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[54] FUEL INJECTION PUMP FOR INTERNAL COMBUSTION ENGINES

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[52] **U.S. Cl.** ....**417/293**, 123/140 FG

[51] **Int. Cl.** **F04b 49/00**

[58] **Field of Search**..................123/139 R, 139 AB, 139 AR, 123/139 AD, 139 AE, 139 AL, 139 AM, 139 AQ, 139 AG, 140 FG; 417/293

[56] **References Cited**

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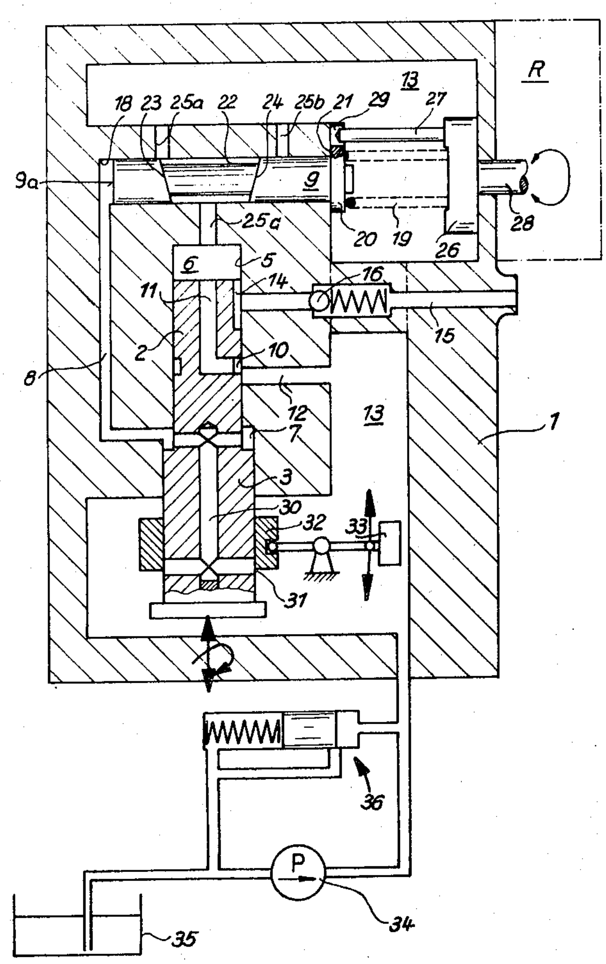
[57] **ABSTRACT**

In a fuel injection pump the quantities delivered during each pressure stroke thereof are varied by opening a bypass channel at a predetermined moment by means of a regulator shuttle driven from a constant abutment by hydraulic pressure generated by pump means operating synchronously with the main piston of the fuel injection pump. Said predetermined moment is variable by turning said regulator shuttle. The moment fuel delivery starts during each pressure stroke may be changed without affecting the delivered fuel quantities by means delaying to a lesser or greater extent the buildup of said hydraulic pressure.

