Feb. 16, 1932. H. T. HERR 1,845,600

FUEL INJECTION SYSTEM

Filed July 12, 1928 3 Sheets-Sheet 1

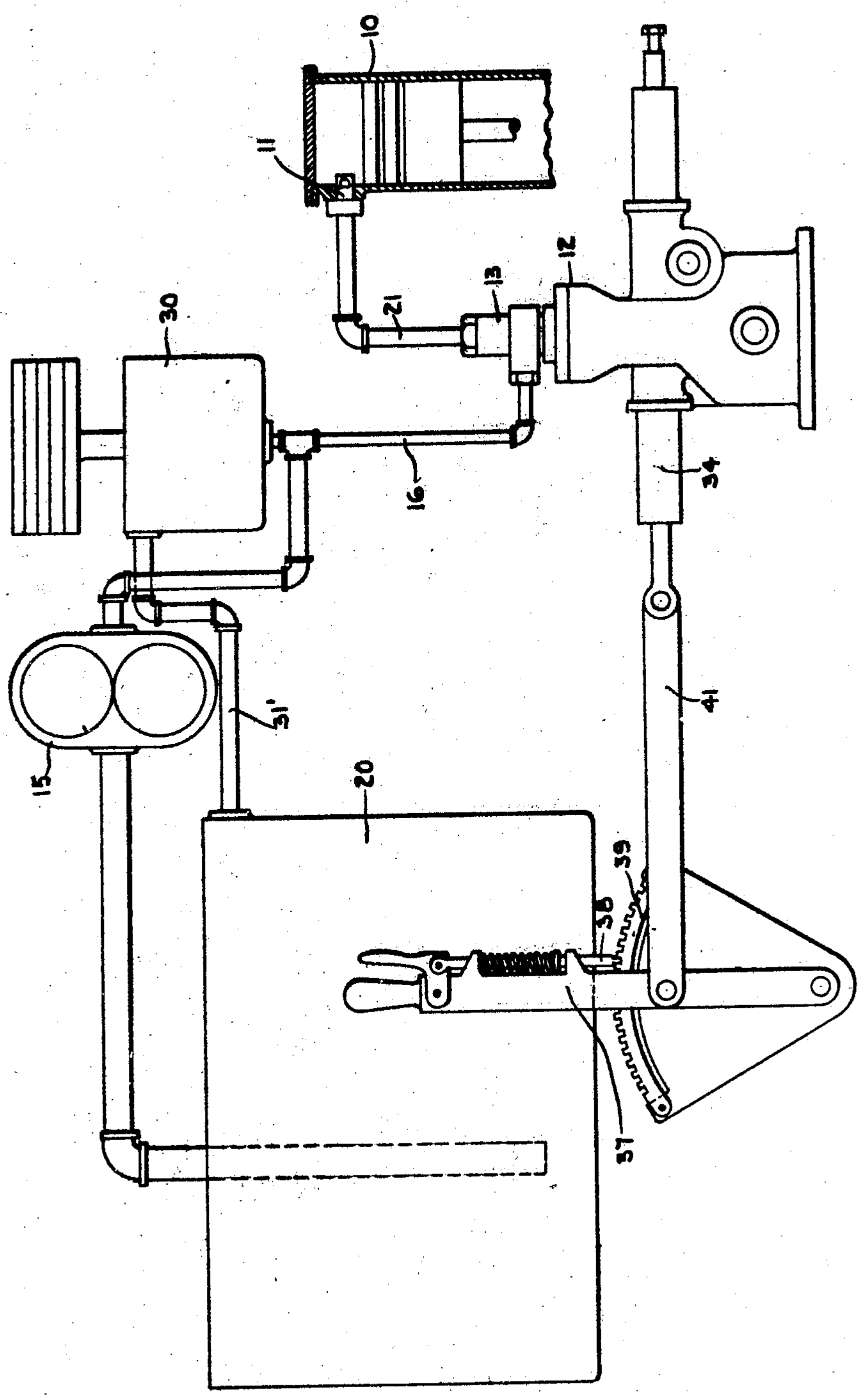

Fig. 1.

WITNESS
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Filed July 12, 1928 3 Sheets-Sheet 2

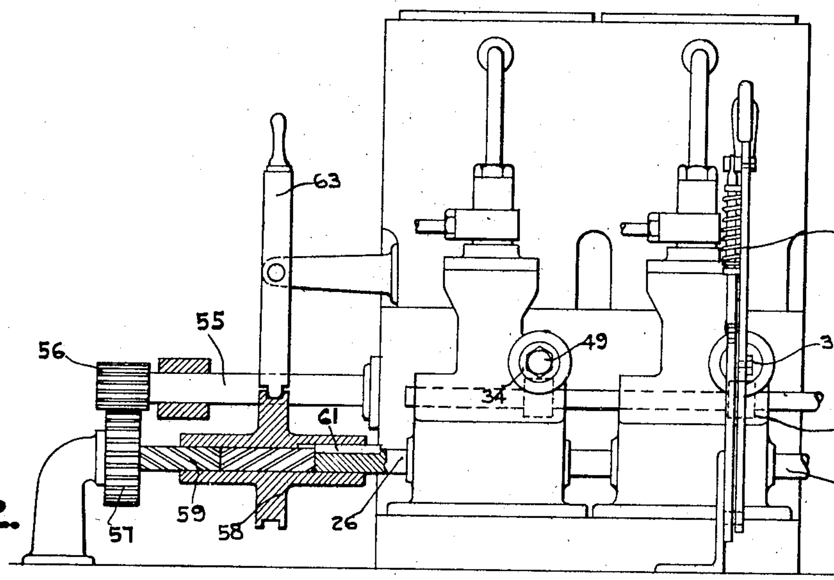

Fig. 2.

