

April 27, 1954

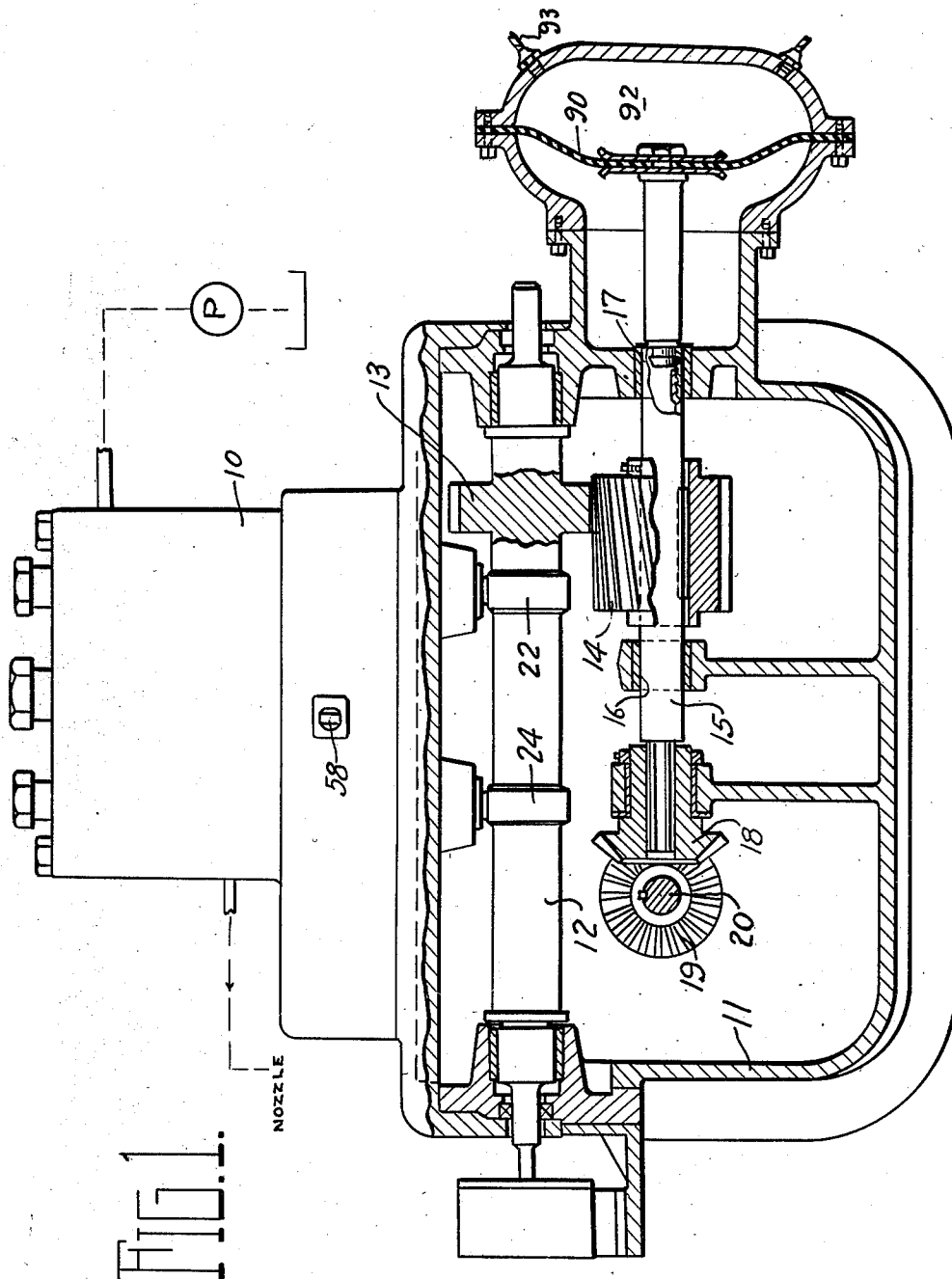
R. P. RAMSEY ET AL

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FUEL PUMP FOR FREE PISTON ENGINES