10 Claims, 3 Drawing Figures



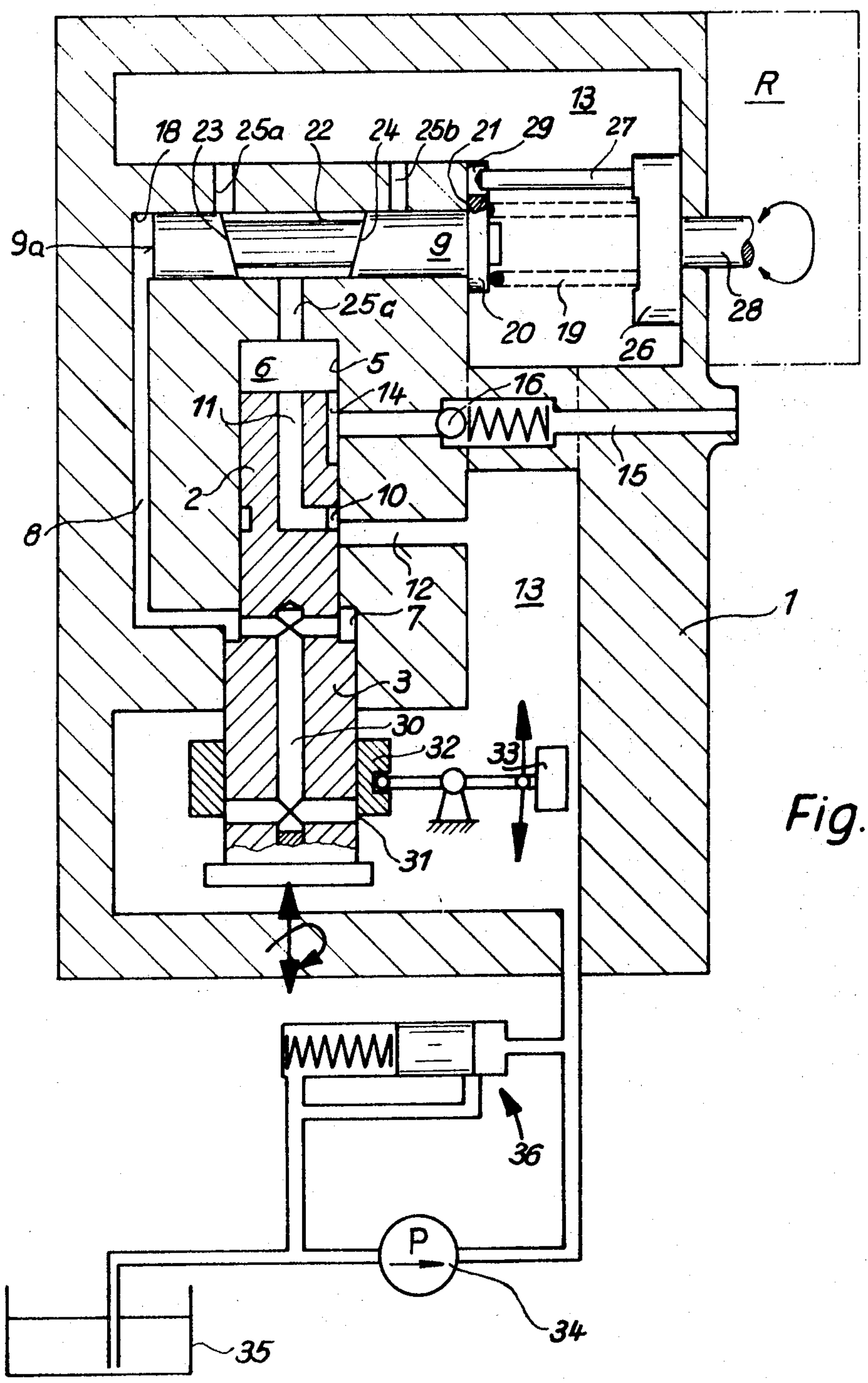


Fig. 1

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