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(54) **High pressure fuel pump**

Hochdruck-Kraftstoffpumpe

Pompe à combustible à haute pression

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Description

[0001] The invention relates to a fuel pump for delivering fuel at high pressure to a fuel injection system of an internal combustion engine. In particular, the invention relates to a fuel pump for regulating the pressure of fuel in an accumulator or common rail of a common rail fuel system, as discribed in e.g. US 5 911 208 A.

[0002] A conventional fuel pump for use in supplying fuel to a common rail fuel injection system includes a plurality of pumping plungers, each of which is slidably mounted within a respective cylinder or plunger bore to cause pressurisation of fuel within a respective pumping chamber. A drive arrangement, typically including a tappet and roller arrangement driven by a cam, is operable to cause reciprocal movement of the plunger within its bore.

[0003] An inlet non-return valve is provided to the pumping chamber and is operable in response to feed pressure from a low pressure pump to control filling of the pumping chamber. A delivery non-return valve is operable in response to fuel pressure in the pumping chamber to control the supply of fuel from the pumping chamber to the common rail.

[0004] Figure 1 illustrates plunger movement as a function of time as the tappet rides over the cam surface of the drive arrangement, Figure 2 illustrates the status of the delivery non-return valve through a pumping cycle and Figure 3 illustrates the status of the inlet non-return valve.

[0005] As the plunger performs a pumping stroke to reduce the volume of the pump chamber, the inlet valve is caused to close (time T1) and fuel pressure within the pumping chamber is increased. When fuel pressure within the pumping chamber exceeds a predetermined amount, the delivery valve is caused to open (time T2) to permit high pressure fuel to flow from the pumping chamber to the common rail. During a return stroke of the plunger, the delivery valve is caused to close (time T3) as fuel pressure within the pumping chamber is reduced to less than the predetermined amount to prevent reverse flow from the common rail. Subsequently, the inlet valve is caused to open (time T4) to permit fuel at feed pressure to be drawn in through the inlet valve, filling the pumping chamber ready for commencement of the next pumping stroke.

[0006] It is known to regulate fuel pressure within the common rail through precise control of the pumped volume of fuel on increasing pressure transients by means of the inlet valve and, additionally, by spilling pressurised fuel to drain through a spill valve arrangement during decreasing pressure transients. One disadvantage of this pressure regulation scheme is that it is wasteful of energy, and this has a detrimental effect on vehicle fuel consumption.

[0007] By way of background to the present invention, EP 0711914 describes a common rail fuel system in which fuel is pressurised within a pump chamber, and directed to either a primary accumulator volume, or to a secondary accumulator volume in the event of overpressurisation of fuel within the first accumulator volume. An eletromagnetically operable inlet valve is provided to control the flow of fuel into the pumping chamber.

[0008] It is an object of the present invention to provide an improved scheme for regulating the pressure of fuel within a common rail. According to a first aspect of the present invention, there is provided a fuel pump for use in delivering high pressure fuel to a common rail of a fuel injection system, the fuel pump including:

a pumping plunger which is reciprocable within a plunger bore to cause pressurisation of fuel within a pumping chamber during a pumping cycle, the plunger having a pumping stroke, in which the plunger is driven inwardly within the plunger bore to reduce the volume of the pumping chamber, and a return stroke in which the plunger moves outwardly from the bore to increase the volume of the pumping chamber, in use,

an inlet valve arrangement having an inlet valve which is movable between an inlet open position, in which the pumping chamber communicates with a low pressure fuel source, and an inlet closed position, in which communication between the low pressure fuel source and the pumping chamber is broken, the inlet valve being movable from the inlet closed position to the inlet open position in response to fuel pressure acting on the inlet valve, and wherein the inlet valve arrangement includes a first actuator which is operable to hold the inlet valve in the inlet open position for at least a part of the pumping stroke,

and a delivery valve arrangement having a delivery valve which is movable between a delivery open position, in which the pumping chamber communicates with the common rail, and a delivery closed position, in which communication between the common rail and the pumping chamber is broken, the delivery valve being movable from the delivery closed position to the delivery open position in response to fuel pressure acting on the delivery valve, and wherein the delivery valve arrangement includes a second actuator which is operable to hold the delivery valve in the delivery open position, for at least a period of the return stroke,

thereby to permit filling of the pumping chamber through the delivery valve during the return stroke and to regulate fuel pressure within the common rail.

[0009] The invention permits rail pressure to be regulated by varying the point during the return stroke at which the delivery valve is closed by the second actua-

tor. If the delivery valve is closed towards the end of the plunger return stroke, a relatively large volume of fuel is permitted to flow from the common rail into the pumping chamber, filling the pumping chamber and relieving fuel pressure in the rail. If the delivery valve is closed part way through the plunger return stroke, fuel pressure within the rail is relieved by a lesser amount.

[0010] The pump is configured so as to provide a pumping function to permit pumped fuel to be delivered to the associated common rail, and a motoring function whereby fuel pressure within the common rail is relieved and a drive force is returned to the plunger to aid the return stroke.

[0011] The fuel pump may, but need not, be manufactured to include a drive arrangement for driving the plunger to perform the pumping stroke. The drive arrangement may include a tappet and roller arrangement which is cooperable with a driven cam, in use.

[0012] Alternatively, the drive arrangement may include a shoe and roller arrangement.

[0013] As high pressure fuel is permitted to flow from the rail to the pumping chamber at the end of the return stroke, a force is applied to the plunger and the associated drive arrangement, returning mechanical energy to the driven cam which serves to aid rotation of the drive shaft (i.e. a motoring effect).

[0014] As the actuators are only required to hold the inlet and delivery valves in their open positions, and opening of the valves is by means of hydraulic forces, the actuators do not need to apply a large actuation force to open the valves and need only be relatively compact.

[0015] The fuel pump may also be operated in a normal pumping mode, in which the inlet and delivery actuators are redundant and do not require any power.

[0016] Preferably, the inlet and/or delivery actuator is an electromagnetic actuator.

[0017] Preferably, the delivery valve is biased against a valve seating by means of a delivery valve spring.

[0018] Preferably, the inlet valve is also biased against a further valve seating by means of an inlet valve spring.

[0019] The fuel pump may include a plurality of pumping plungers, each of which is reciprocable within a respective plunger bore to cause pressurisation of fuel within a respective pumping chamber.

[0020] The plungers may be radially mounted about a central drive shaft carrying a cam common to all of the plungers, the cam having a surface with which the roller of each drive arrangement cooperates, in use.

[0021] The cam may be arranged such that the plungers are driven radially inward or radially outward of the cam surface as the rollers ride over the cam surface.

[0022] According to a second aspect of the present invention, there is provided a method of regulating fuel pressure within a common rail of a fuel injection system using the fuel pump described herein, comprising the steps of:

maintaining the inlet valve in the inlct open position by means of a force applied by the first actuator for at least a part of the pumping stroke, and

maintaining the delivery valve in the delivery open position by means of a force applied by the second actuator for at least a part of the return stroke, thereby to permit high pressure fuel within the rail to flow into the pumping chamber during the return stroke so as to regulate fuel pressure within the common rail.