Filed April 20, 1951

3 Sheets-Sheet 1



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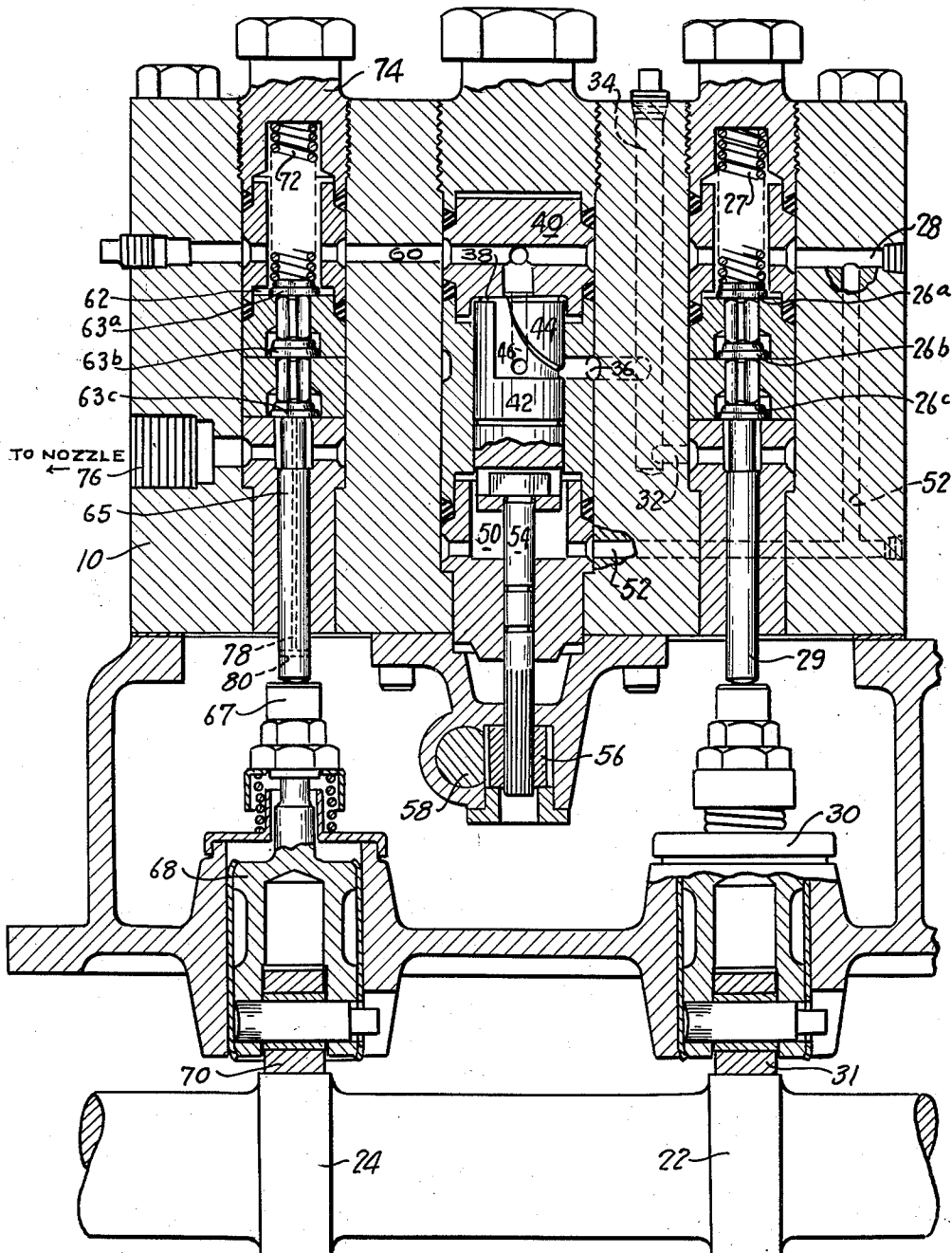


FIG. 2.

