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(54) FUEL INJECTION PUMP FOR AN INTERNAL COMBUSTION ENGINE

(71) We, ROBERT BOSCH GMBH, a German Company, of Postfach 50, 7 Stuttgart 1, Federal Republic of Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a fuel injection pump.

A fuel injection pump is known which comprises a cam drive, for actuating a pump piston. To adjust the timing of the commencement of injection, a member of the cam drive, supported in the pump housing, is pivotable relative to its rotary member by means of a timing control piston, which is acted upon by the engine-speed-dependent pressure of a feed pump, against the force of an injection timing adjustment spring. The force of at least one spring is increasable after starting-up by means of a support member.

In such a fuel injection pump, the support member is adjusted in dependence upon the speed of rotation of the engine, in order to retard the commencement of injection. While the support member enables the timing to be advanced at starting and idling speeds, above a predetermined speed exceeding idling speed the support member is adjusted to retard the timing. Advance of the timing has the advantage of rapid run-up of the internal combustion engine during starting, but the disadvantage that, when the internal combustion engine has warmed up, the running of the engine is very rough, that is, noisy. Engine temperature, in association with the commencement of injection, has a decisive influence on combustion characteristics such as noise, toxic emission and consumption. The inflexibility of these known systems does not permit an adjustment of timing at the commencement of injection with reference to engine speed.

According to the present invention there is provided a fuel injection pump for an internal combustion engine, comprising a cam drive for actuating a pump piston, the cam drive having

a member supported in a housing of the pump and angularly displaceable, for the purpose of adjusting injection timing, relative to a rotary member of the cam drive by means of an injection timing control piston, the control piston being, in use, subject to engine-speed-dependent pressure of fuel acting in opposition to the force of a return spring which abuts a support member, and a control element operative to alter the timing of the commencement of injection after the engine has warmed up with respect to that prevailing before the engine has warmed up by causing displacement of the return spring in a first direction to increase the force of the spring and in a second direction to decrease the force of the spring.

The fuel injection pump according to the present invention has the advantage that, by means of an injection-commencement timing system, controlled primarily in dependence upon the speed of rotation of the engine, the timing of the commencement of injection can be retarded even at low engine speeds, when the internal combustion is warm, in order thus to improve noise, toxic emission and fuel consumption during combustion.

In a fuel injection pump in accordance with the present invention a temperature-dependent injection-timing adjustment may be superimposed upon injection timing governed by injection-technical considerations. Such superimposition may range from a simple, arbitrary timing adjustment or coordinating arrangement to an automated system. The degree of automation may advantageously be increased by the use of modules. A variety of types may thus be achieved by simple means, in which the basic modules, such as an adjustable support member, are provided in all the adjusting devices.

The invention will hereinafter be further described by way of example, with reference to the accompanying drawings in which:

Figure 1 is a graph in which, for a fuel injection pump in accordance with the present invention, injection timing angle is plotted as ordinate and engine speed is plotted as abscissa,

Figure 2 is a cross section through part of a

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first embodiment of an injection pump in accordance with the invention and comprising a cam for effecting timing adjustment,

5 Figure 3 is a cross section through part of a second embodiment of an injection pump in accordance with the present invention in which the control element comprises an expansible material,

10 Figure 4 is a cross section through part of a third embodiment of an injection pump in accordance with the present invention in which the control element comprises an expansible material,

15 Figure 5 is a cross section through part of a fourth embodiment of an injection pump in accordance with the present invention in which the control element comprises an expansible material,

20 Figure 6 is a cross section through part of a fifth embodiment of an injection pump in accordance with the present invention in which the control element comprises an expansible material,

25 Figure 7 is a cross section through part of a sixth embodiment of an injection pump in accordance with the present invention in which the control element comprises a plurality of bimetallic discs,

30 Figure 8 is a cross section through part of a seventh embodiment of an injection pump in accordance with the present invention in which the control element comprises an expansible material,

35 Figure 9 is a cross section through part of an eighth embodiment of an injection pump in accordance with the present invention in which the control element comprises a solenoid, and

40 Figure 10 is a cross section through part of a ninth embodiment of an injection pump in accordance with the present invention in which the control element comprises a throttle.

It is known that, in diesel engines, injection takes place when the engine piston is in the region of its upper dead centre (U.D.C.). According to the engine speed, the instant of commencement of injection occurs before or just after U.D.C., and, in general, earlier at high speeds than at low engine speeds. While the time taken by the fuel to travel from the pump to the nozzle remains substantially constant, irrespective of the engine speed, as the engine speed increases, the commencement of injection is retarded owing to the differential between the pump feed rate and combustion in the engine. This change of relationship with respect to time is compensated by means of the injection timing adjustment, and a substantial proportion of the potential energy of the pump is used for this purpose. The rest of the pump's potential energy, however,

60 serves, according to the requirements of the internal combustion engine, to improve fuel consumption, performance, engine noise, and/or exhaust emission. It is known that ignition lag in a diesel internal combustion engine is dependent upon temperature, namely:

1. the fuel temperature, and
2. the temperature of the internal combustion engine, in the form of cylinder-wall temperature, injection temperature, etcetera.

