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FUEL INJECTION SYSTEM FOR INTERNAL COMBUSTION ENGINES

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This application is a continuation in part of my prior application entitled "Fuel injection system", Ser. No. 681,109, filed July 19, 1933.

This invention relates to internal combustion motors of the compression ignition type, and particularly pertains to a fuel injection system for such motors.

It is the principal object of my present invention to provide an improved fuel injection system for internal combustion engines which overcomes the disadvantages of prior systems by effecting uniform injection to all cylinders throughout a wide range of engine speeds without any throttling effect and with a sharp beginning and cut-off of injection, and in which system the beginning and termination of injection may be independently varied, either manually or by means of an engine driven governor.

In practicing my invention, I provide a fuel injection system of the "common rail" type and which is embodied in an apparatus which includes a fuel accumulator in which fuel under a substantially constant injection pressure is maintained. The apparatus also includes an engine driven distributor which functions to place the accumulator in communication with the cylinders of the engine in their firing order. In the connection between the accumulator and the distributor I provide a pair of piston type valves engine operated at high speed and in synchronism with the distributor and crankshaft operation. These valves are actuated by engine driven eccentrics and are so driven that the opening and closing of the communication between the accumulator and the distributor take place at substantially midway of only one stroke of the valves where their velocity is at a maximum. The valves are so relatively timed that fuel is admitted to the distributor only during one of the two strokes, and one of the valves always prevents communication between the accumulator and the distributor when the other is open on the opposite stroke. Due to the fact that these valves operate at high speed, all throttling of the fuel is eliminated, which is necessary for efficient engine operation. The time of commencement of injection, the time of duration of injection and the time of termination of injection is solely determined by the two valves mentioned and is in no way regulated by the distributor. Consequently, exactly the same

amount of fuel is injected under identical fuel pressure conditions to all of the cylinders, which will result in smooth engine operation. The injection system is applicable to engines with any number of cylinders, with any crank arrangement and regardless of whether or not the engine operates on the two or four cycle principle.

One form which the invention may assume is exemplified in the following description and illustrated by way of example in the accompanying drawing, in which:

The figure is a schematic view of my improved fuel injection system.

Referring more particularly to the accompanying drawing, I have there schematically illustrated my fuel injection system for solid or airless injection type internal combustion engines. My system in some respects resembles the "common rail" type system in that fuel at injection pressure is maintained in a reservoir or accumulator and the injection charge is measured by the interval of time during which the accumulator is in communication with the injection orifice. This interval of time is controlled as to duration, as to time of commencement and as to time of termination with relation to the engine crankshaft operation.

The fuel is stored in a main tank 10 and pumped from there to a day tank 11 by means of any suitable type of pump 12. From the day tank 11, the fuel is conducted through a pipe line 14, having a filter 15 therein, to the intake port 16 of a pump chamber 17. The intake port 16 is controlled by an intake valve 18 as in the usual manner. The pump chamber 17 has a discharge port 19 connected by a conduit 20 to an accumulator 21. The exhaust port 19 is fitted with a discharge valve 22 of any preferred design.

The pump chamber 17 is formed in a primary valve housing 23. This valve housing 23 is formed with a primary piston valve bore 24, in which a piston type primary valve 25 is reciprocally mounted. The piston valve bore 24 communicates with the pump chamber 17 so that as the primary valve 25 reciprocates, it creates a pumping action drawing fuel into the pump chamber 17 through the intake port 16 on one stroke, and discharges the fuel in the pump chamber 17 under high pressure through the discharge port to the accumulator on its opposite stroke. It should be

stated that the primary valve 25 performs its pumping stroke prior to each injection so that the fuel pressure in the accumulator will be the same at the time of commencement of every injection.

The accumulator 21 is fitted with an adjustable regulating valve 26 which determines the pressure of the fuel in the accumulator. This pressure is intended to be the injection pressure and at present I prefer that the injection pressure be approximately 3500 pounds. The accumulator is of sufficient size so that the pressure drop after each injection will be unappreciable. However, any pressure drop will be taken care of prior to each injection by the pump action as previously described.