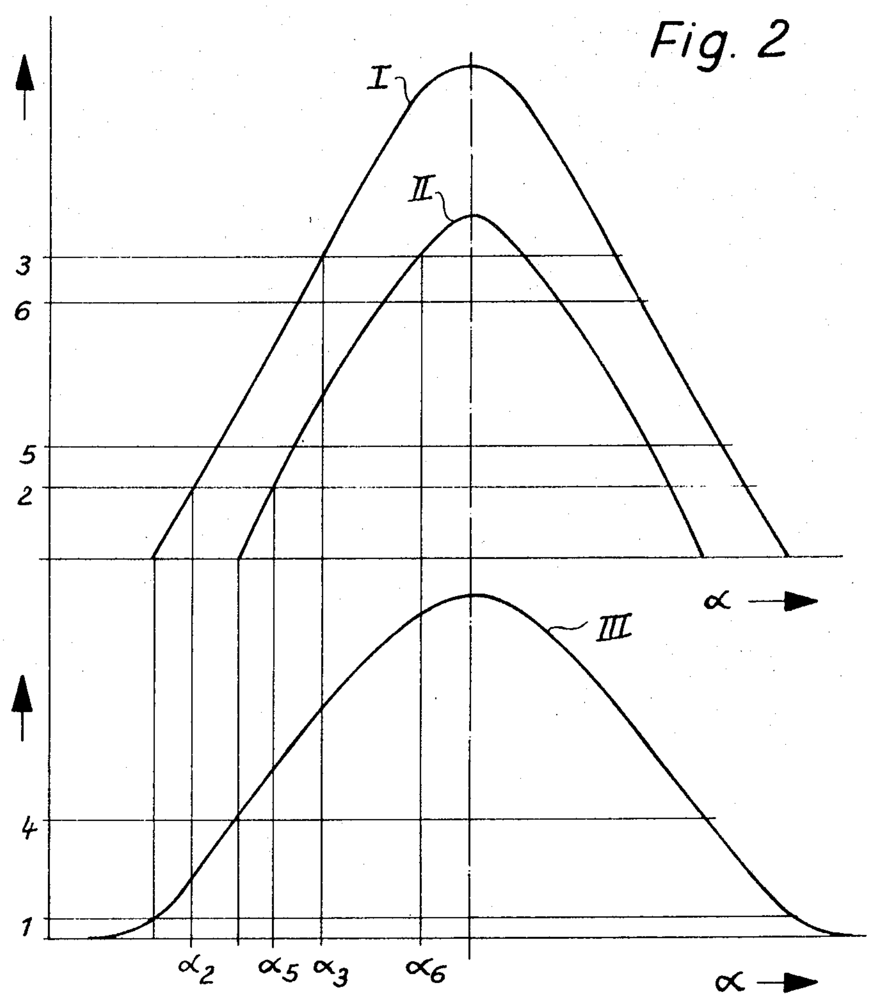
Fig. 2



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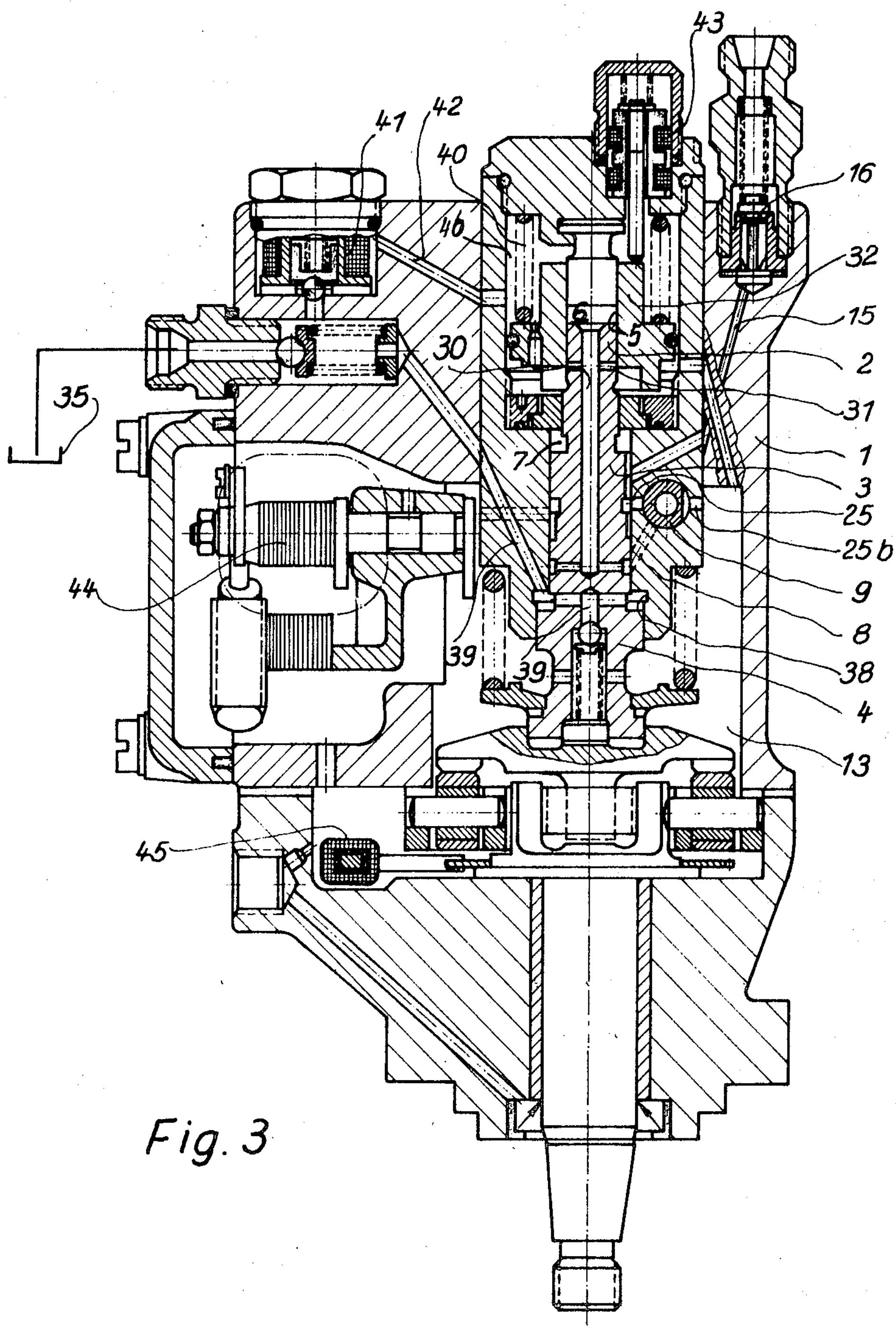