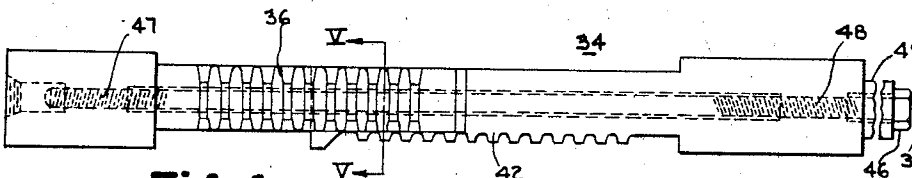

Fig. 4.

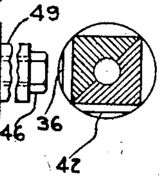

Fig. 5.

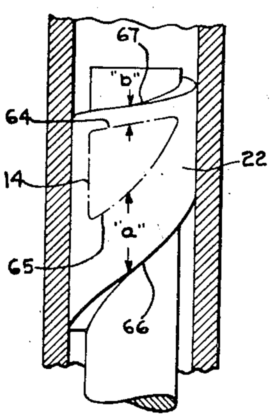

Fig. 8.

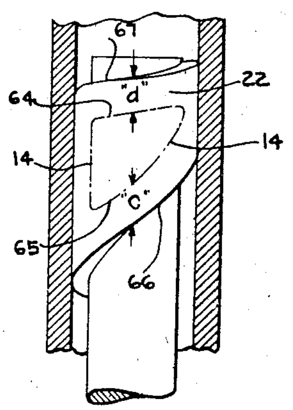

Fig. 9.

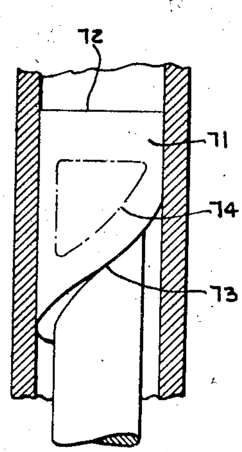

Fig. 10.

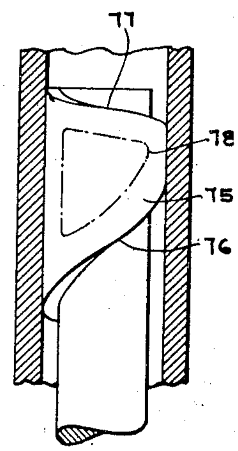

Fig. 11.

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FUEL INJECTION SYSTEM

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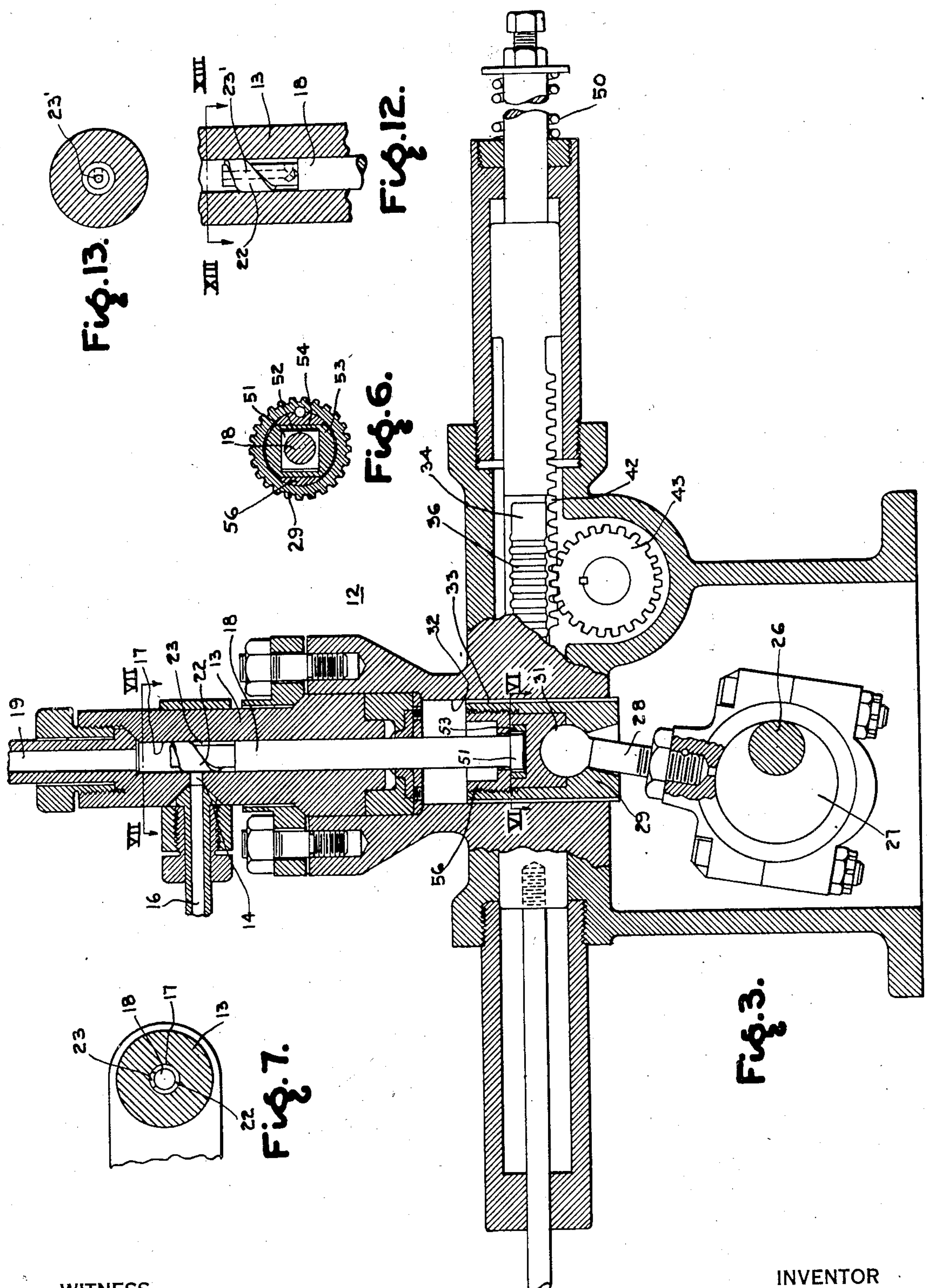