The primary valve housing 23 is provided with a primary intake port 27 which is connected by means of a conduit 28 to the accumulator 21. The primary valve intake port 27 communicates with the piston valve bore 24 so that fuel at the injection pressure will be led to this bore through the conduit 28 from the accumulator.

The primary valve housing 23 is provided with a primary discharge port 29 likewise in communication with the piston bore 24. This port 29 is connected to a secondary intake port 30 formed in a secondary valve housing 31. This valve housing is formed with a secondary piston bore 32 in which a piston type secondary valve 33 is reciprocally mounted.

The secondary valve housing 31 is provided with a secondary discharge port 35 in communication with the secondary piston bore 32, which port 35 is connected by a conduit 36 to a distributor intake port 37 formed in a stationary distributor head 38.

The distributor head 38 is formed with a central bore 39 in which a distributor member 40 is rotatably mounted. The distributor member 40 is formed with an internal distributing chamber 41 which is in constant communication with the port 37 through a port 42. The chamber 41 in the distributor member 40 is formed with a single discharge port 43 which is adapted to successively communicate with distributor discharge ports 44 formed in the distributor head 38. One of these ports 44 is provided for each engine cylinder and is connected to the injection nozzle thereof. The number of the ports 44 depends upon the number of cylinders of the engine and the port 43 registers with the ports 44 leading to the cylinders in their regular firing order.

The distributor member 40 is driven from a shaft 45 through a set of gears 46. The shaft 45 is driven from the engine so that the distributor 40 will operate in synchronism with the crankshaft of the engine so that the port 43 will communicate successively with the cylinders in their proper firing order and at the proper time with relation to the piston operation therein.

It should be stated here that the port 43 registers with the proper port 44 just prior to injection and becomes out of register therewith subsequent to injection. The purpose of this is so that the distributor in no manner determines the quantity or time of injection. By time is meant the time of commencement of injection and the time of termination of injection.

I intend that the primary valve 25 and the secondary valve 33 operate to determine the time of commencement of injection and the time of termination of injection, which, of course, controls the time of duration of injection. I accomplish this by forming the primary valve 25 with a piston

port 47 which is in the form of an annular recess formed in the periphery of the primary valve 25. When this port is in register with the primary intake port 27 and the primary exhaust port 29, fuel under injection pressure from the accumulator 21 may discharge to the secondary intake port 30. The secondary valve 33 is formed with a similar piston port 48 which when in register with the secondary intake port 30 and the secondary exhaust port 35, will enable the fuel from the accumulator to discharge directly to the distributor intake port 37 through the distributor member 40 through the selected distributor discharge port 44 to the injection nozzle of the proper cylinder.

I desire to point out that the primary valve 25 controls the time of commencement of injection, while the secondary valve 33 controls the time of termination of injection. That is to say, that at the proper time for injection in a particular cylinder, the port 43 of the distributor member 40 registers with the proper port 44. The piston port 48 of the secondary valve 33 then comes into register with both of the secondary ports 30 and 35 before the piston port 47 of the primary valve 25 comes into register with the primary intake port 27. However, the piston port 47 of the primary valve 25 registers with the primary exhaust port 29 before it commences registering with the primary intake port 27. As soon as it registers with the latter, injection commences.

To terminate injection, the port 48 in the secondary valve 33 passes out of register with the secondary intake port 30, consequently cutting off injection. During the time that the port 48 goes out of registration with the port 30, the piston port 47 in the primary valve 25 is still in register with the primary ports 27 and 29. So, therefore, it is obvious that the relative positions of the piston ports 47 and 48 of the primary valve 25 and the secondary valve 33 are such that the primary valve 25 determines the time of commencement of injection and the secondary valve 33 determines the time of termination of injection.