[0023] According to a third aspect of the invention, there is provided a common rail fuel system including the fuel pump herein described, whereby the pump is arranged to perform a pumping function to pressurise fuel within a pumping chamber for delivery to a common rail, and a motoring function to relieve fuel pressure in the common rail and return a drive force to the plunger to aid the return stroke.

[0024] It will be appreciated that preferred and/or optional features of the first and second aspects of the invention may also be incorporated in the third aspect of the invention.

[0025] The invention will now be described, by way of example only, with reference to the accompanying figures in which:

Figure 1 is a graph to illustrate plunger movement in a fuel pump over a pumping cycle,

Figures 2 and 3 are graphs to illustrate the status of the delivery and inlet non return valves respectively during the pumping cycle of Figure 1 for a known fuel pump,

Figure 4 is a sectional view of a part of a fuel pump in accordance with the present invention,

Figure 5 is a graph to illustrate plunger movement over a pumping cycle (as in Figure 1) for the fuel pump of the present invention,

Figure 6 is a graph to illustrate the status of the inlet valve in the fuel pump in Figure 4 throughout a pumping cycle during a normal mode of operation,

Figure 7 is a graph to illustrate the status of the delivery valve in the fuel pump in Figure 4 throughout the pumping cycle during a normal mode of operation,

Figures 8(a) and 8(b) are graphs to illustrate the status of the delivery valve and the status of a delivery valve actuator respectively for the fuel pump in Figure 4 throughout a pumping cycle during a modified mode of operation,

Figures 9(a) and 9(b) are graphs to illustrate the status of the inlet valve and the status of a inlet valve actuator respectively for the fuel pump in Figure 4 throughout a pumping cycle during a modified mode of operation,

Figure 10 is a graph to illustrate rail pressure throughout the pumping cycle during a normal mode of operation of the pump in Figure 4, and

Figure 11 is a graph to illustrate rail pressure throughout the pumping cycle during a modified mode of operation of the pump in Figure 4.

[0026] By way of further background to the present invention, EP 0821156 describes a fuel pump for delivering high pressure fuel to a common rail fuel system, the pump including a plurality of pumping assemblies, each of which includes a plunger for pressurising fuel within a respective pump chamber. Each pump chamber is filled through a respective inlet port, but with no inlet valve, such that the plunger always executes a full pumping stroke and there is no limitation on the filling of the chamber. As a result, the delivery stroke of each pumping plunger always results in delivery of a full charge of fuel through an associated delivery valve to the common rail. In order to control the net volume of fuel delivered by the pump, each pump assembly is provided with an electromagnetic valve which is operable to hold the associated delivery valve in an open position. Thus, at the end of each pumping stroke the delivery valve can be held open for a part of the return stroke to permit a reverse flow of fuel into the pump chamber. By varying the point in the return stroke when the delivery valve is closed, the net volume of pressurised fuel delivered from the chamber to the common rail can be controlled (in a range between zero and maximum delivery, but not less than zero).

[0027] Referring to Figure 4, one embodiment of the fuel pump of the present invention includes a plunger 10 which is moveable within a plunger bore 12 defined in a pump housing 14 to pressurise fuel within a pumping chamber 16 defined by a blind end of the bore 12 and an end surface of the plunger 10.

[0028] The plunger 10 is coupled to a drive arrangement including a tappet 18, to which the plunger is connected, and a roller 20 which cooperates with the surface of a cam 22. The cam 22 is mounted upon a drive shaft (not shown) and, as the shaft is rotated in use, the roller 20 is caused to ride over the cam surface, causing reciprocating movement of the tappet 18 and, hence, the plunger 10. Typically, the plunger 10 is provided with a return spring (not shown), which is arranged to act on the tappet 18 so as to urge the plunger 10 to perform a return stroke of a pumping cycle in which the plunger moves outwardly from the bore 12.

[0029] The pump housing 14 is provided with an inlet passage 24 which receives fuel through an inlet metering valve (not shown) in communication with a low pressure fuel pump (also not shown). The inlet metering valve controls the rate of flow of low pressure fuel into the inlet passage 24 and, hence, into the pumping chamber 16. The inlet passage 24 communicates with the pumping chamber 16 through an electromagnetically operable inlet valve arrangement 26. The inlet valve arrangement 26 comprises a first valve housing 27 mounted within a first transverse bore in the pump housing 14, and includes an inlet ball valve 28 which is biased into a closed position, in which it seats against a first valve seating 30, by means of an inlet valve spring 32 so as to break communication between the inlet passage 24 and the pumping chamber 16. In use, the inlet valve 28 is caused to move away from its seating into the open position when the hydraulic force due to fuel pressure within the inlet passage 24 is sufficient to overcome the spring force acting in combination with fuel pressure within the pumping chamber 16, therefore permitting fuel flow between the inlet passage 24 and the pumping chamber 16. The inlet valve 28 is coupled to an armature 34 of an inlet valve actuator 29 including a first winding 36 which may be energised to hold the inlet valve 28 away from the first valve seating 30 (i.e. to the right of the position shown in Figure 4), as described in further detail below. The inlet valve arrangement 26 is configured such that, if the first winding 36 is deenergised, the inlet valve 28 is urged against the first valve seating 30 by means of the hydraulic force due to fuel pressure within the pumping chamber 16 acting in combination with the inlet valve spring 32.

[0030] The pump housing 14 is also provided with an outlet delivery passage 40 through which fuel at high pressure is delivered from the pump chamber 16 to the common rail (not shown) under the control of a delivery valve arrangement 42. The delivery valve arrangement 42 comprises a delivery valve housing 43 mounted within a second transverse bore in the pump housing 14, and includes a delivery valve 44 which is engageable with a second valve seating 46 to control fuel flow between the pumping chamber 16 and the delivery passage 40. The delivery valve 44 is biased towards a closed position, in which it seats against the second valve seating 46, by means of a delivery valve spring 48 and fuel pressure within the delivery passage 40. The delivery valve 44 is movable away from the second valve seating 46 into an open position, in which the pumping chamber 16 communicates with the delivery passage 40, when the hydraulic force due to fuel pressure within the pumping chamber 16 is sufficient to overcome the combined force of the outlet valve spring 48 acting in combination with fuel pressure within the delivery passage 40, as described in further detail below. The delivery valve 44 may be held in the open position by means of a delivery valve actuator 45, including a second winding 50, configured such that when the winding 50 is energised, a magnetic force is generated to hold the delivery valve 44 away from the second valve

seating 46 (i.e. to the right of the position shown in Figure 4). If the second winding 50 is deenergised, the delivery valve 44 is urged into engagement with the second valve seating 46 by means of the hydraulic force due to fuel pressure within the delivery passage 40 and the force of the outlet valve spring 48.

[0031] Referring also to Figures 5 to 7, in a first mode of operation ("normal mode") in which both the first and second windings 36, 50 are deenergised throughout the full pumping cycle. The pumping plunger 10 adopts its innermost position within the plunger bore 12 (i.e. uppermost position in the orientation in Figure 4) at the start of the pumping cycle and fuel pressure within the pumping chamber 16 is high due to the pressurisation caused by the previous pumping stroke. The delivery valve 44 is closed (time T3) due to the equalisation of fuel pressures within the pumping chamber 16 and the delivery passage 40.