WITNESS

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UNITED STATES PATENT OFFICE

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FUEL INJECTION SYSTEM

Application filed July 12, 1928. Serial No. 292,197.

My invention relates to pumps and especially to liquid fuel pumps for internal combustion engines, and has for its object the provision of apparatus of the character designated which shall be simple of design, easy of manufacture, and efficient in operation.

A further object of my invention is to provide a pump which shall be effective to deliver a metered quantity of fluid at a requisite pressure and which pump shall include means for readily varying the quantity of the fluid delivered and, if desired, the time of delivery.

A still further object of my invention is to provide a liquid fuel pump for an internal combustion engine which shall be effective to deliver a metered quantity of liquid fuel to the engine cylinder at injection pressure and which shall include means for readily varying the quantity of fluid so delivered as well as the time of delivery.

A still further object of my invention is to provide, with a multi-cylinder internal combustion engine, a plurality of fuel pumps for supplying the cylinders and which shall include means for varying the fuel pumped by all of the pumps in unison and individual adjustment of each of the pumps with respect to the other.

Liquid fuel pumps, as heretofore known to me, have been very difficult to design due to extremely high pressures required to be developed, the minute quantities of liquid fuel required to be injected into a cylinder for each power stroke thereof, requiring accurate metering, and the leakage through the valves or parts of the pump which necessarily reacted upon the pressure and metering of the liquid fuel.

In accordance with my invention, I have overcome the beforementioned difficulties and have provided a pump far simpler in construction and operation than any heretofore known to me, and which embodies means whereby leakage is reduced to a minimum and wherein wear on the valve means included in the pump tends rather to reduce leakage than to increase it. Briefly, my invention comprises a housing defining a cylinder having inlet means terminating in a port in the wall of the cylinder and outlet means at one end thereof, a plunger reciprocating in the cylinder, and valve means carried by the plunger and effective to open and close the inlet to the cylinder. The valve means are preferably so arranged with respect to the plunger that, when the inlet port is closed during the pressure stroke of the plunger, the plunger is at its most rapid rate of reciprocation, although it is possible to vary the speed of opening and closing the inlet port at will, the pump being capable of adjustment so as to effect relatively quick closing and slow opening, or quick closing and quick opening, or slow closing and quick opening, etc. The result of this is to entrap the liquid fuel ahead of the plunger and strike it a hammer blow, instantly developing a very high pressure ahead of the plunger and forcing it through a suitable injection device into the engine cylinder. The beforementioned valve means is provided with a face of varying effective closing area and there is included means for operating the valve so as to effect a varying duration of the injection period.

Where a number of my improved pump units are associated with a multi-cylinder internal combustion engine, means are provided for operating all of the valve means in unison and also for adjusting any one of the valves with respect to the others. The valves are operated to vary the injection period of the pump, preferably in accordance with the load on the engine. In addition, I provide means for timing the beginning of the pressure stroke of the plunger and preferably do this in accordance with the speed of the engine.

Apparatus embodying features of my invention is illustrated in the accompanying drawings, forming a part of this specification, wherein:

Fig. 1 is a view in elevation of my improved pump as associated with an internal combustion engine cylinder;

Fig. 2 is a view in elevation, showing a plurality of my improved pumps associated with a multi-cylinder internal combustion engine;

Fig. 3 is a longitudinal vertical section of my improved pump;

Fig. 4 is a detailed view of a part of the pump controlling means;

Fig. 5 is a sectional view taken along the line V—V of Fig. 4;

Fig. 6 is a sectional view taken along the line VI—VI of Fig. 3;

Fig. 7 is a sectional view taken on the line VII—VII of Fig. 3;