In order to compensate for this ignition lag, 70 when an internal combustion engine is cold, it is advantageous to advance the commencement of injection. In the case of a warm internal combustion engine, however, advanced injection would result in rough running: the 75 engine would be noisy. It is known that advancement of the injection is advantageous when starting, in order to achieve a rapid run-up of the engine. A further feature of a cold internal combustion engine is that less 80 blue smoke is generated when injection takes place early, than when it is late. According to the present invention, therefore, when the engine is cold, the timing of the commencement of injection is advanced throughout the 85 entire speed range of the engine, and is then retarded when the engine has warmed up. The disadvantage, such as blue smoke and noisy running of the engine when the engine is cold, are less noticeable in the upper range of 90 engine speeds.

In the graph shown in Figure 1, the injection timing angle  $\alpha$  is shown on the y-axis, and the engine speed 'n' on the x-axis. The injection timing angle is understood to refer to the 95 relative angle of rotation between the driving shaft and the piston drive, as further explained hereinafter. The speed 'n' is the speed of rotation of the pump, or the proportional engine speed. The characteristic 'F' corresponds to the 100 injection timing at normal working temperature. According to this characteristic F, any speed 'n' corresponds to a predetermined timing angle  $\alpha$ . The higher the speed 'n', the greater the timing angle  $\alpha$ , and the earlier the commence-105 ment of injection. The present invention seeks to achieve a displacement of the characteristic F to the position F1 shown by a broken line. In the case of the characteristic F1, a predetermined adjustment of the timing angle  $\alpha$  takes place at 110 a corresponding lower speed. While, according to the characteristic F, a timing adjustment just commences at the speed  $n_1$ , at the speed  $n_1$  in the case of the characteristic F1, a timing adjustment  $\alpha_1$ , in a direction to advance the 115 timing, takes place. In the case of the characteristic F1, a timing adjustment would take place at the speed  $H_2$ , that is, a speed far below the idling speed. F1 is obtained by superimposition of the characteristic F, that is, by variation of 120 the restoring force of the injection timing adjuster. F2 shows a transition between the characteristics F1 and F, that is, a gradual reduction in superimposition as the speed increases, the superimposition being controlled in dependence upon 125 engine temperature. The reduction may also be performed in dependence upon rotational speed, by means, for example, of a device as shown in Figure 9.

As shown in Figure 2, an injection timing de- 130

vice 2 acts upon a cam mechanism 1 of an injection pump, which is not shown. In the embodiments selected, the pumps are distributing injection pumps, in which, substantially, two types of cam mechanisms are used. In the case of one type, rollers are connected to a pump piston and cams are arranged on a ring, supported on the pump housing. In the other type, selected here as an example, the rollers are arranged to roll on a ring supported on the pump housing, and the cams are connected by means of a cam disc to the pump piston. In each case, the pump piston is independently driven, while the rollers and cams cooperate to provide the pumping action, the rollers or the cams, according to the type of drive, being rotationally movable relative to each other, via the ring supported on the housing, by means of the injection timing device 2.

A roller ring 4, which is connected to the injection timing device 2 by means of an adjusting pin 5, is supported in a housing 3 of the fuel injection pump shown in the embodiment in Figure 2, Rollers 7, a plan view of which is shown, are supported on axles 6 on the roller ring 4. A cam disc, which is not shown, but which is connected to the pumping and distributing piston, moves on these rollers. The pump piston and the cam disc rotate in the direction shown by the arrow. When the roller ring 4 is rotated only a few angular degrees counter to this direction of rotation, the commencement of delivery by the pump piston takes place earlier. If the amount of fuel for injection is determined, not by regulation of the commencement of fuel delivery, but by regulation of the cessation of fuel delivery, such an adjustment thus means also a variation in the commencement of injection into the internal combustion engine.

The adjusting pin 5 of the cam mechanism engages in a driving cavity 8 in a timing control piston 9, which is movable by means of hydraulic pressure against the force of a return spring 10. The further the piston 9 is displaced against the spring 10, the earlier the commencement of injection. In the initial position shown, the timing control piston 9 is in abutment with a stop 11. The hydraulic pressure serving to effect displacement is generated in a known manner by means of a feed pump (not shown), which is formed integrally with the housing 3 of the fuel injection pump and is driven at the same speed as the latter. The output pressure of this feed pump is so controlled via a pressure control valve, that it varies in proportion to the speed of rotation of the pump, that is, it increases as the speed increases, and decreases as the speed decreases. In the embodiment, this feed pump delivers into the housing 3, fuel serving as the fluid, which is delivered via correspondingly supply bores to the pump working chamber (not shown). Additionally however, it flows via a blind bore 12, provided in the timing control piston 9, into which blind bore 12 the adjusting pin 5 also

extends, via a throttling bore 13 and a bore 14, to the end face 15 of the timing control piston 9. Given a sufficiently high feed pressure, the timing control piston 9 is then displaced against the force of the spring 10, whereby the commencement of injection is advanced, as described above.