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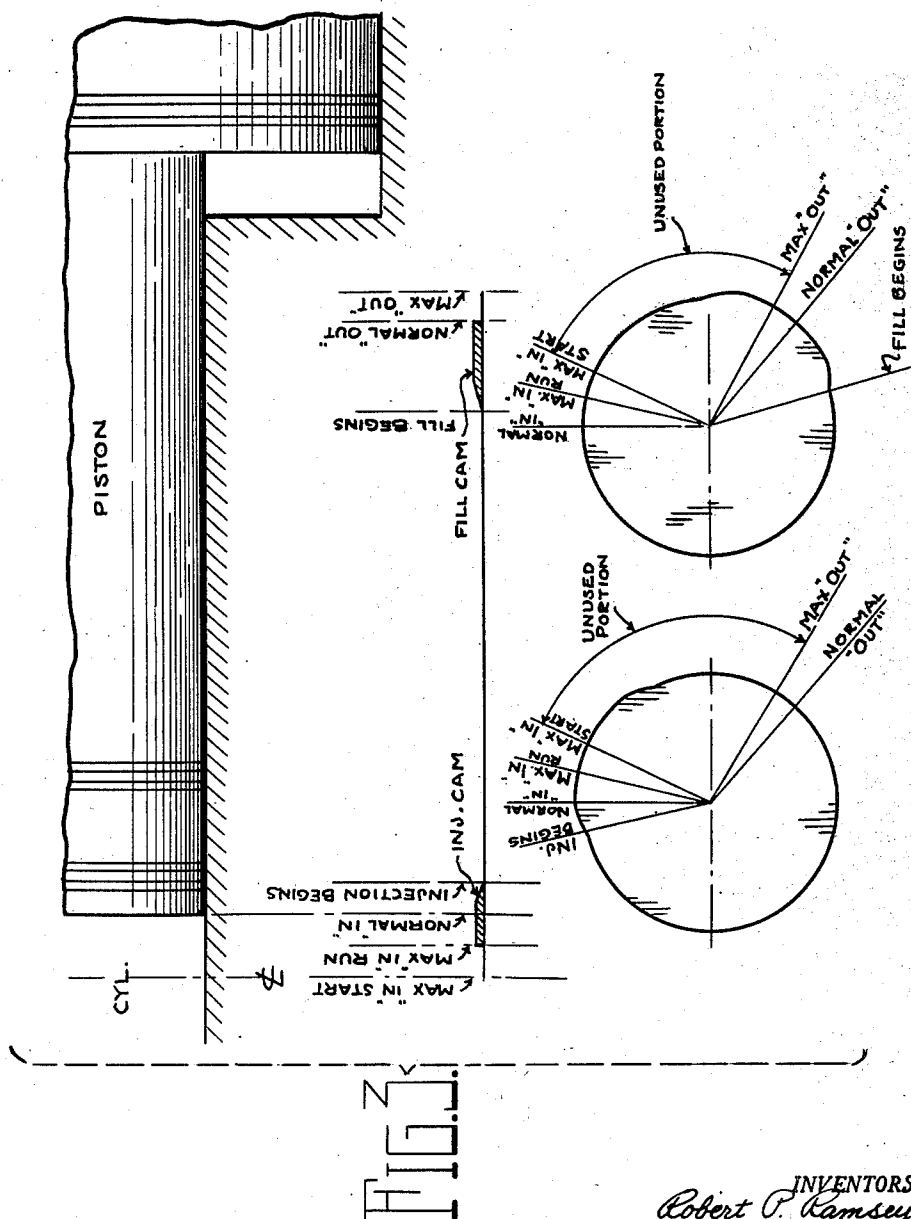
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FUEL PUMP FOR FREE PISTON ENGINES

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9 Claims. (Cl. 123—46)

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This invention relates to fuel pumps for compression ignition engines and is particularly directed to a device of this character that is suitable for use in engines of the free piston type.

Free piston engines operating with compression ignition have experienced some difficulty with the injection of fuel both as to the stability of the injection timing and as to the stability of the quantity of fuel that is forced into the combustion space at each stroke. The free piston engine is unlike the conventional diesel engine in that there is no constantly rotating element from which fuel control cams and fuel pump cams can be driven, nor is the stroke of the pistons always of constant length. The engines are generally provided with piston synchronizing means usually in the form of racks that mesh with a single synchronizing gear which thus oscillates as the pistons reciprocate. The oscillatory movement of the synchronizing element is poorly adapted to operate a conventional injection pump because of the fact that its motion slows down, stops and reverses at the time corresponding to the end of the piston stroke which is the point in the cycle at which it is desired to meter and inject the fuel. This reversal of movement at the time of injection complicates the design of injectors for free piston engines, and one of the primary objects of the invention is to provide a fuel pump in which the beginning and duration of injection may be controlled independently of the extent of piston motion.