[0032] Upon commencement of its return stroke, the plunger member 10 is initially allowed to retract from the plunger bore 12 due to decompression within the pumping chamber 16 and retraction of the tappet 18 under the force of the return spring as the roller 20 rides over the surface of the cam 22. As the pumping chamber 16 is decompressed, a point will be reached at which the pressure in the pumping chamber 16 falls below the pressure required to lift the inlet valve 28 from the first valve seating 30 due to the flow of fuel into the inlet passage 24, and the next filling phase commences (time T4).

[0033] Further movement of the pumping plunger 10 outwardly from the plunger bore 12 is effected by a force exerted on the pumping plunger 10 by the return spring. Retraction of the tappet 18 occurs under the force of the return spring, causing the roller 20 to ride over the surface of the cam 22. During the filling phase, the delivery valve 44 remains seated against the second valve seating 46 due to high pressure fuel within the delivery passage 40 and due to the force of the outlet valve spring 48.

[0034] At the end of the return stroke, after the tappet 18 reaches its lowermost position in the illustration shown in Figure 4, the roller 20 is urged in an upward direction as it follows the surface of the cam 22, thereby causing the tappet 18 to drive the pumping plunger 10 inwardly within the plunger bore 12 (a pumping stroke). Initially, when the pumping plunger 10 adopts its outermost position within the plunger bore 12 and as the pumping plunger 10 starts to move inwardly within the bore 12, the pumping chamber 16 is still in communication with the inlet passage 24 as the inlet valve 28 is open. Further movement of the pumping plunger 10 under the drive of the tappet 18 causes the volume of the pumping chamber 16 to reduce, thereby increasing fuel pressure in the pumping chamber 16. A point will be reached part way through the pumping stroke at which the inlet valve 28 is urged against its seating (time T5) due to increasing fuel pressure within the pumping chamber 16, thereby preventing the further flow of fuel into or out of the pumping chamber 16 through the inlet passage 24.

[0035] As the plunger pumping stroke continues, fuel within the pumping chamber 16 is pressurised to a sufficiently high level to cause the delivery valve 44 to lift from its seating (time T6), thereby permitting pressurised fuel to flow from the pumping chamber 16 into the delivery passage 40 and, hence, to the common rail.

[0036] At the end of the pumping stroke, when the pumping plunger 30 reaches the end of its range of travel, the delivery valve 40 will be urged against its seating (times T3, T7) due to high pressure fuel within the delivery passage 40 and the force of the outlet valve spring 48, thereby holding high fuel pressure within the delivery passage 40 and, hence, within the common rail.

[0037] Figure 10 illustrates rail pressure during normal operation for the pumping cycle described previously. It can be seen that, at the end of the pumping stroke (times T3, T7) when the delivery valve 44 is closed, rail pressure is held at pressure P1.

[0038] In some operating conditions, it is desirable to reduce the rate of rise of pressure of fuel within the rail, for example when fuel injection to the engine is not required. The volume of pumped fuel is determined by the inlet metering valve and the length of time for which the inlet valve 28 is open to permit fuel flow into the pumping chamber 16. The volume of pumped fuel may therefore be controlled by restricted filling of the chamber 16, so that the plunger 10 is only pumping for a part of the pumping stroke ("part stroke pumping"). In this mode of operation, the delivery valve 44 will be caused to open at a later stage of the pumping stroke, as illustrated by the dotted lines in Figure 6. Figure 10 illustrates the pressure, P1, in the rail during the pumping cycle for full stroke pumping compared with the pressure in the rail, P2, for part stroke pumping (as shown in dashed lines). For part stroke pumping, the final pressure delivered to the rail is less than that for full stroke pumping, by an amount ΔP.

[0039] In other operating conditions, it is desirable to actually reduce the pressure in the rail, in which case electromagnetic control of the inlet and delivery valve arrangements 26, 42 can be used to modify the function of the inlet and delivery valves 28, 44 (referred to as "modified pump operation"). Figures 8(a) and 8(b) illustrate the status of the delivery valve 44 during modified pump operation and the corresponding current pulse supplied to the electromagnetic winding 50 of the delivery valve actuator 45 respectively. Figures 9(a) and 9(b) illustrate the status of the inlet valve 28 during modified pump operation and the corresponding current pulse supplied to the electromagnetic winding 36 of the inlet valve actuator 29 respectively.

[0040] Referring to Figure 8(b), part way though the pumping stroke (time T8), the electromagnetic winding 50 of the delivery valve actuator 45 is energised. Upon initial energisation, the magnetic force of attraction act-

ing on the delivery valve 44 is insufficient to cause the valve 44 to move against high pressure fuel within the delivery passage 40, but after a short time (at time T9), as fuel pressure within the pumping chamber 16 is increasing, the delivery valve 44 will be caused to lift from its seating to permit fuel flow into the delivery passage 40 and, hence, to the rail. Energisation of the winding 50 is maintained for the remainder of the pumping stroke, and for an initial period of the return stroke, thereby causing fuel within the rail to flow into the pumping chamber 16 during the return stroke, unloading or releasing the swept volume of fuel within the rail, and therefore causing fuel pressure within the rail to be reduced. The released fuel from the rail serves to apply a force to the tappet 18 and roller 20 arrangement, returning mechanical energy to the driven cam 22 to aid the motion of the drive shaft. By maintaining the delivery valve 44 in its open state for a portion of the return stroke, the pump therefore provides a motoring function to assist drive of the cam 22.

[0041] Just before the end of the return stroke (time T10) the winding 50 is deenergised, and the delivery valve 44 is urged against its seating due to pressure in the delivery passage 40 acting in combination with the outlet valve spring 48, and further relief of rail pressure is prevented.

[0042] At substantially the same time as the winding 50 of the delivery valve actuator 45 is deenergised (time T10), the winding 36 of the inlet valve actuator 29 is energised (as shown in Figure 9(b)). Initially, energisation of the winding 36 is insufficient to cause the inlet valve 28 to lift from its seating due to high pressure fuel within the pumping chamber 16 acting in combination with the inlet valve spring 32, but after the plunger 10 has moved further through its return stroke (i.e. at time T11), a slight suction pressure is generated in the pumping chamber 16 causing the inlet valve 28 to be lifted from its seating due to the pressure of fuel flowing through the inlet passage 24 which acts on the armature 34.

[0043] Energisation of the winding 36 is started at time T10 and is maintained throughout the remainder of the return stroke and the subsequent pumping stroke (until time T12) such that the inlet valve 28 remains lifted from its seating as the plunger 10 is driven inwardly within its bore 12, thereby causing fuel within the pumping chamber 16 to be displaced through the inlet passage 24 to low pressure.

[0044] Shortly before the top of the pumping stroke (time T12), the winding 36 is deenergised causing the inlet valve 28 to be urged against its seating under the force of the inlet valve spring 32. At substantially the same time, the winding 50 of the delivery valve actuator 45 is energised, as described previously at time T8. The remaining plunger motion at the end of the pumping stroke raises the pressure in the pumping chamber 16 so that the delivery valve 44 is caused to open at the commencement of the next return (filling) stroke to complete one actuation cycle.

[0045] Figure 11 illustrates rail pressure during the pumping cycle for modified operation. It can be seen that between time T9, when the delivery valve 44 is caused to open during the return stroke, and time T10 when the delivery valve 44 is caused to close upon deenergisation of the winding 50, rail pressure falls to a final value, P3, which is less than the initial rail pressure P1 (at time T9) by an amount ΔP_A due to reverse flow through the open delivery valve 44.