Shifting of the characteristic F to F1 is performed by variation of the force of the return spring 10. When the force of the spring 10 is reduced, shifting of the commencement of injection commences at lower speeds, for example at the speed  $n_2$ . Consequently, if an idling speed  $n_1$  is selected, an adjustment  $\alpha_7$ , to advance the timing, takes place. If the force of the spring 10 is then again increased, displacement of the piston 9 commences only at the speed  $n_1$ . By the use of two springs, the force, for example of one of which is variable in dependence upon temperature, it is possible to achieve a characteristic F2, representing more advanced timing at low engine speeds than at high engine speeds.

At its end remote from the timing control piston 9, the spring 10 abuts a support member 17, whose position is variable in order to achieve one of the desired characteristics F1 to F. In the embodiment shown in Figure 2, displacement of the support member 17 is performed via a shaft 18, arranged transversely to the axis of the support member 17. On its circumferential surface 19, whose cross-section is substantially circular, the shaft 18 has a flat portion 20. According to the rotational position of the shaft 18, the support member 17 abuts either the circular periphery, or, by transition thereto, the flat portion of the shaft. So long as the support member 17 is in abutment with the flat portion 20, the force of the spring 10 is reduced, as represented by the characteristic F1. The shaft 18 is pivotable by means of a lever 21, which serves as a positioning element, and which is acted upon by a control element, which may be a thermostat, a servo electric motor, or a mechanical device. The shaft 18 can be pivoted by means of the lever 21 to a position in which the support member 17 is in contact with the circumferential surface 19. The force of the spring 10 is thereby increased, so that adjustment of the commencement of injection takes place only at the rotational speed  $n_1$ , as represented by the characteristic F. In the drawing, the lever 21 is shown in an intermediate position, that is, the support member 17 is in abutment, not with the surface 20, but with a transition point 22 between the flat portion 20 and the circumferential surface 19. Such an intermediate position, if maintained, provides a characteristic F3, shown in Figure 1. However, a shift from low speed to high speed, from abutment of the support member 17 with the flat portion 20 to abutment with the circumferential surface 19, then gives the characteristic F2. Thus, superposition of the adjustment on the timing of

the commencement of injection is applied, to a greater or lesser degree, by a pivotal movement of the lever 21. When the support member 17 is in abutment with the circumferential surface 19, no superimposition takes place; when the support member 17 is in abutment with the flat portion 20, maximum superimposition is provided.

The simplest method of effecting the desired partial advance of the timing, when the engine is cold, is by mechanical means, operated by the driver of the internal combustion engine. When the engine has heated up, it also becomes relatively noisy, so that the driver can rotate the lever 21 by means of a device, in order to cancel the superimposed timing advance and restore normal injection timing. This provides substantially quieter running. Should the driver forget to advance the timing when starting a cold engine, this causes, first of all, poor starting of the engine, and, secondly, relatively noisy running. Accordingly, he will be prompted to move the lever 21 to the appropriate starting and warming-up position, and then, as described above, when the engine has warmed up, to move it to the normal position. Such a mechanical device may be compared with the choke of an internal combustion engine, by means of which the fuel-air mixture is enriched for starting and warming-up.

The embodiment shown in Figure 3 shows how adjustment of the injection timing adjusting spring 10 takes place automatically as temperature increases. Here, the control element is an operating member 23, of expansible material, arranged in a portion 24 of the housing, whose internal chamber 25 is adapted to permit the flow of cooling water from the engine. Inlet and outlet connections 26 are provided for the cooling water. A relieving spring 27 abuts the face of the support member remote from the spring 10, the relieving spring 27 being subjected to somewhat greater force than the return spring 10 of the injection timing control piston 9, but the force of the relieving spring being variable by means of the thermostat 23. For this purpose, the operating pin 28 of the expansion element acts via a guide bolt 29 upon a spring retainer 30 for the spring 27. When, on an increase in temperature, the operating pin 28 moves out, it displaces the support member 17, via the relieving spring 17, towards a stop 31, which is integral with the housing. Owing to the displacement of the support member 17, the force of the return spring 10 is correspondingly increased, which causes a shift of the characteristic from F1 to F. The force of the return spring 27 is determined by the bolt 29, which clamps the spring retainer 30 and the support member 17 between its head 32 and a locking ring 33 respectively. When the support member 17 is in abutment with the stop 31, and the temperature continues to rise, the operating pin 28 moves correspondingly further out, and thus compresses the spring 27, without any resultant further alteration of the degree of

adjustment of the injection timing.