Fig. 3

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FUEL INJECTION PUMP FOR INTERNAL COMBUSTION ENGINES

BACKGROUND OF THE INVENTION

This invention relates to a fuel injection pump for internal combustion engines and is of the type wherein the delivered fuel quantities are variable by interrupting the fuel delivery during each pressure stroke of the pump piston. Such interruption is effected by opening a bypass channel (leading from the pump work chamber) by means of a reciprocating regulator member which is displaced in the forward direction against the force of a return spring by a fuel volume driven by an auxiliary pump operating synchronously with the main fuel pump. The regulator member is provided with an oblique control edge and is turnable so that the travelling path of the regulator member prior to opening the bypass channel may be varied as a function of the angular position of the regulator member.

In a known fuel injection pump of the aforenoted type (as disclosed in German Pat. No. 1,153,941), the return motion of the regulator member is braked by directing at least one part of the fuel quantity which caused its forward motion (and which is displaced by the regulator member during its return motion) through a throttle having a variable cross section. As a result, for a given flow passage section and upon reaching a certain r.p.m., the regulator member, by virtue of the appearance of the so-called "fluid abutment" does no longer return to its initial position. In this manner, the bypass channel is opened earlier during the pressure stroke and thus, the fuel quantities delivered by the fuel injection pump are decreased.

Since the viscosity of the fuel changes as a function of the temperature in the fuel injection pumps of the above type, the temperature variations have a disadvantageous effect on the regulation and further, the fuel present in the regulator circuit forms a system capable of oscillation in which resonance phenomena interfering with the fluid abutment might appear.

OBJECT AND SUMMARY OF THE INVENTION

It is an object of the invention to provide an improved fuel injection pump of the aforenoted type in which the delivery of fuel quantities is controlled without a fluid abutment for the purpose of avoiding the aforenoted difficulties.

Briefly stated, according to the invention, adjusting means are provided for an r.p.m.-dependent fuel quantity control ensuring that the initial or starting position of the regulator member is constant and thus independent of load and r.p.m. conditions.

