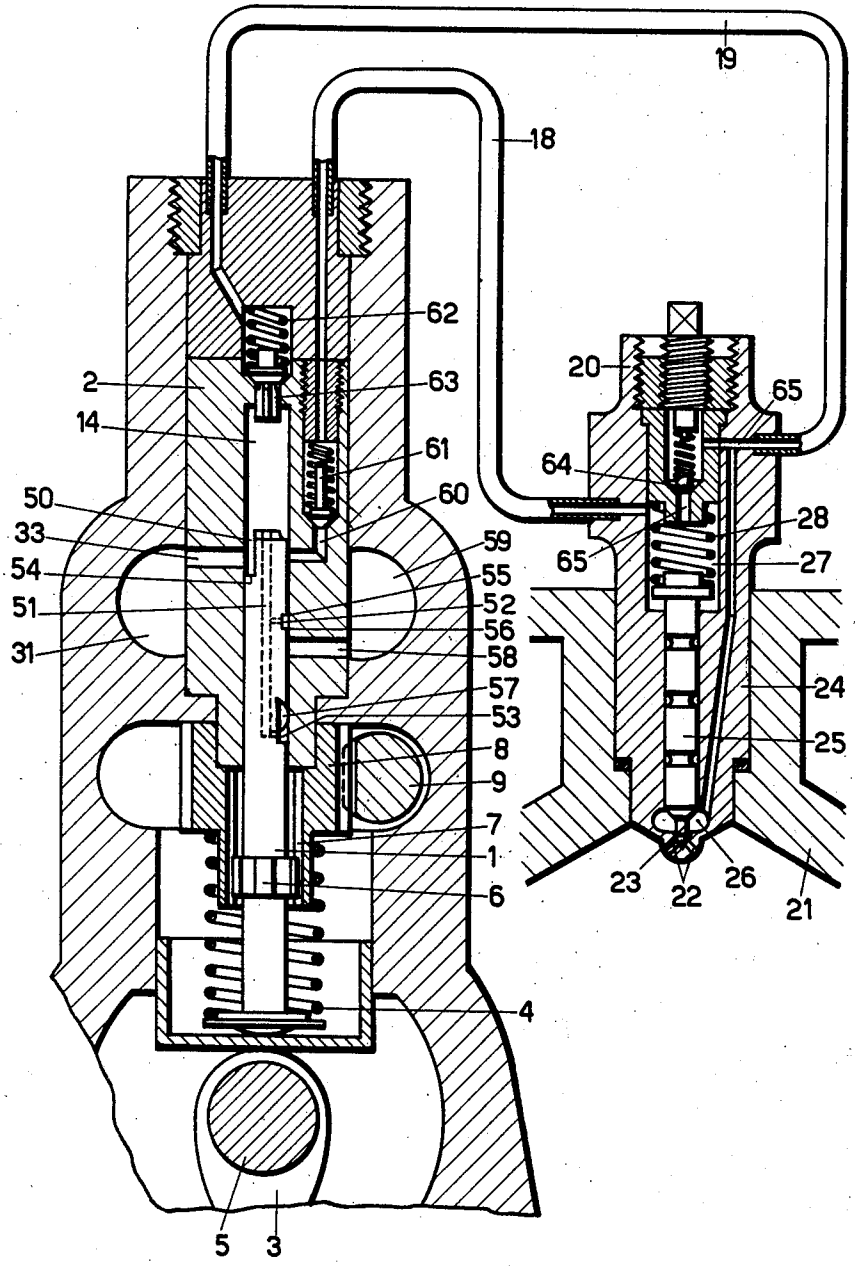
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FUEL INJECTION APPARATUS

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FUEL INJECTION APPARATUS

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7 Claims. (Cl. 123—139)

My invention relates to improvements in fuel injection apparatus especially for internal combustion engines.

An object of this invention is to provide a fuel injection apparatus comprising an injector device whose injection passage is controlled by a valve member acted upon by the fuel pressure in a valve opening and a valve closing chamber, and means for supplying fuel to said injection passage and to said chambers, such as I have described in my U. S. patent application, Serial No. 119,516 filed January 7, 1937. The said application discloses a fuel injection apparatus with a pump cylinder and a pump piston fitting it and forming a working chamber therein, an injector device of the said kind, an injection conduit connecting said working chamber to said opening chamber and to said injection passage, a valve closing conduit connecting said working chamber to said valve closing chamber, and means for controlling the communication from said working chamber to said valve closing conduit. In the present invention I provide means for diminishing the influence of fuel pressure oscillations arising in the fuel chambers and conduits, and for improving the control of the injected fuel quantity.