It has heretofore been proposed to meter a predetermined and variable quantity of fuel to be subsequently injected into the combustion space of a free piston engine and to store this fuel under accumulated pressure until the time of opening of a discharge valve. In some fuel pumps the pressure of accumulation is derived from a spring pressed piston, in others from a separate trapped body of fluid maintained at high pressure on one side of a piston or diaphragm and in still others from the elasticity of the walls of the chamber and the compressibility of the accumulated fuel forced into the chamber. Most of these systems result in a pressure of injection that decreases during the injection period with the relaxation of the spring or the expansion of the trapped body of liquid, and only if the elements are made large or the initial pressure made very high can a substantially constant pressure be maintained during the injection period. It has been found that the large element system is insensitive and incapable of injecting small quantities of fuel as required at idle loads.

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It is another object of the present invention to provide a fuel pump in which the pressure of injection is constant throughout the entire injection period, and in which the quantity of injected fuel may be readily varied over a wide range.

Most accumulator type fuel pumps operate with a continuous motion of a single element to force fuel into an accumulator chamber and to open a discharge valve almost immediately after the desired quantity has been stored. It is apparent that such devices must necessarily meter the fuel during the period of piston movement when the available driving motion is slowing down, and that they are relatively poorly adapted to operate with engines in which the extent of the inward piston stroke varies with load. They are thus best adapted to engines that operate at substantially constant stroke. In the fuel pump of the present invention, metering of the fuel takes place at the outer end of the piston stroke, while discharge or injection, of course, takes place at the inner end of the stroke. By thus separating the two functions of the fuel pump we are enabled to allow ample time for each and to control each independently of the other.

Still another object of the invention is to provide a fuel pump in which the time of injection may be readily varied manually or in accordance with any selected operating characteristic of the associated free piston engine.

Still another object of the invention is to provide a fuel pump in which the elements are so related and constructed that the entire device is relatively simple to build and maintain.

Briefly, the invention comprises a fuel pump having an inlet valve interposed between a source of fuel at constant high pressure and a metering chamber, with the entrance to the metering chamber controlled by a cut-off valve the position of which can be varied to permit more or less fuel to enter the metering chamber. The cut-off valve is preferably in the form of a piston having a helical land on its surface which is adapted to close off the inlet port to the metering chamber. The face of the metering piston opposite the metering chamber is in constant communication with the source of high pressure oil but this face of the piston has a smaller effective area than the face of the piston exposed to the metering chamber. A separate discharge valve is provided between the injection nozzle and the metering chamber which, when open, permits the oil in the metering chamber to discharge to the nozzle under the pressure of the liquid acting on the lower face of the metering piston. Provision

is made for operating the inlet and discharge valves from a common cam shaft driven ultimately from the engine synchronizing pinion, with a phase changing gear drive interposed between the valve operating shaft and the pinion to vary the injection timing.

In the drawings showing a preferred form of the invention,

Fig. 1 is a somewhat diagrammatic elevational view, with parts broken away, of the fuel pump and drive therefor;

Fig. 2 is a central vertical sectional view, with certain parts diagrammatically indicated, of the fuel pump, and

Fig. 3 is a timing diagram indicating the sequence of events in the operation of the pump.

Referring to Fig. 1 of the drawings, the fuel pump comprises an upper body 10 and a lower housing 11 in which an operating shaft 12 is journaled, said shaft having a driven gear 13 intermediate its ends. Gear 12 is provided with helical teeth and meshes with a companion helically cut, phase adjusting idler gear 14 carried by a shiftable stub shaft 15 journaled in suitable bushings 16 and 17 in the lower housing. The stub shaft 15 and gear 14 are adapted to be reciprocated as hereinafter described.

The stub shaft 15 carrying helically cut adjustable gear 14 is splined at its end to connect to a bevel gear 18 meshing with a companion bevel gear 19 carried by a drive shaft 20, which shaft is connected directly to or driven from the engine synchronizing pinion in a known manner. Gear 18 thus oscillates, preferably through an arc of about 250°, and imparts its oscillating motion to shaft 12 through the helically cut gears 13 and 14. The oscillation of shaft 12 may be varied in time with respect to the oscillation of gear 18 and shaft 20 by shifting stub shaft 15 axially, the splined connection between the stub shaft and bevel gear 18 being such as to permit the shifting of the shaft during running.