The invention will be better understood and further objects as well as advantages of the invention will become more apparent from the ensuing detailed specification of two exemplary embodiments taken in conjunction with the drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic sectional view of a first embodiment of the invention;

FIG. 2 is a diagram depicting two sets of graphs showing the stroke of the regulator member and the pump piston as a function of the angular position of the pump piston driving means and

FIG. 3 is a sectional view of a second embodiment of the invention.

DESCRIPTION OF THE EMBODIMENTS

Turning now to FIG. 1, in a housing 1 of a fuel injection pump there operates a stepped piston 2, 3 which is driven by means (e.g., including a cam) not shown. Said piston is adapted to execute a reciprocating axial motion as well as a rotary motion about its axis. While the reciprocating motion serves for delivering the fuel to the engine, the rotary motion serves for fuel distribution. A first piston portion or main piston 2 having a relatively small diameter, operates in a cylinder 5 and bounds therewith a pump work chamber 6 of the fuel injection pump proper. A second piston portion or auxiliary piston 3, having a relatively large diameter, operates in a cylinder 7 and forms therewith an auxiliary pump which displaces fuel in a channel 8 and thus drives hydraulically a regulator shuttle 9. The main piston 2 is provided with a circumferential annular groove 10 which is in continuous communication with the pump work chamber 6 through an axial channel 11. The annular groove 10 controls a fuel supply bore 12 through which the pump work chamber 6, as long as the pump piston is in the vicinity of its lower dead center, is supplied with fuel from a suction chamber 13. A longitudinal distributor groove 14, also provided in the outer face of main piston 2 and continuously communicating with the pump work chamber 6, connects, during each pressure stroke, the pump work chamber 6 with one of the pressure conduits 15 leading to the injection valves associated with the cylinders of the internal combustion engine. In each pressure conduit 15 (only one shown) there is disposed a pressure control valve 16.

During each pressure stroke of the piston 2, 3, the regulator shuttle 9 is displaced in a cylinder 18 against the force of a return spring 19 which moves said regulator shuttle into its initial position during the suction strokes of the piston. When in its initial position, the regulator shuttle 9 engages with its collar 20 an abutment 21 forming part of the housing 1. The regulator shuttle 9 is provided with a circumferential annular groove 22 which is bounded by obliquely extending control edges 23 and 24. The annular groove 22 controls a bypass channel formed of portions 25*a*, 25*b* and 25*c* connecting the pump work chamber 6 with the suction chamber 13. The bypass channel portion 25*c* extending between the pump work chamber 6 and the cylinder 13 is in continuous communication with the annular groove 22.

The bypass channel portions 25*a* and 25*b*, both merging into the suction chamber 13, are controlled, respectively, by means of the oblique control edges 23 and 24.

Fuel delivery from the pump work chamber 6 through one of the pressure channels 15 takes place only during those periods of each pressure stroke of piston 2, when both bypass channel portions 25*a* and 25*b* are closed by the regulator shuttle 9. If either bypass channel 25*a* or 25*b* is in communication with bypass channel portion 25*c* through annular groove 22, no fuel delivery through pressure conduits 15 takes place, since the fuel driven by piston 2, flows from pump work chamber 6 to suction chamber 13 through bypass channel 25*c*, 25*a*, or bypass channel 25*c*, 25*b*.

As it may be observed in FIG. 1, in its initial position, the regulator shuttle 9 maintains bypass channel portion 25*a* open and bypass channel portion 25*b* closed. As the regulator shuttle 9 begins its forward stroke in response to the fuel pressure generated by the auxiliary piston 3 in cylinder 18, it executes first a prestroke during which no fuel delivery takes place, since bypass channel portion 25*a* is still open.

The prestroke terminates as the control edge 23 of the regulator shuttle 9 closes the bypass channel portion 25*a*. This moment marks the beginning of the delivery period since both bypass channel portions 25*a* and 25*b* are closed.