[0046] If it is only desired to partially relieve rail pressure by an amount ΔP_B, the winding 50 of the delivery valve actuator 45 is de-energised at an earlier stage of the return stroke, such that a reduced volume of fuel within the rail is permitted to flow into the pumping chamber 16. This is illustrated in dashed lines in Figures 8(a) and 8(b), and in Figure 11. Thus, rail pressure can be controlled by varying the time at which the delivery valve 44 closes during the return stroke of the plunger.

[0047] In the modified mode of operation, energisation of the winding 50 of the delivery valve actuator 45 is not required to lift the delivery valve 44 from its seating, and is applied only for the purpose of maintaining the delivery valve 44 in an open position during at least a part of the plunger return stroke. This differs from the normal mode of operation, for which the delivery valve 44 is in a closed state during the plunger return stroke, and the pumping chamber 16 is filled only through the open inlet valve 28. As illustrated in Figures 9(a) and 9 (b), in the modified mode of operation the inlet valve 28 is held closed during the return stroke and filling occurs through the open delivery valve 44. The function of the valves 28, 44 is therefore reversed.

[0048] It is also not necessary to energise the winding 36 of the inlet valve actuator 29 to open the inlet valve 28, as this occurs under a hydraulic force. It is only necessary to energise the winding 36 to maintain the inlet valve 28 in the open position during at least a part of the pumping stroke.

[0049] One advantage of the invention therefore is that the actuators 29, 45 for the inlet valve 28 and the delivery valve 44 respectively may be relatively small and compact, as they are not required to initiate opening of the valves 28, 44. As opening of the valves 28, 44 occurs hydraulically, the need for sensitive phasing of valve control in the control electronics is also avoided. This also enables smoother operation by allowing the valves 28, 44 to open "naturally". Additionally, the return of high pressure fuel during the return stroke, by holding the delivery valve 44 open, serves to permit return of mechanical energy to the drive arrangement, aiding rotation of the driven cam. The pump is therefore arranged to provide both a pumping function, to pressurise fuel within the pumping chamber for delivery to the common rail, and a motoring function, whereby fuel pressure in the rail is relieved and is used to assist drive of the cam, the pump and motor functions being provided by a unitary device.

[0050] A further advantage of the invention is that the

actuators 29, 45 are redundant during normal pumping (normal mode of operation), and thus do not consume power.

[0051] In an alternative embodiment of the invention, the inlet metering valve upstream of the pumping chamber 16 may be omitted, so that pump output is controlled by means of the inlet valve arrangement 26 and the delivery valve arrangement 42 alone. For this embodiment, the pumping chamber 16 is filled completely on the return stroke and is fully relieved into the rail during the pumping stroke. As described previously, shortly before the end of the pumping stroke the delivery valve actuator 50 is energised and the delivery valve 44 is held open for a portion of the return stroke, allowing a portion of the fuel within the rail to return to the pumping chamber 16 and returning mechanical energy to the driven cam 22 and shaft. In order to trap the desired pressure in the rail, the winding 50 of the delivery valve actuator 45 is deenergised and the delivery valve 44 is caused to close under the effect of fuel pressure within the rail acting in combination with the spring 48.

[0052] In an alternative mode of operation where the inlet metering valve is omitted, the pumping chamber 16 may fill completely on the return stroke but shortly before the end of the return stroke the inlet valve actuator 29 is energised to hold the inlet valve 28 open during the initial portion of the pumping stroke. This effectively acts as a pre-spill during the initial portion of the pumping stroke so as to control the volume of pumped fuel. After a predetermined portion of the pumping stroke, the inlet valve actuator 29 is deenergised, thereby causing the inlet valve 28 to close due to fuel pressure within the pumping chamber 36 acting in combination with the spring 32. Fuel pressure within the pumping chamber 16 continues to increase through the remainder of the pumping stroke to open the delivery valve 44 in a normal mode of operation.

Claims

1. A fuel pump for use in delivering high pressure fuel to a common rail of a fuel injection system, the fuel pump including:

   a pumping plunger (10) which is reciprocable within a plunger bore (12) to cause pressurisation of fuel within a pumping chamber (16), the plunger (10) having a pumping stroke, in which the plunger (10) is driven inwardly within the plunger bore (12) to reduce the volume of the pumping chamber (16), and a return stroke in which the plunger (10) moves outwardly from the bore (12) to increase the volume of the pumping chamber (16), in use,

   an inlet valve arrangement (26) having an inlet valve (28) which is movable between an inlet open position, in which the pumping chamber (16) communicates with a low pressure fuel source, and an inlet closed position, in which communication between the low pressure fuel source and the pumping chamber (16) is broken, the inlet valve (28) being movable from the inlet closed position to the inlet open position in response to fuel pressure acting on the inlet valve (28), and wherein the inlet valve arrangement (26) includes an inlet valve actuator (29) which is operable to maintain the inlet valve (28) in the inlet open position for at least a part of the pumping stroke,

   and a delivery valve arrangement (42) having a delivery valve (44) which is movable between a delivery open position, in which the pumping chamber (16) communicates with the common rail, and a delivery closed position, in which communication between the common rail and the pumping chamber (16) is broken, the delivery valve (44) being movable from the delivery closed position to the delivery open position in response to fuel pressure acting on the delivery valve (44),

   and wherein the delivery valve arrangement (42) includes a delivery valve actuator (45) which is operable to maintain the delivery valve (44) in the delivery open position, for at least a period of the return stroke, thereby to regulate fuel pressure within the common rail.

2. A fuel pump as claimed in Claim 1, wherein at least one of the inlet valve actuator (29) and the delivery valve actuator (45) is an electromagnetic actuator.

3. A fuel pump as claimed in Claim 1 or Claim 2, wherein the delivery valve (44) is biased against a valve seating (46) by means of a delivery valve spring (48).

4. A fuel pump as claimed in any of Claims 1 to 3, wherein the inlet valve (28) is biased against a further valve seating (30) by means of an inlet valve spring (32).

5. A fuel pump as claimed in any of Claims 1 to 4, further comprising a drive arrangement for driving the plunger (10) to perform the pumping stroke.

6. A fuel pump as claimed in any of Claims 1 to 5, including a plurality of pumping plungers (10), each of which is reciprocable within a respective plunger bore (12) to cause pressurisation of fuel within a respective pumping chamber (16).

7. A method of regulating fuel pressure within a com-

mon rail of a fuel injection system using the fuel pump as claimed in any of Claims 1 to 6, comprising the steps of:

maintaining the inlet valve (28) in the inlet open position for at least a part of the pumping stroke under the control of the inlet valve actuator (29), and
maintaining the delivery valve (44) in the delivery open position under the control of the delivery valve actuator (45) for at least a period of the return stroke, thereby to permit high pressure fuel within the rail to flow into the pumping chamber (16) during the return stroke so as to regulate fuel pressure within the common rail.

8. A common rail fuel system for an internal combustion engine, including a common rail and a fuel pump as claimed in any of Claims 1 to 6, wherein the pump is arranged to perform a pumping function whereby fuel within the pumping chamber (16) is pressurised for delivery to the common rail, and a motoring function whereby fuel pressure in the common rail is relieved and a drive force is returned to the plunger to aid the return stroke.