Drive shaft 12 carries, also intermediate its ends, valve operating cams 22 and 24 for the intake and discharge valves of the pump respectively. Referring to Fig. 2 of the drawings it will be seen that the upper pump body 10 is provided with an inlet valve 26 comprising a series, three in the present instance, of independently disposed serially related disc check valves 26a, 26b, and 26c. The check valves control the flow of oil from an inlet passage 28 which is connected to a constantly operated rail pump which discharges fuel at high pressures, said pump being indicated diagrammatically at P in Fig. 1. The serially related check valves 26a, 26b, and 26c are preferably of the type shown in the patent to Bovard, 2,310,350, issued February 9, 1943, and the interposed valve spacers may be of the type shown in this patent. The inlet valve assembly is thus insensitive to foreign particles in the fuel and is positive in its operation.

The serially related discs are urged into closed or seated position by a compression spring 27. The lowermost valve disc 26c is connected to a stem or tappet 29 which extends outwardly of the pump casing into position to be raised by any suitable operator, such as is shown at 30 which is, in turn moved by cam follower 31 which bears on the inlet valve operating cam 22. By connecting the stem 29 to the lowermost valve disc, the possibility that the pressure of the oil above the disc might be transmitted to the cam 22 and its associated driving parts is eliminated.

At the lower side of the lowermost check valve

26c the inlet passage communicates with a lateral passage 32 which, in turn, opens into a riser passage 34 and to a second lateral passage 36 which communicates with a fuel metering chamber 38. The metering chamber is formed as a cylinder the upper end of which is defined by a plug 40 and the lower end of which is defined by a metering piston 42. The metering piston 42 is provided with a groove having a helically cut land 44 and the full diameter of the piston fits closely into the metering cylinder so that the land 44 is able to close off the inlet passage 36 when the metering piston 42 is moved downwardly.

Oil from passage 35 enters the metering cylinder around land 44 and through a vertical passage 46 in the metering piston 42 to accumulate in the top of the metering cylinder. Oil continues to flow into the metering chamber 38 displacing piston 42 downwardly, until land 44 covers the inlet passage 36 at which time the entrance of fuel into the metering chamber stops.

The lower end of the metering cylinder, that portion designated 50 in Fig. 2 is in constant communication with the rail pump P through passage 28 and a by-pass passage 52 so that the space 50 is maintained at constant high pressure. The metering piston 42 is connected, by, any suitable means such as a T-head stem 54 with a fuel quantity control rack 58 by means of a gear 56 splined at the lower end of the stem 54. Reciprocation of rack 58 and rotation of gear 56 causes the initial position of the helically cut land 44 to be varied and thus the time of closure of inlet passage 36 to be varied since the quantity of fuel permitted to enter the metering chamber 38 may be greater or less depending on the initial position of land 44 and thus the stroke required of the metering piston before land 44 covers the inlet passage 36.

The presence of stem 54 in the chamber 50 results in the effective area of the lower end of the metering piston 42 being less than the effective area of the top surface of the piston so that if equal pressures exist at the top and bottom of the piston, as they do during the inlet period, the piston will move downwardly against the pressure of the liquid in chamber 50 until flow into the metering chamber is cut off.

A discharge passage 60 communicates with the metering chamber 38 through plug 40 and terminates in a chamber 62 at the top of a discharge valve which again preferably comprises a group of three serially related discs with interposed spacers, the discs being designated 63a, 63b, and 63c. The lowermost disc, 63c, is in abutting relation with a valve actuating tappet or stem 65, which stem extends outwardly from the upper pump body 10 into engagement with an adjustable tappet 67 carried at the upper end of a reciprocable valve lifter 68 which, in turn, carries a cam follower 70 in engagement with discharge valve operating cam 24. A suitable compression spring 72 is interposed between the upper valve disc 63a and a sealing and closing nut 74 threaded into the bore of the pump body 10 in which the discharge valve assembly is received.

The lowermost of the series of discharge valve discs 63c, controls the flow of oil into the nozzle passage 76, to which a conduit may be connected in any suitable manner for the transmission of oil to a suitable pressure operated nozzle (not shown).