These valves are driven in synchronism with relation to each other and with relation to the crankshaft operation so that injection will commence at the proper crank angle and will terminate at the proper crank angle. The interval of time between the commencement and termination of injection, of course, determines the quantity of injection at a given injection pressure. By raising the pressure, a greater quantity will be injected, and conversely, lowering the pressure will cut down the amount injected.

The operating mechanism for the valves consists of an eccentric shaft 50 driven from the crankshaft of the engine and in timed relation thereto. Mounted on this shaft 50 are two eccentrics 51 and 52. The eccentric 51 is connected by a connecting rod 53 to a reciprocable plunger 54 which in turn is operatively associated with the primary valve 25 to operate the same. The eccentric 52 is connected by means of a connecting rod 55 to a reciprocable plunger 56 which in turn is operatively connected to one end of a centrally pivoted lever 57. The other end of this centrally pivoted lever 57 is connected to the secondary valve member 33 so that reciprocation of the plunger 56 will be accompanied by reciprocation of the secondary valve 33. The lever 57 is pivoted on an eccentric 58 fixed on a shaft 59 so that by turning the shaft 59, the relative po-

sition of the piston port 48 will be changed relative to the secondary intake and discharge ports 30 and 35, and consequently the time of termination of injection with respect to the crankshaft operation will be varied. The shaft 59 is connected to an engine driven governor 60 as illustrated so that the time of termination of injection will be engine controlled. I may point out, however, that the time of termination may be manually controlled if so desired.

To regulate the operation of the primary valve 25 and thus change the time of commencement of injection with respect to the crankshaft operation, I provide a mechanism indicated at 61 which constitutes a manually operated lever 62, a pair of bevel gears 63, which drives a spur gear 64. This spur gear is in mesh with a spur gear 65 which forms a part of the plunger 54. By turning this spur gear, the threaded connection 66 either shortens the plunger or lengthens it, and consequently changes the position of the piston valve port 47 with relation to the primary intake and discharge ports 27 and 29. This change in position of the piston port in respect to the intake and discharge ports will change the time of commencement of injection relative to the crankshaft operation.

I want to call particular attention to the fact that injection occurs only on one stroke of the two stroke cycle of the primary and secondary valves. In this instance I have shown injection occurring on the down stroke of these valves. I also call attention to the fact that the valvular action of the primary and secondary valves occurs approximately at the center of their down stroke, at which time they are travelling at their highest velocity, due to the position of the eccentrics 51 and 52. This can be readily appreciated from the drawing. The eccentrics revolve in the direction of the arrows in the drawing and although they appear on the drawing to be revolving in opposite directions, they are really fixed on one shaft and it is merely the schematic arrangement of the drawing which gives this false impression.

The eccentric shaft 50 is, of course, driven from the crankshaft of the engine so that the valves will operate in synchronism with relation to each other and in timed relation to the crankshaft and piston operation. By regulating the primary valve, injection can be made to commence at any preferred crank angle, and likewise by regulating the secondary valve, termination of injection can be made to occur at any crank angle. By automatically adjusting the position of the secondary valve through the means of the engine governor, the time of termination of injection will be engine controlled.

It is seen that with a single cylinder engine, the eccentric shaft 50 will operate at one-half crankshaft speed. In a two cylinder motor, the eccentric shaft will operate at crankshaft speed, and in a four cylinder motor, the eccentric shaft will operate at twice crankshaft speed. This is very important in that it moves the primary valve 25 and the secondary valve 33 at comparatively high linear velocity so that the ports are rapidly uncovered and covered, so that throttling of the fuel will be negligible. This is important as throttling is extremely detrimental to efficient engine operation.