With these general statements of the objects and purposes of my invention I will now proceed to describe the embodiment thereof and the manner in which my invention is carried out, and it will be understood that while I have described what may be considered as a preferable embodiment of my invention, I do not limit myself to the precise conditions or proportions herein set forth, as they may be varied by those skilled in the art in accordance with the particular purposes for which they are intended, and the conditions under which they are to be utilized.

In the embodiment shown in the drawing, a displaceable pump piston 1 tightly fitted into the cylinder 2 is moved on its outward stroke by the spring 4 and on its inward stroke by the cam 3 on the shaft 5 driven by the internal combustion engine in a way not shown in the drawing. The pump piston 1 carries a guide cross 6 engaging grooves 7 of a pinion 8 and may be rotated about its axis by means of the said pinion and of a rack 9 without detriment to its reciprocated movement. The pump working chamber 14 is in immediate open communication with a recess 50 and communicates, through a longitudinal bore 51 and transverse bores in the piston 1, with recesses 52 and 53 of the piston surface. The recess 50 is bounded, in a plane perpendicular to the piston axis, by the control edge 54. The control edges 55 and 56, which also are perpendicular to the piston axis, bound the recess 52, and the control edge 57 disposed obliquely with reference to the piston axis bounds the recess 53.

The suction port 33, which is connected through the suction chamber 31 to a fuel supply pump not shown in the drawing, issues at such a level in the bore of the cylinder 2 that its issue faces the recess 50 when the piston 1 is in its outer dead centre position. A by-pass port 58 is placed so as to issue in the recess 53 for the innermost stroke portion of the pump piston 1 in all angular positions of the latter, thus joining the said recess 53 with the by-pass chamber 59 connected to a fuel reservoir not shown in the drawing. To the bore of the cylinder 2, a loading conduit 18 is connected through the duct 60, which contains a non-return valve 61 opening towards said loading conduit 18. In the bottom of the pump cylinder 2 a fuel passage controlled by the delivery valve 63 leads from the pump working chamber 14 to the injection conduit 19. Said delivery valve opens towards the injection conduit 19 and is loaded by a spring 62. The injection conduit 19 leads into the annular chamber 26 of the injection valve 20 provided in the cover 21 of a working cylinder of the internal combustion engine. The communication between the annular chamber 26 and the nozzle bores 22 discharging into the combustion chamber is controlled by the valve needle 23 which is lifted in its time by the fuel pressure in the annular chamber 26, said fuel pressure acting upon the stem 25 of the valve needle, so as to open said communication. To close the latter, the valve needle stem 25 is acted upon by the fuel pressure in the loading chamber 27 which communicates with the loading conduit 18 and in which also a spring 28 is provided for assisting the fuel pressure. The valve needle stem 25 tightly fits the valve housing 24. From the space 27 a passage 65 controlled by a non-return valve 64 leads into the injection conduit 19.

On the outer dead centre position of the piston 1 the suction port 33 communicates through the recess 50 with the pump working chamber 14, so that the suction pressure prevails in the latter; the loading conduit 18, the injection conduit 19 and the spaces 26 and 27 are under the same low pressure as the by-pass chamber 59, but they are secluded from the latter and from the pump working chamber 14 by the delivery valve 63 and the pump piston respectively. On the inward movement of the pump piston 1 the control edge 54 first closes the suction port 33; then the piston displaces fuel past the delivery valve 63 into

the injection conduit 19, and compresses the fuel in the latter and in the annular space 26 up to the opening pressure of the injection valve, so that the needle 23 is lifted from its seat. By going on displacing fuel into the injection conduit the piston 1 then causes a preliminary injection of the fuel to take place.

The displacement of fuel into the injection conduit is interrupted when the control edge 55 uncovers the port 60 and the working chamber 14 of the pump thus is connected past the non-return valve 61, which is opened, to the loading conduit 18 in which a low pressure prevails at that time. The drop of pressure, which, as a consequence, takes place in the working chamber 14 causes the delivery valve 63 to close immediately and to shut off the injection conduit 19 from the working chamber 14 of the pump. The fuel further displaced by the pump piston 1 flows into the loading conduit 18 and raises the pressure therein and in the space 27. After the closing of the delivery valve 63 the fuel contained in the injection conduit 19 expands through the injection nozzle 22 but as soon as the fuel pressure in the space 27 together with the force of the spring 28 is sufficient to overcome the diminishing force exerted upon the needle stem by the fuel pressure in the annular space 26, the needle 23 returns to its seat and closes the injection nozzle, so that further injection by expansion of the fuel in the injection conduit is prevented.