The stem 65 which connects the valve lifting

mechanism with the lowermost disc valve 63c is bored axially to form a passage 78 which extends down through the stem and outwardly as at 80 to discharge into the open lower end of the body 10. The passage 78 is normally closed when the valve 63c is lifted but will be opened when the valve 63c is closed and the valve lifting mechanism withdrawn. The purpose of the passage is to prevent secondary injection by relieving the pressure in the nozzle passage 76 in a known manner.

As above noted, the time of injection may be varied by changing the angular position of shaft 12 with respect to shaft 20 which is driven from the engine synchronizing pinion. This phase adjustment may be accomplished by reciprocation of shaft 15 either by a lever or by some automatic instrumentality such as a diaphragm 90 connected at its center to shaft 15 and exposed on one face to the pressure in a chamber 92 which communicates by conduit 93 with any suitable portion of the engine such, for example, as the scavenging air receiver or the engine bounce chambers. If the phase is made sensitive to scavenging receiver pressure an increase in scavenging receiver pressure will reflect an increase in the load and may, for example, be used to cause an earlier injection of fuel than would be the case with reduced engine loads reflected in lowered scavenging receiver pressures.

The rail pump P may be operated from any suitable power source, such as an electric motor. The purpose of this pump is, of course, simply to displace sufficient fuel for the injection and to maintain the fuel under high pressure, and this purpose may be readily accomplished by using a constantly driven pump.

The operation of the fuel pump can be assisted by reference to the timing diagram shown in Fig. 3. In operation, shaft 12 is oscillated from the synchronizing pinion of the engine through gears 18, 19, 14 and 13 and for the moment it will be assumed that the phase adjustment is set to begin the injection of fuel 1-inch before the pistons reach their inner position. With the pistons making an outward stroke, moving to the right in Fig. 3, the first event is that cam 22 raises the serially related inlet check valves 25a, 25b and 25c from their seats against the compressive force of spring 27, so that oil flows under full rail pressure from pump P and line 28 through passages 32, 34 and 36 to the metering chamber 38 above the metering piston 42. The pressure of the fuel above the metering piston 42 displaces the piston downwardly until land 44 closes off passage 36. There is thus a measured quantity of fuel standing in chamber 38. Filling of the metering chamber 38 may be completed before the pistons reach the outermost position or after they have reversed their direction of movement, the "fill" cam 22 being so arranged that the inlet valves are lifted and held up during the time that the pistons are making the reversal at the outer limit of the stroke, as will be seen by reference to the shaded area 101. This outer limit may vary over a relatively wide range and, so long as the inlet valves are held open long enough, the length of the stroke will have no effect on fuel quantity, this factor being determined solely by the action of the metering piston.

Inasmuch as the lower side of the metering piston 42 is under constant rail pressure by reason of the open communication of space 50 with supply passage 28 through bypass passage 52, the accumulated oil in the metering chamber 38 stands ready to be injected at rail pressure.

Following the reversal of movement, cam 22 again permits the inlet valves to close and the pistons continue on the inward stroke. As the pistons move inwardly oscillation of shaft 12 brings cam 24 into position to raise the serially related discharge valves 63a, 63b, and 63c. This event takes place at a predetermined, shiftable point towards the inner end or limit of the stroke, indicated at 103.

Raising the discharge valves permits oil to pass from the metering chamber through passage 60, around the valves and out to nozzle passage 76. Cam 24 is designed to hold the discharge valves open as the pistons make their reversal at the inner end of the stroke, and, therefore, until the motion is reversed, and shaft 12 has also reversed, the valves will not again be seated. There is ample time for the injection of fuel, the quantity of which is unrelated to piston movement, and the pressure of which is likewise independently determinable. The duration of injection is a function of the rail pressure exerted by pump P and of the physical dimensions of the passages and conduits between the metering chamber and the nozzle orifice. By changing either the pump pressure or the flow characteristics of the parts, injection can be made to occur rapidly or with considerable lag, lasting well beyond the actual reversal of movement of the engine pistons.

When the discharge valves are again seated, stem 65 moves slightly away from its abutting contact with valve disc 63c, thus opening relief passage 78 and reducing the pressure in passage 76 to the nozzle. Secondary injection or dribble is thereby effectively prevented.