Patentansprüche

1. Kraftstoffpumpe zur Verwendung bei der Zufuhr von unter hohem Druck stehendem Kraftstoff an eine gemeinsame Druckleitung ("common rail") eines Kraftstoff-Einspritzsystems, wobei die Kraftstoffpumpe umfasst:

einen Pumpenkolben (10), der innerhalb einer Kolbenbohrung (12) hin- und herbewegbar ist, um zu bewirken, dass Kraftstoff innerhalb einer Pumpenkammer (16) unter Druck gesetzt wird, wobei der Kolben (10) im Betrieb einen Förderhub, in dem der Kolben (10) innerhalb der Pumpenbohrung (12) nach innen getrieben wird, um das Volumen der Pumpenkammer (16) zu verringern, und einen Rückwärtshub aufweist, in welchem sich der Kolben (10) aus der Bohrung (12) heraus bewegt, um das Volumen der Pumpenkammer (16) zu vergrößern,

eine Einlassventil-Anordnung (26) mit einem Einlassventil (28), das zwischen einer Einlass-Offenstellung, in welcher der Pumpenkolben (16) mit einer Niederdruck-Kraftstoffquelle in Verbindung steht, und einer Einlass-Geschlossenstellung, in welcher die Verbindung zwischen der Niederdruck-Kraftstoffquelle und der Pumpenkammer (16) unterbrochen ist, bewegbar ist, wobei das Einlassventil (28) in Reaktion auf den Kraftstoffdruck, der auf das Einlassventil (28) einwirkt, von der Einlass-Geschlossenposition zur Einlass-Offenposition bewegt werden kann, und worin die Einlassventil-Anordnung (26) ein Einlassventil-Betätigungsorgan (29) umfasst, das betrieben werden kann, um das Einlassventil (28) für mindestens einen Teil des Förderhubs in der Einlass-Offenstellung zu belassen,

und eine Auslassventil-Anordnung (42) mit einem Auslassventil (44), das zwischen einer Auslass-Offenstellung, in der die Pumpenkammer (16) mit der gemeinsamen Druckleitung (dem "common rail") in Verbindung steht, und einer Auslass-Geschlossenstellung, in welcher die Verbindung zwischen dem "common rail" und der Pumpenkammer (16) unterbrochen ist, bewegbar ist, wobei das Auslassventil (44) in Reaktion auf den Kraftstoffdruck, der auf das Auslassventil (44) einwirkt, von der Auslass-Geschlossenstellung zur Auslass-Offenstellung bewegt werden kann,

und worin die Auslassventil-Anordnung (42) ein Auslassventil-Betätigungsorgan (45) umfasst, das betrieben werden kann, um das Auslassventil (44) für zumindest einen Zeitraum des Rückwärtshubs in der Auslass-Offenstellung zu belassen, wodurch der Kraftstoffdruck innerhalb des "common rail" reguliert wird.

2. Kraftstoffpumpe nach Anspruch 1, worin mindestens eines der Betätigungsorgane, das Einlassventil-Betätigungsorgan (29) und/oder das Auslassventil-Betätigungsorgan (45), ein elektromagnetisches Betätigungsorgan ist.

3. Kraftstoffpumpe nach Anspruch 1 oder Anspruch 2, worin das Auslassventil (44) mit Hilfe einer Auslassventil-Feder (48) gegen einen Ventilsitz (46) gespannt ist.

4. Kraftstoffpumpe nach einem der Ansprüche 1 bis 3, worin das Einlassventil (28) mit Hilfe einer Einlassventil-Feder (32) gegen einen weiteren Ventilsitz (30) gespannt ist.

5. Kraftstoffpumpe nach einem der Ansprüche 1 bis 4, weiterhin umfassend eine Antriebsanordnung, die den Kolben (10) antreiben soll, so dass er den Förderhub ausführt.

6. Kraftstoffpumpe nach einem der Ansprüche 1 bis 5, umfassend eine Mehrzahl von Pumpenkolben (10), von denen jeder innerhalb einer entsprechenden Kolbenbohrung (12) hin- und herbewegbar ist, um die Beaufschlagung von Kraftstoff mit Druck innerhalb einer entsprechenden Pumpenkammer (16) zu

bewirken.

7. Verfahren zum Regulieren des Kraftstoffdrucks innerhalb eines "common rail" eines Kraftstoffeinspritzsystems unter Verwendung der Kraftstoffpumpe wie in einem der Ansprüche 1 bis 6 beansprucht, umfassend die Schritte:

Belassen des Einlassventils (28) in der Einlass-Offenstellung für mindestens einen Teil des Förderhubs unter der Steuerung des Einlassventil-Betätigungsorgans (29)
und

Belassen des Auslassventils (44) für mindestens einen Zeitraum des Rückwärtshubs in der Auslass-Offenstellung unter der Steuerung des Auslassventil-Betätigungsorgans (45), wodurch innerhalb des "rail" unter hohem Druck stehender Kraftstoff während des Rückwärtshubs in die Pumpenkammer (16) fließen kann, um den Kraftstoffdruck innerhalb des "common rail" zu regulieren.

8. Kraftstoffsystem mit gemeinsamer Druckleitung für eine Verbrennungskraftmaschine, umfassend ein "common rail" und eine Kraftstoffpumpe wie in einem der Ansprüche 1 bis 6 beansprucht, worin die Pumpe so angeordnet ist, dass sie eine Pumpenfunktion, durch die Kraftstoff innerhalb der Pumpenkammer (16) zur Abgabe an das "common rail" unter Druck gesetzt wird, und eine Antriebsfunktion besitzt, durch die Kraftstoffdruck im "common rail" abgebaut wird und eine Antriebskraft auf den Kolben rückübertragen wird, um den Rückwärtshub zu unterstützen.

Revendications

1. Pompe de carburant destinée à être utilisée pour délivrer du carburant à haute pression à une rampe commune d'un système d'injection de carburant, cette pompe de carburant comprenant :

un piston de pompage (10) animé d'un mouvement de va-et-vient dans un alésage de piston (12) pour entraîner la pressurisation du carburant dans une chambre de pompage (16), le piston (10) ayant une course de pompage, dans laquelle le piston (10) est entraîné vers l'intérieur dans l'alésage de piston (12) afin de réduire le volume de la chambre de pompage (16), et une course de retour dans laquelle le piston (10) se déplace vers l'extérieur depuis l'alésage (12) afin d'augmenter le volume de la chambre de pompage (16), en cours de fonctionnement,

un mécanisme de clapet d'aspiration (26) comportant un clapet d'aspiration (28) pouvant se déplacer entre une position d'aspiration ouverte, dans laquelle la chambre de pompage (16) communique avec une source de carburant à basse pression, et une position d'aspiration fermée, dans laquelle la communication entre la source de carburant à basse pression et la chambre de pompage (16) est rompue, le clapet d'aspiration (28) pouvant se déplacer entre la position d'aspiration fermée et la position d'aspiration ouverte en réponse à la pression de carburant agissant sur le clapet d'aspiration (28), et dans lequel le mécanisme de clapet d'aspiration (26) comprend un actionneur de clapet d'aspiration (29) pouvant fonctionner de façon à maintenir le clapet d'aspiration (28) en position d'aspiration ouverte durant au moins une partie de la course de pompage,
et un mécanisme de clapet de refoulement (42) comportant un clapet de refoulement (44) pouvant se déplacer entre une position de refoulement ouverte, dans laquelle la chambre de pompage (16) communique avec la rampe commune, et une position de refoulement fermée, dans laquelle la communication entre la rampe commune et la chambre de pompage (16) est rompue, le clapet de refoulement (44) pouvant se déplacer entre la position de refoulement fermée et la position de refoulement ouverte en réponse à la pression de carburant agissant sur le clapet de refoulement (44),
et dans laquelle le mécanisme de clapet de refoulement (42) comprend un actionneur de clapet de refoulement (45) pouvant fonctionner de façon à maintenir le clapet de refoulement (44) en position de refoulement ouverte, durant au moins une période de la course de retour, afin de réguler ainsi la pression de carburant dans la rampe commune.