As the regulator shuttle 9 travels a predetermined distance, the control edge 24 opens the bypass channel portion 25*b* at which moment the delivery period is terminated.

Thereafter, until the end of the pressure stroke of piston 2, 3, continuous communication exists between the pump work chamber 6 and the suction chamber 13 through bypass channel 25*c*, 25*b*.

It is thus seen that the control edge 23 determines the beginning of the fuel injection, while the control edge 24 determines the termination thereof.

By virtue of a predetermined coordination of the oblique control edges 23 and 24, the travelling path of control shuttle 9, during which injection takes place (delivery period), may be altered by varying the angular position of the regulator shuttle 9. In this manner, the quantities delivered by the fuel injection pump may be set.

The regulator shuttle 9 is angularly adjustable by a rigid assembly formed of a shaft 28 extending outwardly from the housing 1, a disc 26 disposed axially spaced from collar 20 and simultaneously serving as a spring seat disc for return spring 19 and a pin 27 affixed to disc 26 and extending into a depression 29 of collar 20.

In order to improve the scale of adjustment and the accuracy thereof, it is advantageous that the displacement of the regulator shuttle 9 be relatively large. To ensure such result, i.e., the effect a displacement of the regulator shuttle 9 that is greater than that of the pump piston, the radial area or work face 9*a* of regulator shuttle 9 exposed to the fuel pressure in cylinder 18 is greater than the surface area of auxiliary piston 3 generating the fuel pressure in channel 8 and cylinder 18.

During the return stroke of piston 2, 3, the spring 19 causes the regulator shuttle 9 to execute its return stroke.

During its return stroke, the regulator shuttle 9 displaces fuel from the cylinder 18 through channel 8 in an unthrottled manner, so that, independent of r.p.m. and load conditions, the regulator shuttle 9 will always be permitted to return to its initial position (engaging the stationary abutment 21) before the subsequent pressure stroke of piston 2, 3 begins.

The shaft 28 is turnable by an r.p.m. regulator schematically shown at R, which effects, by virtue of the oblique control edge 23, a load-dependent shift in the beginning of the injection. The r.p.m. regulator may be of the electric, hydraulic, pneumatic or mechanical type; it may control idling and terminal r.p.m.s. or may be effective over a large r.p.m. range.

In order to make possible a solely r.p.m.-dependent adjustment of the start of the fuel injection for any given injected fuel quantity per stroke (that is, for any given angular position of the regulator shuttle 9), in auxiliary piston 3 there is provided a channel 30 which extends from the pump work chamber of the auxiliary pump 3, 7. The channel 30 has a throttle 31 which is controlled as a function of the r.p.m. by an axially displaceable sleeve 32 surrounding the auxiliary piston 3. At the beginning of the pressure stroke of piston 2, 3, as long as the throttle 31 is open, the fuel in channels 8, 30 and in cylinder 18 communicates with the suction chamber 13, so that there is insufficient pressure to displace the regulator shuttle 9 in the forward direction against the force of the return spring 19.

As the piston 2, 3 has travelled a predetermined distance, the throttle 31 is closed by the sleeve 32, at which moment the forward motion of the regulator shuttle 9 begins. Dependent upon the position of the sleeve 32, during the beginning of the pressure stroke of the pump piston 2, 3, one part of the fuel is discharged from the pump work chamber of the auxiliary pump 3, 7 into the suction chamber 13, whereby the forward motion of the regulator shuttle 9 and thus the beginning of the injection may be delayed to a greater or lesser extent. The sleeve 32 is displaceable by a hydraulic, electric, pneumatic or mechanical device schematically indicated at 33.

The suction chamber 13 is supplied with fuel by a continuously operating delivery pump 34 which draws fuel from a tank 35. In order to obtain in the suction chamber 13 a pressure increase in response to an r.p.m. increase to operate, for example, a hydraulic device 33, between the pressure side and the suction side of the fuel delivery pump 34 there is provided a return conduit containing a pressure control valve 36.