Figure 4 shows an automatic device, whose operation is similar in principle to that of Figure 3. Instead of the relieving spring 27, however, the fuel pressure of the feed pump acts upon the spring support member. For this purpose, the spring support member 17 is in the form of a stepped piston, whose end face 35 extends into a chamber 36, into which fuel is fed, under the pressure of the feed pump, via a line 37. In the housing 24 there is provided a radial seal 38, abutting the piston 17. The end face 35 is preferably smaller than the end face 15 (Figure 1) of the timing control piston 9. Owing to the pressure in the chamber 36, a force less than the force of the spring 10 acts upon the piston 17, so that no displacement of the piston 17 takes place. Only when the operating pin 28 of the thermostat 23 moves out, when the thermostat reaches a sufficiently high temperature, is the piston 17 displaced against the spring by means of this pin 28, acting upon the end face 35, with a resultant increase in the force of the spring, and hence shifting of the characteristic F1 to F, as in the previous embodiment. If the piston 17 is in abutment with the stop 11, on further heating of the thermostat 23, the latter is displaced against the force of a spring 39, which must, of course, be stronger than the spring 10. The advantage of hydraulic assistance is, in particular, that the force required to be exerted by the pin 28 is very much less than if no assistance at all were provided. Consequently, much more accurate control of the stroke of the operating pin 28, according to temperature, is possible.

In the embodiment shown in Figure 5, the arrangement of which is similar to that shown in Figure 4, the control function of the thermostatic operating element 23 is reversed. At the same time as the diesel engine is preheated by means of a heater plug, the expansion element is heated by means of an electrical heating filament 41, so that the thermostat 23 is displaced by the operating pin 28 against the force of the spring 39. For this purpose, the operating pin 28 abuts a base 42, formed integrally with the housing. The support member 17, in the form of a piston, as in Figure 4, is claimed between the spring 10 and the housing of the thermostat 23. Pins 44, attached either to the piston 17 or to the housing of the thermostat 23, are used for clamping. On heating and displacement of the thermostat 23, the piston 17 also moves to the left in the drawing, so that the force of the spring 10 is reduced, with resultant advance of the commencement of injection at lower engine speeds (see Figure 1). As soon as the internal combustion engine has been started, the heating filament 41 is switched off (for example, by means of the starter switch), whereafter cooling of the expansion element 23 takes place. This cooling naturally takes longer than the heating-up,

since it is performed purely by the ambient atmosphere. Only when the expansion element 23 has cooled and the operating pin 28 retracts accordingly, are the pins 44 displaced by the spring 39 via the body of the thermostat 23, so that the support member 17 moves to the right in the drawing to abut against the stop 11. In this position, the force of the spring 10 is increased, and corresponds to an adjustment of the timing of the commencement of injection in accordance with the characteristic F of Figure 1, for normal operation. Balancing of the cooling time of the thermostat 23 with the warming-up time of the internal combustion engine can be achieved without difficulty. Under certain circumstances, the heating action of the heating filament 41 must be correspondingly prolonged. As in the case of the embodiment shown in Figure 4, in this case also, the end face 35 of the piston 17 is acted upon by the pressure of the fuel, which is delivered by the feed pump via the line 37 to the chamber 36. This force acting upon the piston 17 assists its displacement in a direction towards the spring 10. However, the end face 45 of the thermostat 23 also extends inside the chamber 36, so that the fuel pressure in the chamber 36 assists displacement of the thermostat 23 against the force of the spring 39. The operating force of the operating pin 28 can thereby be reduced to a necessary minimum, with consequently enhanced accuracy of control.

In the embodiment shown in Figure 6, adjustment of the support member 17 is blockable via the thermostatic control element. The support member 17 is a stepped piston, whose two steps and the housing 34 define a chamber 47. Again, its end face 35 is acted upon by fuel at feed-pump pressure, the fuel being fed via the line 37 to the chamber 36. The end face 35 must be of such a size that, when subjected to the pressure of the feed pump, it permits displacement of the spring 10. For this purpose, it must be larger than the end face 15 of the injection timing control piston 9, which is not shown here. In this case, the thermostat 23 controls a valve 48, arranged in a line 49, which leads to the chamber 47 and is connected to a low-pressure source. When the operating pin 28 of the thermostat 23 is retracted, as shown in the drawing, the connection is open, and the piston 17 is movable against the force of the spring 10, whereby the force of the spring 10 is increased. As in the preceding example, the thermostat is heated by means of an electrical filament 41 on preheating of the internal combustion engine. The valve 48 is thereby closed by means of a ball 50, which is pressed against a valve seat 41. Following closure of the valve, the complete thermostat can be displaced against the spring 39, in order to permit the operating pin 28 to move out again. When the valve 48, in order, by means of the low feed-pressure not be displaced during starting of the engine