2. Pompe de carburant selon la revendication 1, dans laquelle au moins un de l'actionneur de clapet d'aspiration (29) et de l'actionneur de clapet de refoulement (45) est un actionneur électromagnétique.

3. Pompe de carburant selon la revendication 1 ou la revendication 2, dans laquelle le clapet de refoulement (44) est poussé contre un siège de clapet (46) au moyen d'un ressort de clapet de refoulement (48).

4. Pompe de carburant selon l'une quelconque des revendications 1 à 3, dans laquelle le clapet d'aspiration (28) est poussé contre un autre siège de clapet (30) au moyen d'un ressort de clapet d'aspiration (32).

5. Pompe de carburant selon l'une quelconque des revendications 1 à 4, comprenant en outre un mécanisme d'entraînement destiné à entraîner le piston (10) afin d'effectuer la course de pompage.

6. Pompe de carburant selon l'une quelconque des revendications 1 à 5, comprenant une pluralité de pistons de pompage (10), dont chacun est animé d'un mouvement de va-et-vient dans un alésage de piston (12) respectif pour entraîner la pressurisation du carburant dans une chambre de pompage (16) respective.

7. Procédé de régulation de pression de carburant dans une rampe commune d'un système d'injection de carburant utilisant la pompe de carburant selon l'une quelconque des revendications 1 à 6, comprenant les étapes de :

maintien du clapet d'aspiration (28) en position d'aspiration ouverte durant au moins une partie de la course de pompage sous le contrôle de l'actionneur de clapet d'aspiration (29), et
maintien du clapet de refoulement (44) en position de refoulement ouverte sous le contrôle de l'actionneur de clapet de refoulement (45) durant au moins une période de la course de retour, pour permettre ainsi le transfert de carburant à haute pression dans la chambre de pompage (16) durant la course de retour de façon à réguler la pression de carburant dans la rampe commune.

8. Système de carburant à rampe commune pour un moteur à combustion interne, comprenant une rampe commune et une pompe de carburant selon l'une quelconque des revendications 1 à 6, dans lequel la pompe est montée de façon à exécuter une fonction de pompage, de manière à pressuriser le carburant dans la chambre de pompage (16) en vue de son transfert vers la rampe commune, et une fonction de motorisation, de manière à libérer la pression de carburant dans la rampe commune et à renvoyer une force d'entraînement au piston pour permettre sa course de retour.