After the pressure in the pump working chamber 14 and in the loading conduit 18 has reached that in the injection conduit 19, and has again opened the delivery valve 63, the pump piston simultaneously displaces fuel into both conduits 18 and 19, so that the pressure rises in both chambers 26 and 27 until the port 60 is again closed by the control edge 56 whereby the conduit 18 is shut off from the working chamber 14. Thereafter, the displacement of the fuel into the injection conduit 19 causes a further increase of pressure in the annular space 26 so as to lift the needle 23 against the loading force of the spring 28 and the fuel pressure in the space 27 whereupon the principal injection of the fuel is effected as the piston 1 proceeds.

To terminate the fuel displacement into the injection conduit 19 the oblique control edge 57 uncovers the by-pass port 58 and connects the working chamber 14 of the pump to the by-pass chamber 59. As a low pressure prevails in the latter, the delivery valve immediately shuts the injection conduit off from the working chamber 14 of the pump on account of the drop of pressure in the pump working chamber. The injection still continues for a short time because of the expansion of the fuel contained in the injection conduit 19, until the pressure in the annular space 26 has sunk so far that the needle 23 closes the nozzle holes 22 under the action of the fuel pressure in the space 27 and of the spring 28. By rotating the piston 1 by means of the rack 9 and of the pinion 8, the time at which the oblique control edge 57 uncovers the by-pass port 58 and causes the injection conduit 19 to be shut off from the working chamber 14, may be varied and the injected fuel quantity may thus be adjusted.

Near the inner dead centre position of the piston 1 the delivery valve 63 is pushed open by the face of the piston 1; therefore, the fuel in the injection conduit 19 can expand into the by-pass chamber 59 through the pump working chamber 14 and the by-pass port 58. Thereby, the pressure in the injection conduit 19 falls below that in the loading conduit 18 and in the space 27, so that the non-return valve 64 opens and the fuel pressure in the conduit 18 and in the space 27 also comes down to the pressure prevailing in the by-pass chamber 59.

On the outward stroke of the pump piston 1 the delivery valve 63 closes and the by-pass port 58 is covered again by the edge 57. Thereafter, the pump working chamber 14 is partly evacuated so that the opening of the non-return valve 61 when the recess 52 passes in front of the mouth of port 60 is prevented. At that time, the pressure in the working chamber 14 has no influence upon the condition of the fuel in the loading conduit 18.

What I claim is:

1. The combination of a fuel injection device including a housing provided with a passage through which fuel is supplied to an injection nozzle, a fuel valve controlling flow through said passage, means connected with said fuel valve and acting thereon in an opening direction under the pressure of supplied fuel, a loading chamber in which fuel under pressure may act in a valve closing direction, a relief valve permitting flow from said chamber to said passage, and means biasing said fuel valve in a closing direction; a pump comprising a cylinder and a piston, said pump having a discharge connection leading to the supply passage of said injection device and a loading connection leading to the loading chamber of said fuel valve and including a loading port controlled by the piston of said pump; and a one-way flow valve in the last-named connection for permitting flow toward said loading chamber; the cylinder having an unloading port and the piston having ports which selectively connect the working space of the pump with said loading port and with said unloading port, the parts being so arranged that as the piston moves in displacing direction it displaces fuel through said discharge connection, then connects the working space of the pump with said loading connection, and then interrupts the last-named connection and establishes a connection from the working space of the pump to said unloading port.

2. The combination with the structure defined in claim 1, of means for varying the point in the discharge stroke of the piston at which the connection from the working space to the unloading port is established.