and the building-up of feed-pump pressure in the chamber 36, since the chamber 47 is blocked. When the valve 48 opens, after the thermostat 23 has cooled, fuel flows out of the chamber 47, via the line 49, and the piston 17 is displaced, to increase the force of the spring 10. A further non-return valve 52 is provided in the valve 48, in order, by means of the low feed-pressure during the normal mode of the internal combustion engine, to fill the chamber 47 with fuel. This non-return valve 52 also enables the chamber 47 to be filled, as long as the valve 48 is closed owing to heating up and the piston 17 is biased to the left by the spring 10. Such a situation may arise when, the internal combustion engine having been switched off, the piston is in a corresponding retarded-timing position (moved to the right), and movement of the piston 17 to the left is possible only through a reduction of the feed-pump pressure. Since the primary feed pump, which produces the pressure in the line 49, starts to operate as soon as preheating for the start takes place, before pressure is built up by the feed pump in the chamber 36, the primary feed pump is able to fill the chamber 47 via the valve 52, even if, owing to the preheating, the ball 50 is already in abutment with the valve seat 51. Thus, when the thermostat 23 cools down after the heating element 41 is switched off, it must first, owing to the force of the spring 39, assume its initial position as shown, before the ball 50 lifts away from the seat 51 permitted by retraction of the operating pin 28. This period must be coordinated with the warming-up period of the internal combustion engine. Also, when the ball starts to lift away from the seat 51, first of all only a cross-section of the throttle is opened, which then permits slow displacement of the piston 17 in the direction of the spring 10. Thus, there is no abrupt transition from the characteristic F1 to the characteristic F, but a transition via the characteristic F2 or a plurality of characteristics F3.

The embodiment shown in Figure 7 operates on the same principle as that of Figure 3. In this case, instead of an expansion element, a sleeve 53, provided with bimetallic discs 54, serves as a thermostat. The sleeve 53 is likewise arranged in the housing 24, and is subject to the flow of cooling water, for which inlet and outlet connections 26 are provided. These bimetallic discs 54 curve to an increasing degree as the temperature rises. A number of such bimetallic discs 54 are arranged in the sleeve 53, and act cumulatively upon the support member 17 for the spring 10. Since the bimetallic discs 54 may curve to an extent exceeding the desired stroke, and thereby cause an increase in the length of the stroke, a spring 56, which cooperates via a spring retainer 57 with the bimetallic discs 54 and absorbs an excessive length of stroke, serves to neutralise this effect. An adjusting screw 58 is arranged in the spring retainer 57 for

adjusting the basic setting. The bimetallic discs 54 are shown in the drawing in the warm state, that is, the spring 10 is stressed and the injection timing deviec is correspondingly retarded.

5 An arrangement incorporating bimetallic discs is also possible, in which the bimetallic discs straighten as temperature increases, that is, maximum curvature occurs in the cold  
10 state, so that, similarly to the embodiments shown in Figures 5 and 6, heating of the bimetallic discs takes place before starting, with a consequently greater release of force of the spring 10. Following starting-up of the internal  
15 combustion engine, these bimetallic discs 54 then cool off, which causes them to curve and to shift the piston 17 so the position shown, in which the force of the spring 10 is once again increased.

20 In the embodiment shown in Figure 8, as in the embodiment shown in Figure 6, the end face 35 of the piston, serving as a support member 17 for the spring 10, is acted upon by fuel at feed-pump pressure. In order to effect displacement of the piston 17 independently of  
25 the timing control piston 9, the end face 35 is larger than the end face 15 of the timing control piston 9. The line 37, carrying the fuel at feed-pump pressure, is controlled by a thermostatic valve 60, before it discharges into the chamber 36. This thermostatic valve incorporates an operating member 23, of expansible material, whose operating pin 28 actuates the valve member 61, so that, when the pin 28 is  
30 in an extended position, an annular groove 62 on the valve member 61 opens the line 37. The valve member 61 is displaced against the force of a spring 63. The expansion element 23 is once again arranged in a housing 24, in whose interior 25 cooling water circulates, connections  
40 26 being provided for the inlet and outlet of the cooling water. When the engine is cold, the piston 17, displaced by the spring 10, assumes an initial position adjacent to the valve 60, for  
45 which the force of the spring 10 is reduced, which corresponds to an advance of the timing in accordance with the characteristic F1. When after the internal combustion engine has heated up, the line 37 is opened, as shown, and the  
50 piston 17 is moved in the direction of the spring 10, the force of the latter is increased, in accordance with the characteristic F for retardation of the timing. Since, in this case also, displacement of the valve member 61 is gradual,  
55 intermediate positions of the piston 17 occur, according to the throttle effect. In order to ensure a slight, but constant, flow of fuel via the line 37 when the thermostatic valve 60 is open, a throttle bore 64 is provided in the piston 17,  
60 for connecting the chamber 36 to the pressure-relieved chamber accommodating the spring 10.

Instead of an expansion element, a magnet may be used for actuating the valve member 61. When the engine is switched off, the line 37  
65 would then be blocked before the piston 17

had reached its initial position. Owing to the throttle bore 64, the piston 17 is nevertheless able to move to its initial position, in order to permit the corresponding desired advance of the timing on renewed cold starting.