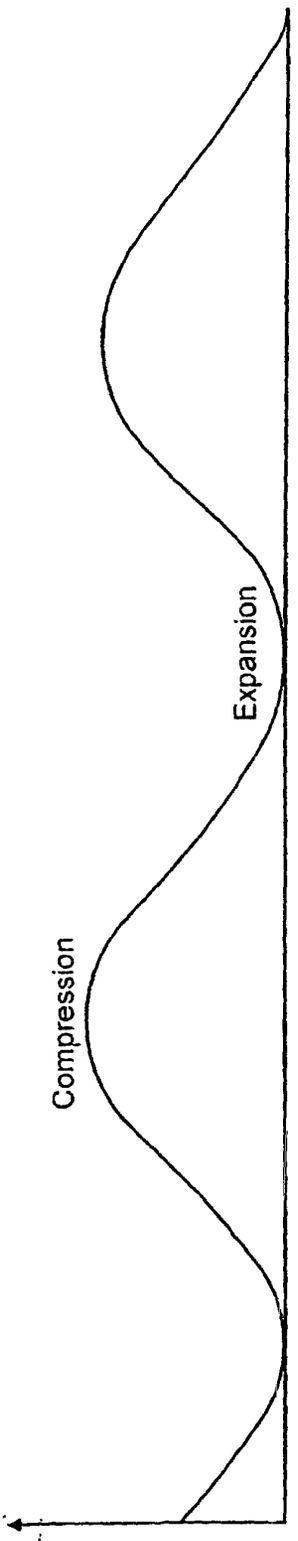


FIG. 1

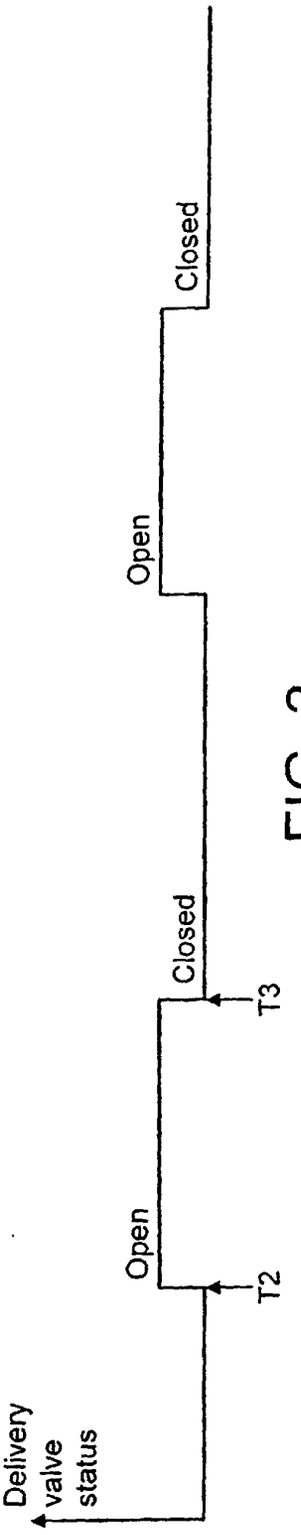


FIG. 2

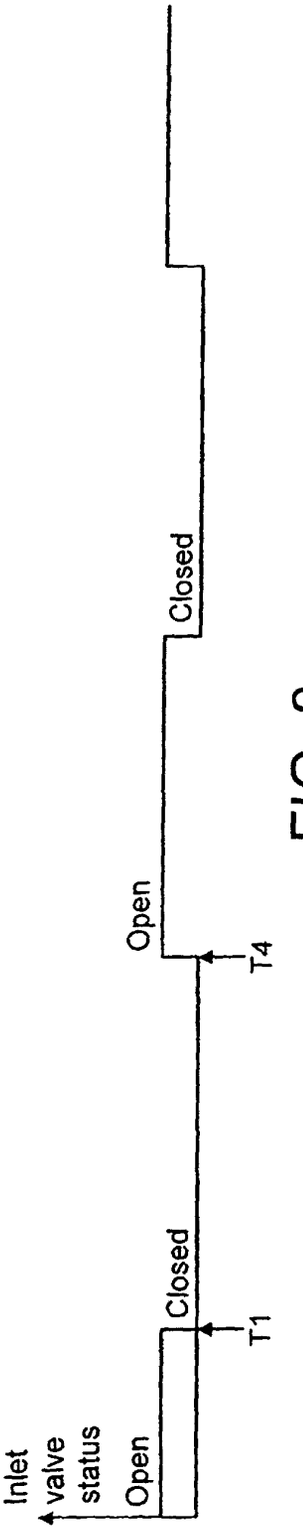


FIG. 3

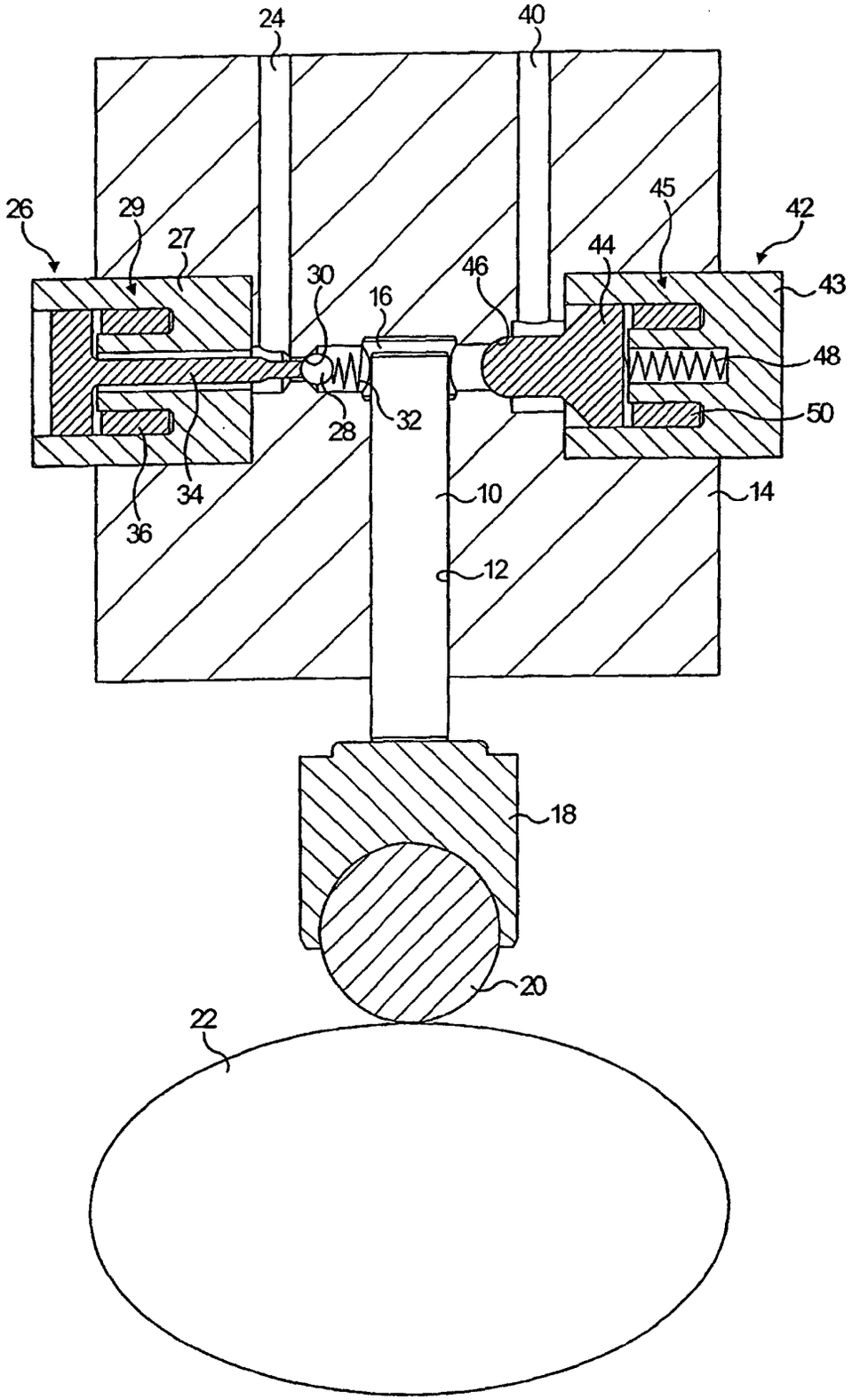


FIG. 4

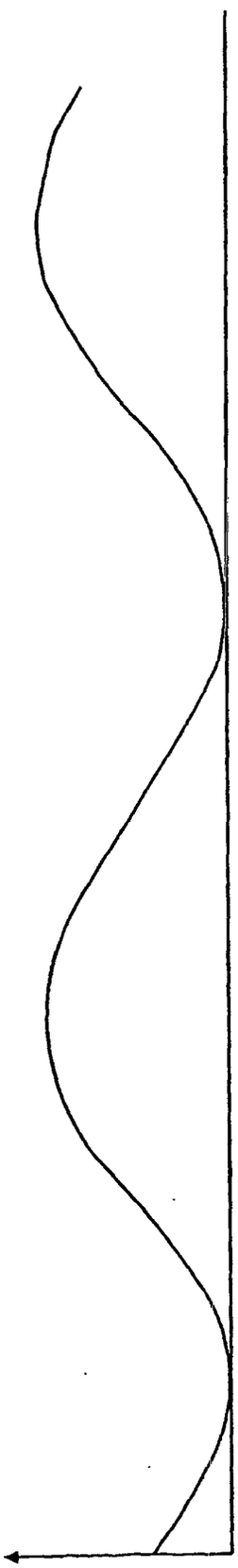


FIG. 5

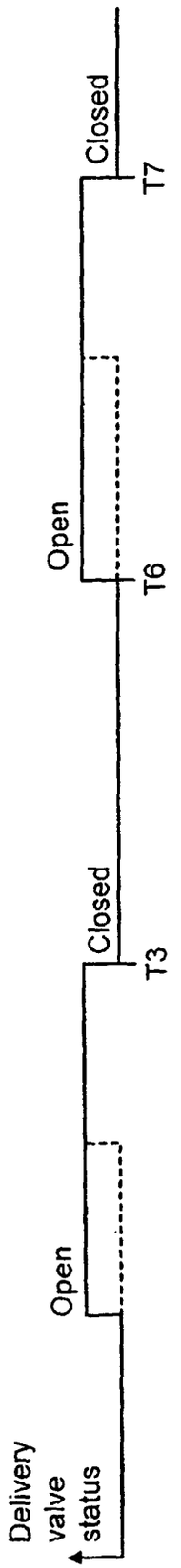


FIG. 6

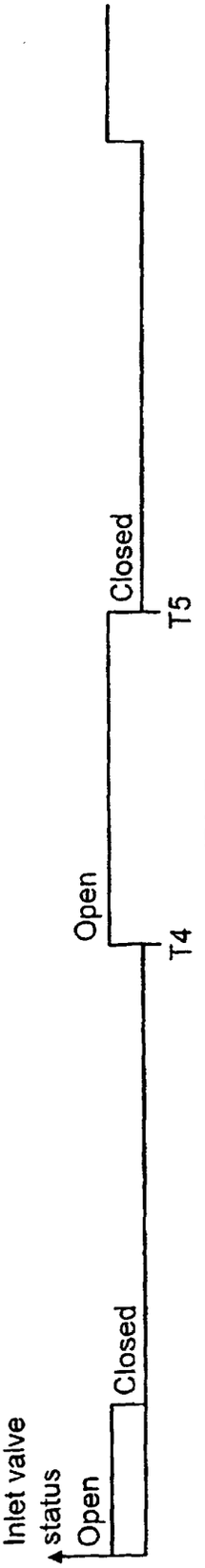