Figs. 8 and 9 are enlarged, partial views of the plunger valve and pump cylinder shown in Fig. 3, Fig. 8 showing the angular position of the plunger valve relative to the cylinder for a relatively long and late period of fuel injection, and Fig. 9 showing the angular position of the plunger valve relative to the cylinder for a relatively short and early period of fuel injection;

Fig. 10 is a partial view of another embodiment of my invention and shows a form of plunger valve and cylinder which is similar to Figs. 3, 8 and 9, except that it is so arranged that the timing of the fuel injection period is constant irrespective of its duration;

Fig. 11 is a partial view of still another embodiment of my invention and shows a form of plunger valve and cylinder which is similar to Figs. 3, 8 and 9 except that it is arranged to provide relatively early injection of fuel for long periods and relatively late injection of fuel for short periods;

Fig. 12 is a partial view, in sectional elevation, of another embodiment of the fuel valve shown in Figs. 3 and 7 in which embodiment the valve entirely surrounds the pump plunger and wherein a separate passageway is provided for transferring fuel between the oppositely disposed lateral faces of the valve; and

Fig. 13 is a plan view, in section, taken on the line XIII—XIII of Fig. 12.

Referring now to the drawings for a better understanding of my invention, I show in Fig. 1, at 10, a fragment of an internal combustion engine cylinder provided with a fuel injection device 11. At 12, is shown my improved pump for supplying liquid fuel under pressure to the cylinder through the injection device 11. The pump comprises a housing 13 defining a cylinder 17 (Fig. 3), said cylinder having a liquid fuel inlet port 14 which communicates with a suitable liquid fuel supply conduit 16, which latter may be connected to any suitable source of supply. While I have termed the port 14 an inlet port, nevertheless this port is also utilized to discharge fuel from the cylinder as described hereinafter. The liquid fuel supplied through the conduit 16 should be, preferably, at a sufficient initial pressure to pass freely into the pump. For example, in Fig. 1, I show a gear pump 15 pumping fuel from a reservoir 20 into the conduit 16 which may include an accumulator 30 in the line for insuring an even pressure in the conduit. Overflow from the accumulator 30 may return to the fuel reservoir through a conduit 31′ as shown. Referring again to Fig. 3, a reciprocable plunger 18 operates within the cylinder 17 developing liquid fuel under pressure which is discharged from the cylinder through an outlet 19 in the upper end of the cylinder and thence through a conduit 21 to the injection device 11.

Carried by the plunger 18, is a valve 22 formed integrally with the plunger 18. As shown in Fig. 7, the valve 22 may not extend entirely around the plunger 18 so that on one side of the valve a longitudinal opening 23 is provided which permits fluid to freely pass from one side or lateral face of the valve to the other side or lateral face of the valve and permits liquid fuel under pressure within the cylinder 17 to act against one side of the valve and exert an unbalanced effect thereon when the inlet port 14 is closed, forcing the valve tightly against the port 14. While, in Fig. 7, the valve does not extend entirely around the plunger, nevertheless, it is obvious that I may arrange the valve so that it does entirely surround the plunger, as shown in Figs. 12 and 13. In the latter figures a separate passageway 23′ extends longitudinally and radially through the plunger and permits the fuel to transfer from one lateral face of the valve to the other. The valve 22 reciprocates in front of the inlet port 14, so that at each stroke of the plunger 18 the valve opens and closes the inlet port 14.

In the drawings, Fig. 3, the plunger 18 is at the mid stroke with the inlet port 14 closed. Assuming that the plunger 18 is at its outer position, the cylinder 17 will be filled with liquid fuel. During the first portion of the inward or working stroke of the plunger 18 and until the valve 22 covers the supply port 14, liquid fuel will be expelled back through the supply port 14; when the valve 22 covers the supply port 14, liquid fuel will be entrapped in the cylinder 17 and the plunger 18 will impart a hammer-like blow to the fuel causing very rapid development of pressure and consequent injection of fuel through the injection device; and during the final stage of movement of the plunger 18 during the working stroke, when the valve 22 uncovers the supply port 14, the built-up injection pressure is suddenly relieved, thereby permitting of instant cessation of fuel injection. During the outward stroke of the plunger 18, the cylinder 17 fills with liquid fuel, first from the supply port until the latter is covered by the valve 22 and thereafter from the time the supply port 14 is uncovered by the valve 22 and until the end of the outward or suction stroke. As will be more clearly seen hereafter, closure of the supply port 14 by the valve 22 preferably takes place during the most rapid speed of reciprocation of the plunger 18.

The fuel thus entrapped is acted upon by the plunger 18 in a manner striking it a hammer blow and developing a pressure requisite for injection purposes, discharging the liquid fuel outwardly through the outlet 19. As soon as the valve 22 has passed over the inlet port 14 on its outward stroke, liquid fuel in the cylinder 17 passes from the upper transverse or lateral face of the valve to the lower transverse or lateral face of the valve through suitable passageway means, such as the opening 23, and outwardly of the cylinder through the inlet port 14 until the plunger has completed its upward stroke.

It will be seen from the foregoing that the duration of the injection period into the engine cylinder is determined by the duration of the closure of the inlet port 14 while the plunger 18 is moving inwardly. In order that this period may be varied, and in order that the time of injection may be varied, I dispose the leading and trailing edges or margins of the valve angularly with respect to the direction of reciprocation so as to form in effect a somewhat triangular-shaped bearing surface for the valve against the walls of the cylinder. When relative rotation between the valve 22 and the cylinder 17 occurs, a longer or shorter face portion of the valve is caused to be opposite the inlet port 14, and, in addition, the leading edge or margin of the valve registers earlier or later with the fuel inlet port. The method of accomplishing this result will now be described.