Turning now to FIG. 2, it will be discussed in more detail how the adjustment of the beginning of the fuel injection by the control edge 23 and the adjustment of the fuel injection by the bypass channel 30 cooperate.

In the upper diagram of FIG. 2 the ordinate indicates the displacement s_R of the regulator shuttle 9 as a function of the angular position α (indicated along the abscissa) of a driving means (usually a cam) associated with the pump piston to cause a reciprocating motion thereof. In the lower diagram, the ordinate indicates the piston stroke s_K of the pump piston as a function of said angle α.

The curve I characterizes the motion of the regulator shuttle 9 when the sleeve 32 is in a relatively low position (as viewed in FIG. 1). As soon as the pump piston has travelled a distance s_1 (curve III), (at which instant the bypass channel 30 is closed by sleeve 32), the regulator shuttle 9 begins its forward motion. As soon as the regulator shuttle 9 is displaced a distance s_2, the control edge 23 closes the bypass channel portion 25*a*. Thus, fuel injection begins at the moment the driving cam assumes an angle α_2 and lasts until it reaches an angle α_3. By that time the regulator shuttle 9 has travelled a distance s_3 at which point the oblique control edge 24 opens the bypass channel portion 25*b*. Upon this occurrence, the fuel injection is interrupted and the fuel still present in the pump work chamber 6 is displaced during the remainder of the pressure stroke of the piston from the pump work chamber 6 into the suction chamber 13. If now for the same angular position of the regulator shuttle 9, the flow passage section 31 is, for example, due to an increasing r.p.m., enlarged (i.e., the sleeve 32 is shifted to a relatively higher position), then the axial motion of the regulator shuttle 9 is characterized by curve II. In such a case, the pump piston has to travel a distance s_4 before the regulator shuttle 9 begins its forward motion. Only when the driving means reaches an angular position α_5, will the control edge 23 close the bypass channel portion 25*a*. The displacement of the regulator shuttle 9 prior to opening the bypass channel portion 25*b* by the control edge 24 is, as in case of curve I, again s_3. At that moment, the angular position of the driving means is α_6. It is thus seen that by changing the flow passage section 31, the beginning of the fuel injection may be adjusted leaving the delivered fuel quantities unchanged.

When the r.p.m. regulator R angularly displaces the regulator shuttle 9, the length of its stroke portion s_3-s_2 varies and consequently, the injected fuel quantities change. Thus, for example, for another given angular position of the regulator shuttle 9, the beginning of the fuel injection would start after travelling a distance s_5, whereas the termination of the injection would occur upon travelling a distance s_6. Since the stroke portion s_6-s_5 is smaller than s_3-s_2, the injected fuel quantities for this new angular position of regulator shuttle 9 are smaller than those for the previous angular position.

Turning now to FIG. 3, the second embodiment shown therein operates substantially in the same manner as the first embodiment described in connection with FIG. 1 except for some structural and functional differences now to be described.

In the said second embodiment depicted in FIG. 3, the pump piston, in addition to stepped portions 2 and 3, has a third stepped portion 4 which operates in a cylinder 38 and serves as a delivery pump drawing fuel from the tank 35 through a supply channel 39 and introducing it to the suction chamber 13. In this embodiment, the pump 3, 7 is the injection pump proper, whereas the pump 2, 5 associated with the pump work chamber 6 operates as the auxiliary pump. For adjusting the beginning of the injection as a function of the r.p.m., the sleeve 32 is displaced against a spring 40 by the pressure prevailing in the suction chamber 13. In this manner the flow passage section 31 is changed. This regulation may be effected, for example, by electrical means, Thus, the sleeve 32 may be displaced only if a solenoid shutoff valve 41 opens a channel 42 which connects the chamber 46 containing the spring 40 with the supply channel 39. Signals characterizing the actual position of the sleeve 32 may be applied by an electromagnetically operated position sensor 43 to an electronic control device (not shown) for setting the beginning of the injection.