3. The combination of a fuel injection device including a housing provided with a passage through which fuel is supplied to an injection nozzle, a fuel valve controlling flow through said passage, means connected with said fuel valve and acting thereon in an opening direction under the pressure of supplied fuel, a loading chamber in which fuel under pressure may act in a valve closing direction, a relief valve permitting flow from said chamber to said passage, and means biasing said fuel valve in a closing direction; a pump comprising a cylinder and a piston, said pump having a discharge connection leading to the supply passage of said injection device; a loaded check valve opening from said cylinder toward said discharge connection, said check valve being arranged to be unseated by said piston near the end of its discharge stroke; a loading connection leading to the loading chamber of said fuel valve and including a loading port controlled by the piston of said pump; and a one-way flow valve in the last-named connection for permitting flow toward said loading chamber; the cylinder having an unloading port and the piston having ports which selectively connect the work-

ing space of the pump with said loading port and with said unloading port, the parts being so arranged that as the piston moves in displacing direction it displaces fuel through said discharge connection, then connects the working space of the pump with said loading connection, then interrupts the last-named connection and establishes a connection from the working space of the pump to said unloading port and finally, while maintaining the last-named connection, unseats the loaded check valve in said discharge port.

4. The combination with the structure defined in claim 3, of means for varying the point in the discharge stroke of the piston at which the connection from the working space to the unloading port is established.

5. Fuel injection apparatus comprising in combination, a pump cylinder and reciprocable pump piston enclosing together a variable pump working space; means providing an inlet for supplying liquid fuel to said pump working space; means providing a by-pass for by-passing liquid fuel from said pump working space; an injector having an injection passage; an injection conduit for supplying liquid fuel from said pump working space through said injection passage; valve means controlling the communication between said pump working space and said injection conduit; an injection valve for controlling said injection passage; actuating means for said injection valve having a valve opening space communicating with said injection passage and a valve loading space adapted to communicate with said pump working space, said actuating means being so arranged that the pressure in said valve opening space tends to open the injection valve and the pressure in said valve loading space tends to close the injection valve and to counteract the opening thereof; biasing means for keeping said injection valve closed when the pressures are substantially equal in said valve opening and loading spaces; means providing a connection between said valve opening space and said valve loading space; an automatic non-return valve in the last-named connection for preventing the flow of liquid from said valve opening space to said valve loading space; and valve means for controlling the said inlet, the said by-pass and the communication between said pump working space and said valve loading space, said valve means being arranged to function in timed relation with the motion of said pump piston.

6. Fuel injection apparatus comprising in combination, a pump cylinder and reciprocable pump piston enclosing together a variable pump working space; means providing an inlet for supplying liquid fuel to said pump working space; means providing a by-pass for by-passing liquid fuel from said pump working space; an injector having an injection passage; an injection conduit for supplying liquid fuel from said pump working space through said injection passage; an automatic non-return valve for preventing the back-flow of fuel from said injection conduit to said pump working space; an injection valve for controlling said injection passage; actuating means for said injection valve having a valve opening space communicating with said injection passage and a valve loading space adapted to communicate with said pump working space, said actuating means being so arranged that the pressure in said valve opening space tends to open the injection valve and the pressure in said valve loading space tends to close the injection valve and to counteract the opening thereof; biasing means for keeping said injection valve closed when the pressures are substantially equal in said valve opening and loading spaces; means providing a connection between said valve opening space and said valve loading space; an automatic non-return valve in the last-named connection for preventing the flow of liquid from said valve opening space to said valve loading space; and valve means for controlling the said inlet, the said by-pass and the communication between said pump working space and said valve loading space, said valve means being arranged to function in timed relation with the motion of said pump piston.

7. Fuel injection apparatus comprising in combination, a pump cylinder and reciprocable pump piston enclosing together a variable pump working space; means providing an inlet for supplying liquid fuel to said pump working space; means providing a by-pass for by-passing liquid fuel from said pump working space; an injector having an injection passage; an injection conduit for supplying liquid fuel from said pump working space through said injection passage; valve means controlling the communication between said pump working space and said injection conduit; an injection valve for controlling said injection passage; actuating means for said injection valve having a valve opening space communicating with said injection passage and a valve loading space adapted to communicate with said pump working space, said actuating means being so arranged that the pressure in said valve opening space tends to open the injection valve and the pressure in said valve loading space tends to close the injection valve and to counteract the opening thereof; biasing means for keeping said injection valve closed when the pressures are substantially equal in said valve opening and loading spaces; means providing a connection between said valve opening space and said valve loading space; an automatic non-return valve in the last-named connection for preventing the flow of liquid from said valve opening space to said valve loading space; valve means for controlling the said inlet, the said by-pass and the communication between said pump working space and said valve loading space, said valve means being arranged to function in timed relation with the motion of said pump piston; and an automatic non-return valve in the communication between said pump working space and said valve loading space for preventing the back-flow of liquid from the valve loading space through the said communication to the pump working space.

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