said chambers, a conduit leading from said secondary chamber to a plurality of fuel control valves each of which communicates with a spring-loaded valve and injector nozzle in an engine cylinder combustion chamber, a cam shaft for controlling the operation of said metering valve and said fuel control valves, the cams on said shaft being arranged to open said fuel control valves successively in accordance with the firing order of said engine and to open and close said metering valve immediately following the opening and closing of each of said fuel control valves.

5. A mechanism for metering fuel for internal combustion engines comprising a primary and a secondary fuel chamber, means of forcing fuel under pressure into said primary chamber, a conduit leading from said primary chamber to said secondary chamber, a throttle valve in said conduit and a metering valve in said conduit, mechanically operated means for opening and closing said metering valve in timed relation with said engine, a second conduit between said primary and secondary chambers, a movable partition in said conduit one surface of which is exposed to the fuel pressure in said primary chamber and the opposite surface of which is exposed to the fuel pressure in said secondary chamber whereby said movable partition is caused to reciprocate in accordance with the pressure differential in said chambers, a conduit leading from said secondary chamber to a plurality of valves each of which is operated in timed relation with said engine and communicates with an injector nozzle therein.

ALLAN M. STARR.