70 Figure 9 shows a further possibility of varying the force of the spring 10. It is possible for the spring retainer 17 to be displaced, against the force of the spring 10, by means of a solenoid 65, screwed into the housing 24. For this  
75 purpose, the armature 66 of the solenoid valve cooperates with the support member 17. For partial force equalisation, a spring 67, whose rear end abuts the housing 24, acts upon the side of the support member 17 remote from the  
80 spring 10. As in the case of the above embodiments, several methods of actuation and control are possible. According to the method shown, the armature 66 is rigidly connected to the support member 17. The solenoid 65 is energised on 85  
starting up, and the support member 17 is thereby displaced against the force of the spring 67. The force of the spring 10 is thereby reduced, as desired. When the internal combustion engine has heated up, the solenoid is switched off,  
90 and the spring 67 displaces the support member 17, against the force of the spring 10, so that its force now corresponds to the characteristic F in Figure 1. There is also the other possibility however, of constructing the solenoid to operate  
95 in the reverse direction, so that the solenoid is switched on only after warming-up, in order then to displace the support member 17, against the force of the spring 10. For this purpose, the spring 67 would, in contrast to the previous  
100 example, have to be weaker than the spring 10. A disadvantage of such a method would be, of course, that the solenoid would be energised during normal operation; however, it would have the advantage that the internal combustion  
105 engine would be easy to start, even in the event of failure to the solenoid.

In the embodiment shown in Figure 10, as in the embodiment shown in Figure 8, a piston 17  
110 is used to vary the force of the spring 10, the piston 17 being larger in diameter than the timing control piston 9, and being displaceable by means of the pressure of the feed pump, acting upon one face 35 of the piston 17.

115 Between the piston 17 and the cylinder 69, in which it is guided, there is provided a seal 70, for providing a seal between the chamber 36 and the spring compartment.

Towards the feed end of the piston 17 there is provided a smaller-diameter portion 71, which  
120 is guided in a bore 72 of the timing control piston 9, and has a seal 73, for providing a seal with respect to the bore 72. The bore 72, in its turn, is connected to the blind bore 12 (Figure 2), which is subject to the pressure of the feed  
125 pump, in the timing control piston 9. A bore 74, which connects the chamber 36 to the bore 72 and hence also to the blind bore 12, extends through the piston 17 and the piston portion 71.

The bore 74 is in the form of a throttle bore, 130

so that, after starting-up of the engine, the piston is displaced very slowly against the force of the spring 10, according to the throttle effect in the bore 74, as represented by the characteristic F2. The throttle must be relatively narrow, as the adjusting time must correspond to the warming-up time of the engine. On cooling of the engine, and when it is stationary, the pistons 17 slides back gradually to its initial position. In order to be able to size this throttle, a pin 75 attached to the end wall of the chamber 36, is arranged in the bore 74. Obstruction of the annular clearance is prevented by the relative movement of the pin 75 and the piston 17.

The fuel, subjected to the pressure of the feed pump, can also be fed to the chamber 36 from outside, of course, in which case the pin is attached, advantageously, to the piston, and extends into the feed bore. Moreover, instead of a piston serving to vary the force of the spring 10, it is possible to use a smaller-diameter auxiliary piston, biased by an auxiliary spring and arranged axially in the timing control piston 9. The chamber defined by the timing control piston bore and the auxiliary piston is then in throttled communication with the feed-pump pressure, so that, by means of a displacement of the auxiliary piston, an overall displacement in a direction to retard the timing takes place.

As is clear from the many individual examples, any possible combination of the individual positioning and controlling elements is feasible, in order, in accordance with the present invention, to achieve a relatively stronger adjustment to advance the timing when the internal combustion engine is cold, than when the engine is warm.

WHAT WE CLAIM IS:—

1. A fuel injection pump for an internal combustion engine, comprising a cam drive for actuating a pump piston, the cam drive having a member supported in a housing of the pump and angularly displaceable, for the purpose of adjusting injection timing, relative to a rotary member of the cam drive by means of an injection timing control piston, the control piston being, in use, subject to engine-speed-dependent pressure to fuel acting in opposition to the force of a return spring which abuts a support member, and a control element operable to alter the timing of the commencement of injection after the engine has warmed up, with respect to that prevailing before the engine has warmed up by causing displacement of the return spring in a first direction to increase the force of the spring and in a second direction to decrease the force of the spring.

2. A fuel injection pump as claimed in claim 1 in which positioning means, controlled by the control element, are operative to effect the displacement of the support member.

3. A fuel injection pump as claimed in claim 1 or 2, in which the control element comprises

a thermostat.

4. A fuel injection pump as claimed in claim 3 in which means are provided for heating the thermostat with water from the cooling system of the internal combustion engine.

5. A fuel injection pump as claimed in claim 3, in which means are provided for electrically heating the thermostat.

6. A fuel injection pump as claimed in any of claims 3 to 5 in which the thermostat comprises an operating element of expansible material.