FIG. 7

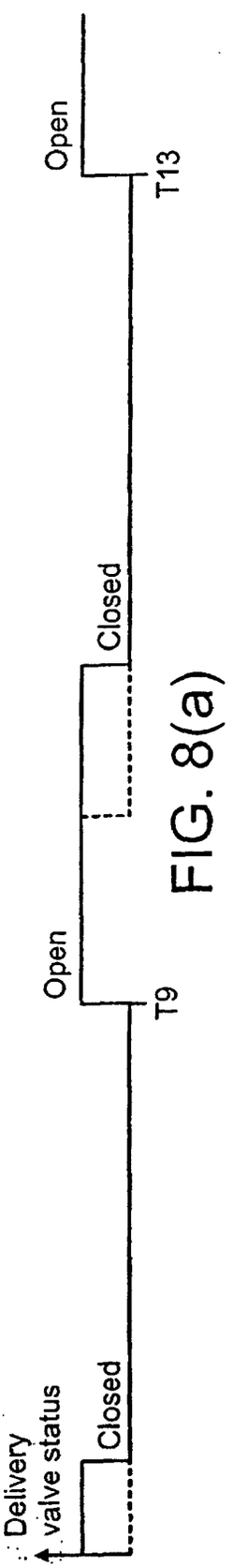


FIG. 8(a)

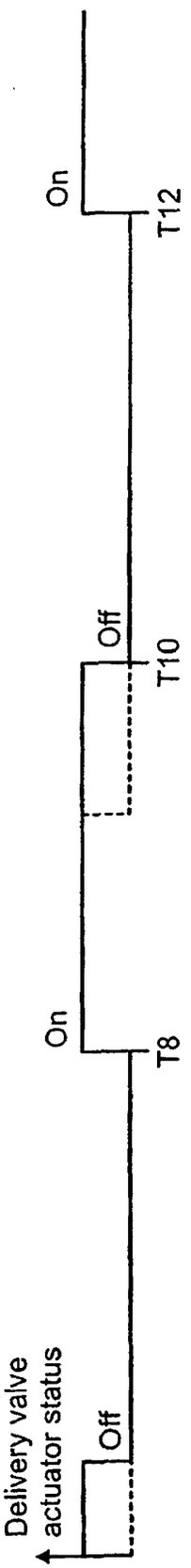


FIG. 8(b)

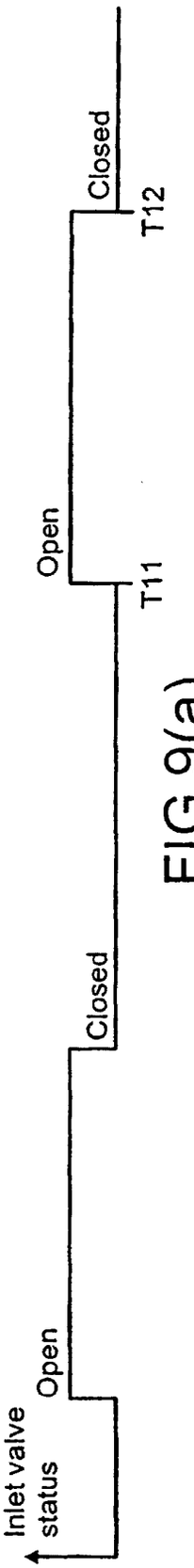


FIG.9(a)

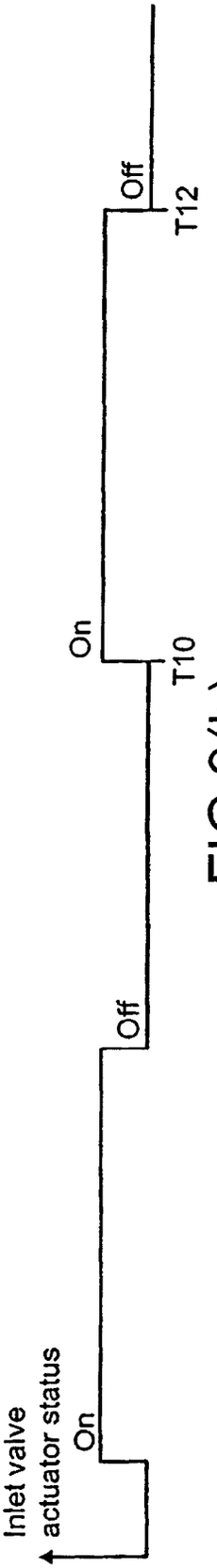


FIG.9(b)

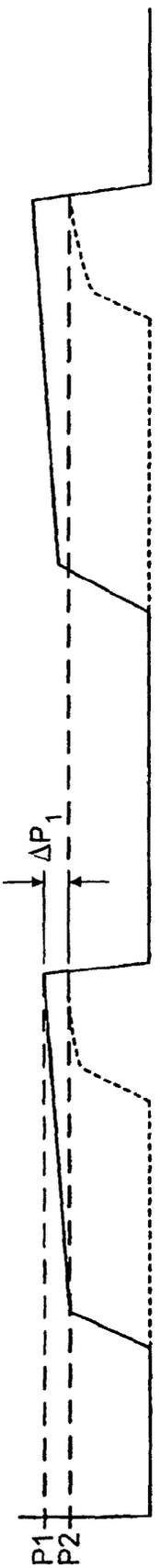


FIG. 10

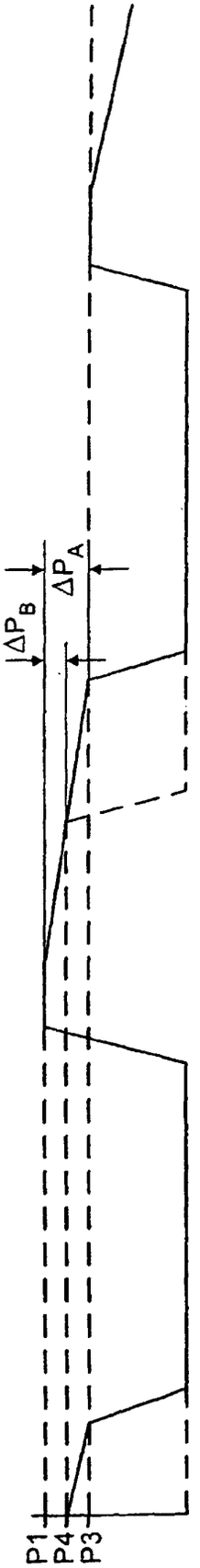


FIG. 11