The plunger 18 is driven from a shaft 26 through an eccentric 27, a connecting rod 28 and a cross-head 29. The plunger 18 is connected to the cross-head 29 in a manner to be presently described. The cross-head 29 is connected to the rod 28 through a ball and socket joint 31, whereby the cross-head 29 is freely rotatable with respect to the connecting rod 28. The cross-head 29 is cylindrical in cross-section and reciprocates within cylindrically-shaped guide means 32 so that it is freely rotatable with respect to the guide means. The cross-head 29 is provided on its outer periphery with longitudinally-extending teeth 33. Carried by the guide means 32 is a rack 34 having teeth 36 provided thereon and meshing with the teeth 33.

The rack 34 may be operated by any suitable means, either automatically or manually, in order to vary the relative position of the valve 22 with respect to the inlet 14 and thus vary the quantity of fuel being fed to the engine. For example, in Figs. 1 and 2, I show a lever 37 carrying a latch 38 which fits in a quadrant 39 and which is connected to the rack 34 through a link 41. By this means the operator may vary the amount of fuel being pumped in accordance with the load on the engine.

Where a plurality of pumps are employed in connection with a multi-cylinder internal combustion engine it is desirable that all of the pumps be operated in unison so that each of the cylinders may receive its proportionate supply of fuel. I, accordingly, form the rack 34 with teeth 42 at right angles to the teeth 36 and which mesh with a pinion 43. The pinion 43, Fig. 2, is made to extend along all of the pumps so as to mesh with all of the racks 34, whereby, when one of the racks 34 is moved back and forth, it causes similar movement of all the other racks through the pinion 43. While, in Fig. 2, I have shown a separate fuel pump for each cylinder, nevertheless it is to be understood that I may utilize a single pump to supply fuel to a plurality of cylinders. In addition, my fuel pump is adapted to supply fuel to either a single or a plurality of cylinders, whether the engines be of the two-cycle type or four-cycle type, the speed of the pump drive shaft 26 being made to suit the conditions.

In addition, I prefer to so dispose the racks that they will not have imposed upon them the side thrust of the plunger cross-head and one way of accomplishing this, as will be noted from Figs. 1, 2 and 3, is to have the eccentric 27 and the racks 34 lie in planes parallel to each other. The reason the rack 34 is thus disposed is to place it in position where it will not have imposed upon it the side thrusts of the cross-head 29 due to the action of the eccentric 27. With the pumps disposed as shown in Fig. 2 this locates all of the racks 34 in parallelism, and with the pinions 43 extending at right angles to the racks. In this manner none of the racks is subjected to the side thrusts of their associated cross-heads.

In an installation, such as is shown in Fig. 2, it may happen that one of the pumps shown would deliver a different amount of fuel to its associated cylinder than the remaining pumps and it would therefore be desirable that such a pump be adjustable so as to bring it in unison of operation with the other pumps. I accordingly form, as shown in Figs. 4 and 5, each of the racks 34 in two parts and join the parts together by means of a bolt 46 which screws through one of the parts and into the other. The bolt 46 is provided at one end thereof, in the example shown, the left-hand end, with right-handed threads 47 fitting into similarly formed threads in the left-hand part, as shown. The other end of the bolt is provided with left-hand threads 48 which fit similar threads in the other part of the rack.

By turning the bolt 46, the parts of the rack may be brought closer together or further apart, as desired. Inasmuch as one end of the rack meshes with the pinion 43, the pinion 43 acts as an abutment, causing that part of the rack meshing with the cross-head 29 to move with respect thereto and thus imparts an angular movement to the valve 22 and varies the period of injection of that particular pump. After the desired adjustment is made, the bolt 46 is locked in position by means of a lock nut 49. It will be seen that this adjustment can be readily made while the engine is running. As shown in Fig. 3, a compression spring 50 is preferably interposed between each adjustable rack 34 and the pump housing 13 to take up the back-lash of the rack on the cross-head 29 and the pinion 43.

A further refinement in the design of my improved pump lies in the means provided for joining together the plunger 18 and the cross-head 29. The plunger 18, Fig. 6, is formed with a squared head 51 fitting within a recess 52 formed in a washer 53. The washer is provided with parallel sides and fits in a complementary recess 54 formed in the cross-head. A slight movement is permitted in one direction between the cross-head 29 and the washer 53, while a slight movement at right angles to the movement just described is permitted between the plunger head 51 and the washer 53. The whole is held together by means of a nut 56 screwing into a suitably formed recess in the cross-head 29 and bearing down upon the washer and the plunger head. By thus fitting the cross-head and the plunger together, the machining of the cylindrical guides 32 with respect to the cylinder 17 is simplified in that it is not absolutely necessary that they be machined with coinciding centers. The slight movement permitted between the cross-head and the plunger permits the cross-head to turn without imposing a side stress upon the plunger, which might entail undue wearing of the cylinder, it being understood, of course, that the plunger 18 must be as nearly fluid-tight with respect to the cylinder 17 as is possible.