In operation of my fuel injection system, when the engine commences to operate, the piston primary valve 25 will draw fuel from the day tank 11 and pump the fuel under high pressure into

the accumulator 21. By adjusting the regulating valve 26, the injection pressure may be determined. Fuel at injection pressure from the accumulator 21 will be present at the bore 24. The port 43 of the distributor member 40 will register with the proper port 44 in the distributor head 38 which is connected with the injection nozzle of the selected cylinder. The secondary valve 33 then moves downwardly to place its port 48 into communication with both of the secondary ports 30 and 35, which places the distributor intake port 37 into communication with the primary discharge port 29. The piston port 47 of the primary valve 25 has already commenced registering with the discharge port 29 and then commences registering with the primary intake port 27, placing the accumulator 21 into communication with the distributor and through the latter to the selected cylinder, effecting an injection. The time of termination of the injection occurs by the piston port 48 of the secondary valve 33 passing out of register with the secondary intake port 30.

I also intend to relieve the line between the injection nozzle at the cylinder and the secondary valve 33, and I accomplish this by providing the secondary valve housing 31 with a relief port 31a which communicates with the main storage tank 10 through a pipe line 31b. After the piston port 48 of the secondary valve 33 passes out of register with the secondary intake port 30, but before it passes out of register with the secondary discharge port 35, it registers with the relief port 31a, relieving the line between the nozzle and the secondary valve. This is advantageous in that it aids in effecting a sharp cut-off of injection and prevents dribbling of fuel into the cylinder.

As previously described, the port 43 becomes in register with the selected port 44 prior to the commencement of injection and goes out of register with the port 44 subsequent to the termination of injection. Therefore, there is no throttling action here and likewise the distributor in no way affects either the quantity or duration of injection.

On the upstroke of the primary valve 25, it, of course, pumps fuel to the accumulator to maintain the pressure therein. The injection pressure, of course, can be regulated by the regulator 26 so that the injection pressure in the accumulator will remain substantially constant at any given setting, and will not be a function of engine speed. On the upstroke of the valves 25 and 33, one of the two valves is always in a position cutting off communication between the accumulator and the distributor. The latter offers a second seal against leakage. It is obvious that due to this double seal during non-injection periods, the chances of fuel leaking from the accumulator to the injection nozzle at the cylinder are slight, and consequently the fit of these parts in their bores need not be made as accurately as it is necessary to fit the parts in a "jerk pump" system. Likewise, my system will be less sensitive to wear.

It is also obvious that since the fuel passes through exactly the same elements on its way from the accumulator to the outlet of the distributor for each and every injection, it does not matter if these various elements leak slightly, since any leakage will affect all injections in all cylinders to the same degree.

It is obvious that there will be no appreciable throttling of the fuel due to the fact that the valves 25 and 33 operate at high velocity, so that they rapidly uncover and cover the ports. This

is of great importance, particularly with respect to efficient operation of the engine.

I also call attention to the fact that the volume of fuel between the valves and the injection nozzles of the cylinders will be small, and consequently the effects of inaccuracy due to the compressibility of the fuel will be negligible.

From the foregoing it is obvious that I have provided a very efficient fuel injection system in which exactly the same amount of fuel will be injected in all of the cylinders under identical fuel pressure conditions, and in which the time of commencement of injection and the time of termination of injection may be independently varied.

While I have shown the preferred form of my invention, it is to be understood that various changes in its construction may be made by those skilled in the art without departing from the spirit of the invention as defined in the appended claims.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. In a fuel injection system for multi-cylinder internal combustion engines, an accumulator containing fuel under a predetermined injection pressure, an engine driven fuel distributor adapted to communicate with each cylinder of the engine in its proper firing order and in proper timed relation to the crankshaft operation, a fuel conducting connection between said distributor and said accumulator, a primary valve and a secondary valve interposed in said connection to control the passage of fuel from the accumulator to the distributor, said primary valve operating to open said connection and said secondary valve operating to close said connection, said secondary valve unobstructing the said fuel conducting connection at the time the primary valve operates to open it, and said primary valve unobstructing the said connection at the time said secondary valve operates to close said connection, said valves being engine operated in synchronism and in timed relation to the crankshaft operation, said distributor communicating with the proper cylinder prior to the opening of said connection and cutting off said communication subsequent to the closing of said connection.