7. A fuel injection pump as claimed in claim 2 or 3, in which the thermostat comprises bimetallic discs serially grouped inside a sleeve.

8. A fuel injection pump as claimed in claim 7 in which a compensating spring is serially connected to the bimetallic discs.

9. A fuel injection pump as claimed in any of claims 5 to 8 comprising an electrical heating filament operative to heat the thermostat only during the engine warming-up period.

10. A fuel injection pump as claimed in claim 1 or 2, in which the control element comprises an electric slave motor.

11. A fuel injection pump as claimed in claim 10 in which the electric slave motor comprises a solenoid.

12. A fuel injection pump as claimed in any preceding claim in which the support member comprises a servo piston, the control element being operative to actuate a valve for controlling a flow of liquid to the servo piston, a throttle bore being also provided for permitting a constant overflow of liquid.

13. A fuel injection pump as claimed in claim 12 in which the throttle bore is disposed in the servo piston.

14. A fuel injection pump as claimed in any preceding claim further comprising means for supplying a restoring force which acts upon the control element and/or the positioning means.

15. A fuel injection pump as claimed in any preceding claim in which the positioning means comprise a positioning element rotatable for displacement of the support member.

16. A fuel injection pump as claimed in claim 15 in which a cam is provided for applying thrust against the support member when the positioning element is rotated.

17. A fuel injection pump as claimed in claim 15 or 16 in which the positioning element comprises a shaft mounted transversely to the support member and pivotable about its longitudinal axis, the shaft having a face extending, in the form of a cam, eccentrically of the axis of rotation, and cooperating with the support member.

18. A fuel injection pump is claimed in which the shaft has a flat portion.

19. A fuel injection pump as claimed in any of claims 1 to 14, further comprising a relieving piston, which in use is acted upon by the pressure of the fuel supplied by a feed pump, the piston being operative to act on a

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- side of the support member remote from the return spring.
20. A fuel injection pump as claimed in claim 19 in which a working surface of the relieving piston and a working surface of the injection timing control piston are of unequal area.
21. A fuel injection pump as claimed in claim 19 in which the relieving piston is a stepped piston, the control element defining a fuel filled volume operative to prevent movement of the stepped piston in a direction towards the return spring.
22. A fuel injection pump as claimed in any of claims 3 to 21, in which the thermostat is operative in its heated state, to reduce the force of the return spring.
23. A fuel injection pump as claimed in claim 22, in which the thermostat is so disposed as to be in abutment with the injection pump housing such that, on being heated, it displaces a stop on the support member.
24. A fuel injection pump as claimed in claim 10 or 11 in which an armature of the slave motor is connected to the support member, which is acted upon by a compression spring against the force of the return spring.
25. A fuel injection pump as claimed in claim 24 in which the slave motor acts as a traction magnet upon the support member, the compression spring being constructed to have a stronger force than that of the return spring, the magnet being energised during the warming-up period.
26. A fuel injection pump as claimed in claim 1 in which the support member, serving as a positioning element, is an hydraulic piston whose end face remote from the spring is adapted to be acted upon by fuel supplied at feed-pump pressure via a throttle serving as a control element.
27. A fuel injection pump as claimed in claim 26 in which the throttle comprises a pin extending inside the supply bore, the axial position of the pin being variable with respect to the position of the bore on the adjusting movement.
28. A fuel injection pump as claimed in claim 26 or 27 in which the support member has a portion which is sealingly supported in a bore of the timing control piston, and an hydraulic connection exists between the pressure side of the timing control piston and the bore.
29. A fuel injection pump as claimed in claim 28 in which the diameter of the timing control piston is smaller than that of the support member, and larger than that of the smaller diameter portion of the support member, the injection timing spring being arranged between the support member and the timing control piston, and the pin, connected to the pump housing, being disposed so as to extend into an axial through bore of the support member and its smaller-diameter portion.
30. A fuel injection pump constructed and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in Figure 3 of the accompanying drawings.
31. A fuel injection pump constructed and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in Figure 3 of the accompanying drawings.
32. A fuel injection pump constructed and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in Figure 5 of the accompanying drawings.
33. A fuel injection pump constructed and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in Figure 5 of the accompanying drawings.
34. A fuel injection pump constructed and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in Figure 6 of the accompanying drawings.
35. A fuel injection pump constructed and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in Figure 7 of the accompanying drawings.
36. A fuel injection pump constructed and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in Figure 8 of the accompanying drawings.
37. A fuel injection pump constructed and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in Figure 9 of the accompanying drawings.
38. A fuel injection pump constructed and adapted to operate substantially as hereinbefore particularly described with reference to and as illustrated in Figure 10 of the accompanying drawings.
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Fig. 1