The pump shaft 26 is driven from the engine shaft 55 having a pinion 56 thereon meshing with the gear 57 connected to the shaft 26. The phase relation of the pump or pumps with respect to the engine may be varied by varying the angular relationship of the gear 57 with respect to the pump shaft 26; and, to this end, I provide a longitudinally movable sleeve 58 having a steep threaded connection with respect to a shaft extension 59 on the gear 57 and connected by a spline 61 to the shaft 26. The sleeve 58 may be shifted longitudinally in any suitable manner, as, for example, by the lever 63.

The operation of the apparatus so far described will now be explained. As the shaft 26 rotates, it causes the plunger 18 to reciprocate within the cylinder 17 carrying with it the valve 22, to and fro across the inlet port 14. Liquid fuel under sufficient pressure to cause it to enter the cylinder 17 is supplied through the conduit 16 and enters the cylinder 17 during the inward stroke of the plunger. Upon an outward stroke of the plunger 18, when inlet port 14 is not covered by valve 22, liquid fuel is forced outwardly of the pump through the inlet port 14. This continues until the upper edge or margin of the valve 22 cuts off the port 14 whereupon the liquid fuel above the plunger is entrapped in the cylinder 17 and a pressure sufficiently high for injection purposes is immediately produced. As will be seen from consideration of Fig. 3, the arrangement may be such that this occurs during the most rapid speed of reciprocation of the plunger 18 so that the entrapped oil above the plunger is, in effect, given a hammer blow by the plunger which effects an immediate production of an extremely high pressure. The pressure produced within the cylinder 17 acts on the valve 22 to press it tightly against the wall of the cylinder over the port 14 so that no leakage can occur outwardly through said port. This feature of the invention is extremely important as the tendency to leakage in fuel injection pumps has heretofore been one of the major difficulties to be overcome. After the lower edge or margin of the valve 22 has passed over the port 14, fluid is by-passed through the by-pass groove 23 and outwardly of the inlet port 14 until the plunger has completed its outward stroke.

The amount of fuel to be injected at each stroke of the plunger varies with the load and may be regulated in any suitable manner as by the lever 37 through the racks 34 and the cross-head 29. Where a plurality of pumps are employed, the racks associated with the respective pumps are all operated in unison through the pinion 43 which meshes with all of the racks. Where an individual pump requires adjustment relative to the other pumps, this can be accomplished by turning the adjusting screw 48 which alters the relative position of the racks 36 and 42 and consequently changes the angular position of the plunger 18.

Referring now to the detail operation of the valve 22, reference may be had to Figs. 8 and 9 wherein an enlarged view of the inlet port 14 is shown. As is apparent from these figures, the inlet port 14 is preferably made somewhat triangular in shape, its upper edge 64 and its lower edge 65 being disposed substantially parallel with the leading and trailing edges or margins, respectively, of the valve 22. Such a form of fuel inlet port is especially adapted for engines of the high-speed type wherein the time available for filling the cylinder 17 of the pump during the suction stroke is so short that difficulties are sometimes encountered in securing the proper amount of liquid fuel in the cylinder before

While I have shown my invention in several forms, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various other changes and modifications without departing from the spirit thereof, and I desire, therefore, that only such limitations shall be placed thereupon as are imposed by the prior art or as are specifically set forth in the appended claims.

What I claim is:

1. In a fuel pump for a high speed internal combustion engine, the combination of a pump cylinder having a head portion, fuel inlet and fuel discharge passages provided in the cylinder, said fuel discharge passage being located near the head portion and said fuel inlet passage being spaced from the discharge passage, a plunger reciprocable within the cylinder toward and away from the head portion and including a slide valve engaging the bore of the cylinder, said slide valve having circumferentially extending leading and trailing cut off margins arranged to cooperate with the inlet port so as to close off said inlet port during a portion of each stroke of the plunger and to discharge fuel through the discharge passage when the plunger is moving in a direction from the fuel inlet toward the fuel discharge passage, and fuel passageway means extending between the cut off margins of the valve, said passageway means being disposed in such angular relation as to cause the pressure of the fuel therein to exert a thrust upon the plunger in the direction of the fuel inlet port.

2. In a fuel pump for a high speed internal combustion engine, the combination of a pump cylinder having a head portion, fuel inlet and outlet means provided in the pump cylinder and spaced from the head portion thereof, fuel discharge means located near the head portion of the cylinder, a plunger disposed in the cylinder and arranged to reciprocate in directions toward and away from the head portion thereof, said plunger having a diametral portion closely fitting the bore of the cylinder and a reduced diametral end portion, a slide valve secured to and extending about a substantial portion of the circumference of the reduced diametral portion of the plunger, said slide valve having circumferentially extending leading and trailing cut off margins cooperating with said fuel inlet and outlet means for establishing communication between the bore of the cylinder and said fuel inlet and outlet means during a portion of each stroke of the plunger, said leading and trailing cut off margins being inclined with respect to each other and the trailing cut off margin being spaced from the enlarged diametral portion so as to form an intervening annular chamber arranged to communicate, during each stroke of the plunger, with said fuel inlet and outlet means, a passageway formed between the circumferential end portions of the valve and extending between the end of the plunger and said annular chamber, and means for adjusting the relative angular positions of the slide valve with respect to the fuel inlet and outlet means.