2. In a fuel injection system for multi-cylinder internal combustion engines, an accumulator to contain fuel under a predetermined injection pressure, a fuel supply tank, engine driven pump means drawing fuel from said tank and pumping it to said accumulator to maintain the fuel pressure therein substantially constant, an engine driven rotary fuel distributor adapted to separately communicate with the cylinders of the engine in their firing order and in proper timed relation to the crankshaft operation, a fuel conducting connection between said distributor and said accumulator, a primary valve and a secondary valve interposed in said connection to control the passage of fuel from said accumulator to said distributor, said primary valve operating to render said connection effective and said secondary valve operating to render said connection ineffective, said secondary valve unobstructing the flow of fuel through said connection at the time said primary valve operates to render said connection effective, said primary valve unobstructing the flow of fuel through said connection at the time said secondary valve operates to render said connection ineffective, said valves being engine driven in synchronism and in timed relation to the crankshaft and distributor oper-

ation, said distributor communicating with the selected cylinder prior to commencement of injection and ceasing to be in communication therewith just subsequent to injection, and separate means for regulating both of said valves whereby the time of commencement of injection and the time of termination of injection with relation to the crankshaft operation may be independently varied.

3. In a fuel injection system for multi-cylinder internal combustion engines, an accumulator containing fuel under a predetermined injection pressure, said accumulator being of sufficient capacity to maintain said predetermined injection pressure substantially constant, adjustable means for predetermining said injection pressure, pump means associated with said accumulator for maintaining the pressure therein, an engine driven fuel distributor adapted to separately communicate with the cylinders of the engine in their proper firing order and in timed relation to the crankshaft operation, said communication existing during the period just prior to commencement of injection and just subsequent to the termination of injection, a fuel conducting connection between said distributor and said accumulator, a primary and a secondary valve interposed in said connection to control the passage of fuel from the accumulator to the distributor, said primary valve operating to render said connection effective and thereby determine the time of commencement of injection, said secondary valve operating to render said connection ineffective and thereby determine the time of termination of injection, said secondary valve unobstructing fuel flow through said connection at the time said primary valve operates to commence injection, said primary valve unobstructing fuel flow through said connection at the time said secondary valve operates to terminate injection, said valves being of the reciprocable piston type and operating at high velocity to effect sharp commencement and cut-off of injection and thereby prevent throttling, said valves being engine driven in synchronism and in timed relation to the crankshaft and distributor operation, and means for adjusting said primary valve to vary the time of commencement of injection with relation to the crankshaft operation.

4. In a fuel injection system for internal combustion engines, an accumulator containing fuel under a predetermined injection pressure, said accumulator being of sufficient capacity to maintain said predetermined injection pressure substantially constant, adjustable means for predetermining said injection pressure, pump means associated with said accumulator for maintaining the pressure therein, an engine driven fuel distributor adapted to separately communicate with the cylinders of the engine in their proper firing order and in timed relation to the crankshaft operation, a fuel conducting connection between said distributor and said accumulator, a primary and a secondary valve interposed in said connection to control the passage of fuel from the accumulator to the distributor, said primary valve operating to render said connection effective and thereby determine the time of commencement of injection, said secondary valve operating to render said connection ineffective and thereby determine the time of termination of injection, said secondary valve unobstructing injection at the time said primary valve operates to commence injection, said primary valve unobstructing said connection at the time said sec-

ondary valve operates to terminate injection, said valves being of the piston type and operating at high velocity to prevent throttling, said valves being engine driven in synchronism and in timed
5 relation to the crankshaft and distributor operation, said distributor communicating with the selected cylinder prior to the rendering of said

connection effective and ceasing communication with said cylinder subsequent to the time said connection is rendered ineffective, and means for adjusting said secondary valve whereby the time of termination of injection may be varied with
5 relation to the crankshaft operation.

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