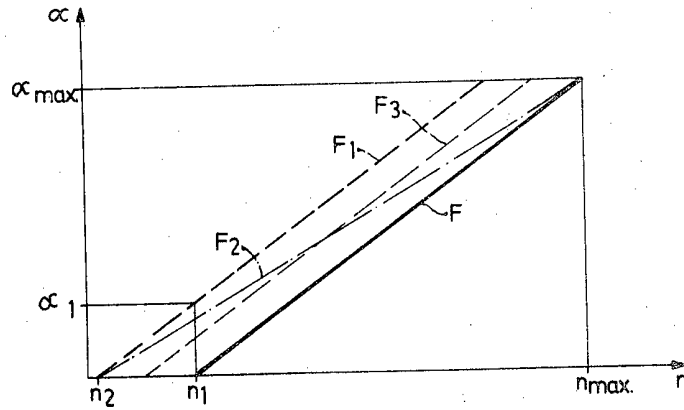


Fig. 2

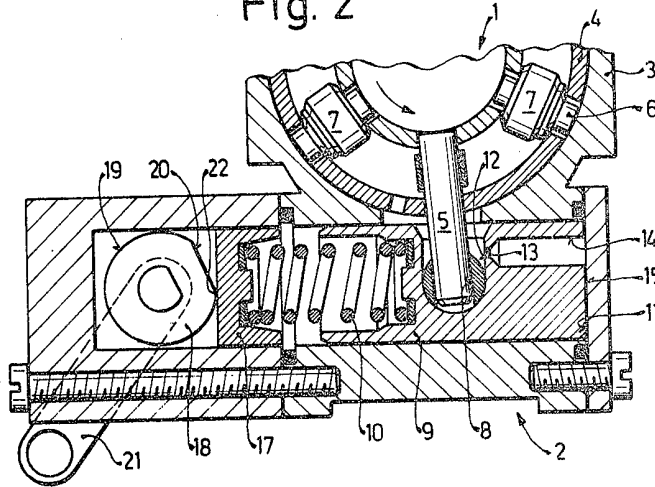


Fig.3

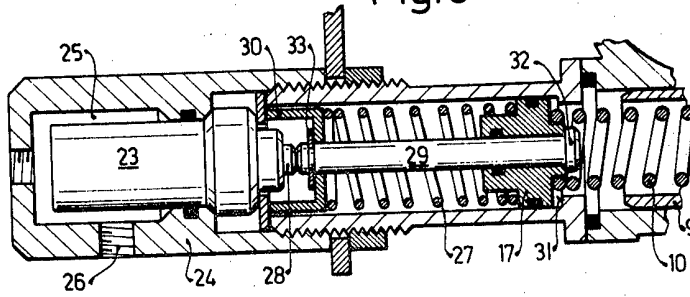


Fig.4

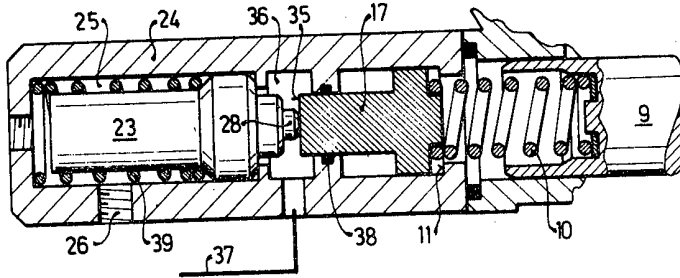


Fig.5

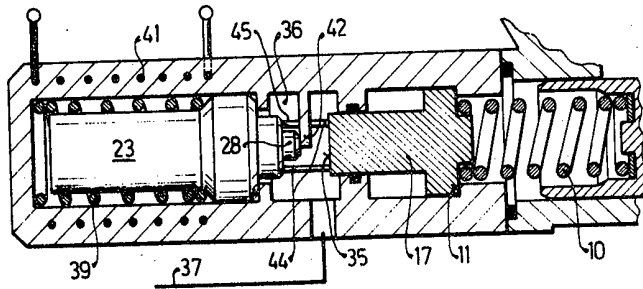


Fig. 6

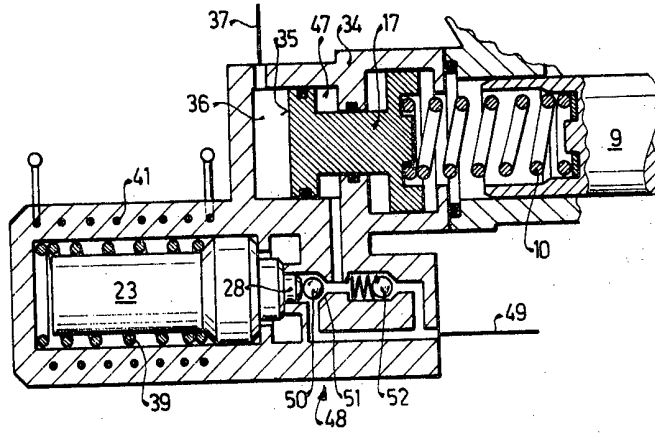


Fig. 7