3. In a fuel feeding system for a high speed internal combustion engine, the combination of a plurality of pump cylinders having a fuel inlet and a fuel outlet, a plunger reciprocable within each pump cylinder, cut off slide valve means provided on each plunger and cooperating with their associated fuel inlet means during a portion of each working stroke of the plunger for effecting periodic discharge of fuel under pressure through the outlet means, said slide valve having leading and trailing cut off margins inclined with respect to each other so as to vary the quantity of fuel discharged through the fuel outlet in accordance with its angular position in the cylinder, a member associated with each individual plunger for adjusting the angular position of the same in the cylinder, said adjusting members being disposed in spaced, parallel relationship, and common master adjusting means cooperating with each of said adjusting members for effecting simultaneous and coextensive movements thereof, said master adjusting means extending in a direction which is substantially normal to the direction of adjustment of said individual members.

4. In a fuel feeding system for a high speed internal combustion engine, the combination of a plurality of pump cylinders having a fuel inlet and a fuel outlet, a plunger reciprocable within each pump cylinder, cut off slide valve means provided on each plunger and cooperating with their associated fuel inlet means during a portion of each working stroke of the plunger for effecting periodic discharge of fuel under pressure through the outlet means, said slide valve having leading and trailing cut off margins inclined with respect to each other so as to vary the quantity of fuel discharged through the fuel outlet in accordance with the angular position of the valve in the cylinder, a member associated with each individual plunger for adjusting the angular position of the same in the cylinder, said adjusting members being disposed in spaced, parallel relationship, and a rotatably mounted master member extending at right angles to the respective individual adjusting members and engaging said individual adjusting members so as to effect simultaneous and co-extensive movements thereof.

5. In a fuel feeding system for a high speed internal combustion engine, the combination of a plurality of pump cylinders having a fuel inlet and a fuel outlet, a plunger reciprocable within each pump cylinder, cut off slide valve means provided on each plunger and cooperating with their associated fuel inlet means during a portion of each working

the beginning of the pressure stroke of the plunger. With such a form of inlet port, both of its edges 64 and 65 are defined by helixes and the upper edge 64 is adapted to cut off the port 14 when it coincides with the upper edge or margin of the valve 22.

Referring now particularly to Fig. 8, I show the relative angular positions of the valve and the port for a relatively heavy load and a long period of fuel injection while Fig. 9 shows the relative angular positions of the valve and the port for a relatively light load and short period of fuel injection. (In both of these views, the inlet port 14 is shown in dot and dash lines as being in front of the valve 22 in order to make the illustration as clear as possible. With the valve 22 and its plunger 18 in the angular position shown in Fig. 8, it will be seen that the injection period is relatively long due to the fact that the distance "*a*" and "*b*" is considerable. In other words, fuel is fed into the engine during the upward stroke of the plunger 18 until such time as the edge or margin 66 of the valve passes the lower edge 65 of the inlet port, whereupon the fuel in the pump cylinder 17 is relieved through the inlet port 14 to the conduit 16. It will be further apparent from Fig. 8 that the upper edge or margin 67 of the valve 22 is disposed only a relatively short distance "*b*" above the upper edge 64 of the inlet port so that the time of injection is made relatively late, the period of injection not starting until such time as the leading edge 67 of the valve has passed over the upper edge 64 of the inlet port.

Referring now to Fig. 9, this figure shows the valve 22 and plunger 18 in a different angular position from that shown in Fig. 8, the setting of the valve in Fig. 9 being for relatively light load. As will be apparent from this figure, the distance "*c*" and "*d*" is relatively short as compared with the distance "*a*" and "*b*" in Fig. 8 so that the period of fuel injection is of much shorter duration. It will also be apparent from Fig. 9 that, due to the angular adjustment of the plunger 18, the leading edge or margin 67 of the valve 22 assumes a higher position in the cylinder and consequently the distance "*d*" intervening between the upper edge of the inlet port 14 and the upper edge or margin 67 of the valve 22 is considerably greater than the distance "*b*" in Fig. 8 and consequently the timing of the injection period is made relatively early. In other words, my valve may be so formed that the timing is made later for full loads and earlier for light loads, but it will be apparent that the timing may be the same or opposite if desired by simply arranging the upper edge of the inlet port and the edge 67 of the valve 22 to suit any desired condition.

As shown in Figs. 8 and 9, the upper and lower edges of the inlet port preferably extend in the same general direction or coincide with the leading and trailing edges or margins of the valve so that a sharp or rapid beginning and ending of the injection period is assured and consequently the fuel is very accurately metered. While I have shown a form of inlet port in which the upper and lower edges are made to coincide with the cut-off edges of the valve, nevertheless it is to be understood that my invention is not restricted to such an arrangement in that with some forms of engine, it may not be necessary to define the fuel injection period so sharply, and in such cases, the edges of the inlet port need not coincide with the cut-off face of the valve.

In Fig. 10, I show a different form of valve 71 wherein the leading or cut-off margin 72 is arranged normal to the axis of the cylinder so that the time of injection is the same irrespective of the length of the period of fuel injection. As in the valve shown in Figs. 8 and 9, the trailing margin 73 is so arranged that the period of fuel injection varies for different angular positions of the plunger relative to the inlet port 74. The latter is preferably so formed that its upper and lower edges are substantially parallel with the leading and trailing margins of the valve.