It will be apparent that, since shaft 12 oscillates, and that the extent of the oscillation varies with the stroke of the pistons, the arrangement of the cams 22 and 24 is such that filling of the metering space 38 is accomplished at one end of the piston stroke, and injection of the fuel at the opposite end. Both events are independent and subject to independent control. Thus, the fuel quantity may be changed without changing the time of injection, and the time of injection may likewise be changed without affecting the quantity of fuel that is permitted to pass the discharge valves. Fuel quantity is controlled as above noted, by rotating piston 42 through gear 56 and rack 58. Timing of the onset of injection is controlled by shifting the longitudinal position of stub shaft 15 and its helical idler gear 14, either manually or by an automatic device such as diaphragm 90.

What we claim is:

1. A fuel pump for a free piston engine having at least one variable stroke piston, an injection nozzle and a source of fuel at high pressure, said pump comprising, means operable at one end of the stroke of the engine piston to accumulate a predetermined quantity of fuel under the full pressure of said source, and separate means operable at the other end of the stroke of said engine piston to discharge said accumulated fuel to said nozzle under the full pressure of said source.

2. A fuel pump in accordance with claim 1 in which said accumulating means comprises a differential area metering piston.

3. A fuel pump in accordance with claim 1 in which said accumulating means comprise a differential area metering piston and means to alter the initial position of said piston to alter the ultimate volume of said accumulating means.

4. A fuel pump for a free piston engine having at least one variable stroke reciprocating piston,

an injection nozzle, and a source of fuel under high pressure, said pump comprising, a normally closed inlet valve connected to said source, a metering cylinder, a piston in said metering cylinder having a greater effective area on one side than on the other, an inlet conduit connecting said inlet valve to the large area side of said metering piston, a constantly open second conduit connecting said high pressure source and the small area side of said piston, means formed on said metering piston to close said inlet conduit when said piston has been displaced in said metering cylinder by fuel flow through said conduit, whereby the volume of fuel standing in said metering cylinder is cut off from said first conduit irrespective of said inlet valve and stands under the pressure exerted on the small area side of said metering piston, a discharge valve, and a discharge conduit controlled by said discharge valve extending between said metering cylinder and said injection nozzle, and separate engine oscillated cams to open said inlet valve and said discharge valve.

5. A fuel pump in accordance with claim 4 in which said engine oscillated cams act at opposite ends of the engine piston stroke.

6. A fuel pump in accordance with claim 5 and means to shift the relative phase of said engine operated cams and said variable stroke reciprocating piston.

7. A fuel pump for a free piston engine having at least one variable stroke piston, an injection nozzle, and a source of fuel at high pressure, said pump being interposed between said source and said nozzle and including a body, an inlet valve in said body, a fuel metering chamber in said body, an inlet passage between said fuel metering chamber and said source controlled by said inlet valve, a metering piston forming one side of said metering chamber, means to determine the ultimate position of said metering piston and thereby the capacity of said metering chamber, a passage between said metering chamber and said injection nozzle, a discharge valve in said last pas-

sage, means driven from said engine and in synchronism with the movement of said variable stroke piston to open said inlet valve and said discharge valve, and means to shift the relative phase of said valve opening means and the movement of the variable stroke engine piston.

8. A fuel pump for a free piston engine having at least one variable stroke piston, an injection nozzle, and a source of fuel at high pressure, said pump being interposed between said source and said nozzle and including a body, an inlet valve in said body, a fuel metering chamber in said body, an inlet passage between said fuel metering chamber and said source controlled by said inlet valve, a metering piston forming one side of said metering chamber, means to determine the ultimate position of said metering piston and thereby the capacity of said metering chamber, a passage between said metering chamber and said injection nozzle, a discharge valve in said last passage, means driven from the engine and in synchronism with the movement of said variable stroke piston to open said inlet valve and said discharge valve, said metering piston comprising a body having a sealing fit in said metering chamber, and a groove having a helical edge on the surface of said metering piston, said groove being normally in register with said inlet passage and moved out of register with said inlet passage by the pressure of fuel entering past said helical edge and into said metering chamber.

9. A fuel pump in accordance with claim 8 and means to rotate said piston to determine the initial position of said helical edge and thereby the length of movement required to move said groove out of registry with said inlet passage.

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