A control device 44 for setting the delivered fuel quantities receives signals from an electronic r.p.m. regulator (not shown) to which the signals characterizing the actual r.p.m. are applied by an r.p.m. sensor 45.

What is claimed is:

1. In a fuel injection pump the improvement comprising

A. a first cylinder,

B. a main piston slidably disposed in said first cylinder and defining therewith a pump work chamber,

C. means for reciprocating said main piston,

D. pressure conduit means communicating with said pump work chamber to carry fuel pressurized in said pump work chamber by each pressure stroke of said main piston,

E. a second cylinder,

F. an auxiliary piston slidably disposed in said second cylinder,

G. means to operate said auxiliary piston synchronously with said main piston,

H. a third cylinder,

I. a regulator shuttle slidably disposed in said third cylinder and having a work face and at least one oblique control edge,

J. a channel connecting said second cylinder with said third cylinder to carry to said work face liquid pressurized by each pressure stroke of said auxiliary piston for displacing said regulator shuttle,

K. spring means in engagement with said regulator shuttle for opposing the hydraulic pressure generated by said auxiliary piston during its pressure strokes,

L. a bypass channel communicating with said pump work chamber and with said third cylinder, said bypass channel being opened by said control edge during the reciprocation of said regulator shuttle to interrupt the delivery of fuel through said pressure conduit means,

M. r.p.m.-dependent means connected to said regulator shuttle for angularly displacing the latter to vary the position of said control edge as a function of the r.p.m.,

N. a stationary abutment engaged by said regulator shuttle in the initial position thereof, said spring means urging said regulator shuttle into engagement with said stationary abutment and

O. an unthrottled conduit means communicating with said third cylinder adjacent the work face of said regulator shuttle for carrying in a free flow the liquid displaced by said work face of said regulator shuttle when moved towards said stationary abutment by said spring means, said unthrottled conduit means permitting said regulator shuttle to return to said initial position during the suction strokes of said main and auxiliary pistons regardless of the magnitude of the r.p.m.

2. An improvement as defined in claim 1, wherein said channel defined in (J) and said unthrottled conduit means defined in (O) are one and the same component.

3. An improvement as defined in claim 1, wherein the work face of said regulator shuttle exposed to said hydraulic pressure is larger than the surface of said auxiliary piston generating said hydraulic pressure.

4. An improvement as defined in claim 1, including

A. an additional bypass channel leading from said pump work chamber and

B. means forming part of said regulator shuttle to close said additional bypass channel upon a predetermined displacement of said regulator shuttle during the forward stroke thereof away from said abutment.

5. An improvement as define in claim 4, wherein said last-named means is constituted by an additional oblique control edge closing said additional bypass channel after a displacement of said regulator shuttle, said displacement is determined by the angular position of said regulator shuttle.

6. An improvement as defined in claim 4, wherein said last-named means is constituted by an additional control edge; said regulator shuttle includes a circumferential annular groove bounded by the two said control edges, said groove is in continuous communication with said pump work chamber.

7. An improvement as defined in claim 1, wherein said regulator shuttle includes an axially extending groove maintaining said bypass channel continuously open during displacement of said regulator shuttle if the latter is in a predetermined angular position.

8. An improvement as defined in claim 1, wherein a plurality of main pistons and regulator shuttles are provided in a serial arrangement, said regulator shuttles are angularly adjustable as a unit by a sole toothed rack.

9. An improvement as defined in claim 4, including

A. an auxiliary pump work chamber associated with said auxiliary piston,

B. an additional bypass channel leading from said auxiliary pump work chamber and

C. r.p.m.-dependent means for controlling said additional bypass channel to delay the buildup of said hydraulic pressure as a function of the r.p.m.

10. An improvement as defined in claim 9, wherein said additional bypass channel is closed by said auxiliary piston after a predetermined displacement forming a part of its pressure stroke.

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