In Fig. 11, I show still another embodiment of my invention, wherein the valve 75 has a trailing margin 76 arranged as heretofore. However, in this embodiment, the leading or cut-off margin 77 is angularly disposed with respect to the cylinder axis but in such a direction as to provide an earlier period of fuel injection for full load and a later period of fuel injection for light load. In this embodiment, the inlet port is represented at 78.

From the foregoing, it will be apparent that I have devised an improved fuel injection pump for internal combustion engines which is simple of design, easy of manufacture and which is capable of operation with a minimum amount of leakage while at the same time assuring an accurately metered quantity of fuel to the engine cylinder. It will be further apparent that I have invented a fuel injection system for internal combustion engines which is extremely flexible in operation in that the timing of the fuel injection period may be automatically varied in response to the load or to the length of period of fuel injection merely by angular adjustment of the plunger within the cylinder. Furthermore, all of the plungers may be simultaneously adjusted by manipulation of the lever 37 while individual adjustment of each plunger may be had by manipulation of the respective racks. In addition, the phase relationship of the entire fuel injection system relative to the engine cycle may be readily adjusted by manipulation of the lever 63.

stroke of said plunger for effective periodic discharge of fuel under pressure through the outlet means, said slide valve having leading and trailing cut off margins inclined with respect to each other so as to vary the quantity of fuel discharged through the fuel outlet in accordance with the angular position of the valve in the cylinder, means for reciprocating each of the plungers and including a cross head member, longitudinally extending gear teeth disposed about the periphery of each of said cross head members, a rack meshing with the gear teeth of each cross head member, said individual racks being disposed in parallel relationship, and a master adjusting member extending at right angles to the individual members and engaging the same for effecting simultaneous and co-extensive adjustments thereof.

6. In a fuel feeding system for a high speed internal combustion engine, the combination of a plurality of pump cylinders having a fuel inlet and a fuel outlet, a plunger reciprocable within each pump cylinder, cut off slide valve means provided on each plunger and cooperating with their associated fuel inlet means during a portion of each working stroke of the plunger for effecting periodic discharge of fuel under pressure through the outlet means, said slide valve having leading and trailing cut off margins inclined with respect to each other so as to vary the quantity of fuel discharged through the fuel outlet in accordance with the angular position of the valve in the cylinder, means for reciprocating each of the plungers and including a cross head member, longitudinally extending teeth disposed about the periphery of each of said cross head members, a separate rack for adjusting each cross head member, said separate racks being disposed in side-by-side relation and having teeth provided in one side thereof for engaging the teeth of their associated cross heads, a second group of teeth provided in each of said racks, said second group of teeth being provided in a side of the rack which is at right angles to the side containing the teeth engaging the cross head, and a rotatably mounted master adjusting member provided with toothed portions engaging the second group of teeth of the respective separate racks for effecting simultaneous and co-extensive adjustments of the latter.

7. In a fuel feeding system for a high speed internal combustion engine, the combination of a plurality of pump cylinders having a fuel inlet and a fuel outlet, a plunger reciprocable within each pump cylinder, cut off slide valve means provided on each plunger and cooperating with their associated fuel inlet means during a portion of each working stroke of the plunger for effecting periodic discharge of fuel under pressure through the outlet means, said slide valve having leading and trailing cut off margins inclined with respect to each other so as to vary the quantity of fuel discharged through the fuel outlet in accordance with the angular position of the valve in the cylinder, a member associated with each individual plunger for adjusting the angular position of the same in the cylinder, said individual adjusting members being disposed in side-by-side relation, means embodied in some of said individual adjusting members for effecting an alteration in the angular position of their associated plungers and valves relative to the other plungers and valves, and master adjusting means engaging each of said individual adjusting members for effecting simultaneous and co-extensive movements of the latter, said master adjusting means extending in a direction which is substantially normal with respect to the direction of movement of said individual members.

8. In a fuel feeding system for a high speed internal combustion engine, the combination of a plurality of pump cylinders having a fuel inlet and a fuel outlet, a plunger reciprocable within each pump cylinder, cut off slide valve means provided on each plunger and cooperating with their associated fuel inlets during a portion of each working stroke of the plunger for effecting periodic discharge of fuel under pressure through the outlet means, said slide valve having leading and trailing cut off margins inclined with respect to each other so as to vary the quantity of fuel discharged through the fuel outlet in accordance with the angular position of the valve in the cylinder, means for reciprocating each of the plungers and including a cross head member, longitudinally-extending gear teeth disposed about the periphery of each cross head member, a separate adjusting rack for each cross head member, said separate adjusting racks being disposed in side-by-side relation and each rack having a group of gear teeth provided in one side thereof and engaging the teeth of their associated cross head and a second group of teeth provided in a side of the rack which is normal to the side containing the first group, means embodied in some of the individual racks for adjusting the position of the second group of teeth relative to the first group, whereby the angular position of the individual pump plungers and valves may be adjusted relative to the remaining pump plungers and valves, and a rotatably mounted master adjusting member provided with toothed portions engaging the second groups of teeth of the respective adjusting racks, said master adjusting member extending at right angles to the individual adjusting racks.

In testimony whereof, I have hereunto subscribed my name this 3rd day of July, 1928.

HERBERT T. HERR.