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KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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Declarations under Rule 4.17:

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))
- of inventorship (Rule 4.17(iv))

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(54) **Title:** AUXILIARY PRESSURE RELIEF VALVE IN SINGLE PISTON FUEL PUMP

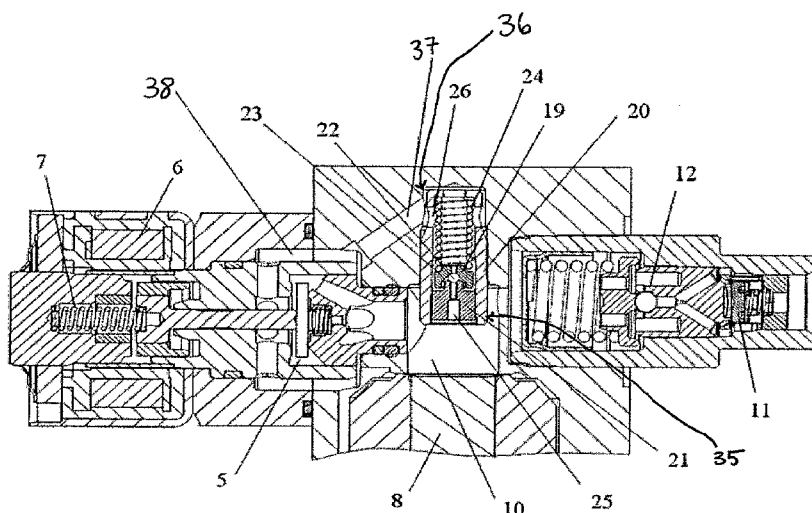


Figure 5

(57) **Abstract:** A fuel pump has a low pressure fuel inlet (40) and a single piston pumping chamber (10) for supplying high pressure fuel through a pump outlet to an inlet side of a common rail (16). The fuel pump comprises a primary pressure relief valve (12) having an inlet side in hydraulic communication with the inlet side of the common rail (16) and an outlet side in fluid communication with the pumping chamber (10); and an auxiliary pressure relief valve (19) having an inlet side (35) in hydraulic communication with the pumping chamber (10) and an outlet side in direct fluid communication with a fuel passage (37) at the low pressure of the pump inlet (40).

AUXILIARY PRESSURE RELIEF VALVE IN SINGLE PISTON FUEL PUMP

Background

[0001] The present invention relates to single piston, cam driven high pressure fuel pumps for generating high pressure fuel in common rail direct injection gasoline engines.

[0002] It is known in the industry that the pump must incorporate an outlet check valve to prevent pressure bleed back from the rail while the pump is in the intake stroke cycle. It has become an industry requirement to incorporate a pressure relief valve within the pump to protect the entire high pressure system from an unexpected excess pressure caused by a system malfunction. In order to protect the rail and injectors, the pressure relief valve must be in hydraulic communication with the rail, i.e., in parallel with the pump flow. Two such executions are described in U.S. Patent Nos. 7401593 and 8,132,558.

[0003] The executions described in the prior art are successful in their ability to achieve a reasonable relief pressure by hydraulically disabling the relief device during the pumping event when normal high pressure line pulsations occur. However, in high output pump applications there are some significant limitations. Firstly, the necessary increased flow rate and required upsizing of the relief valve device becomes prohibitive in packaging within a modern single piston pump. Secondly, the added flow rate into the low pressure side of the pump by the upsized relief valve device can cause significantly increased low pressure pulsations, leading to failure of the low pressure side components.

Summary

[0004] The present invention solves the aforementioned drawbacks of the prior art by addition of an auxiliary pressure relief valve device in direct

communication with the high pressure pumping chamber, relieving pressure into the low pressure side of the pump during the pumping event. This has the advantage of maintaining a reasonable relief pressure of the primary relief valve, close to the normal operating rail pressure. As in the prior art, this primary relief valve opens only during the charging stroke of the pump. The new auxiliary valve relieves pumping chamber pressure during the pumping stroke, thereby “averaging” the flow back to the low pressure side of the pump. This keeps the low pressure pulsations to a minimum, and alleviates the need for a very large primary relief valve. Because the auxiliary relief valve is in direct communication with the pumping chamber, it can easily be installed within the pump housing.

Brief Description of the Drawings

[0005] Figure 1 shows a system schematic of a prior art fuel system for an internal combustion engine;

[0006] Figure 2 shows a system schematic of a fuel system incorporating the auxiliary relief valve in accordance with the present disclosure;

[0007] Figure 3 shows the normal operational plunger motion and pressure profiles of the pump of the fuel system of Figure 2;

[0008] Figure 4 shows the pressure profiles of the pump of the fuel system of Figure 2 during a high speed system malfunction;

[0009] Figure 5 shows one embodiment of the auxiliary pressure relief valve device in accordance with the present disclosure; and

[0010] Figure 6 shows an outlet fitting assembly for use with an alternate embodiment of the pump assembly depicted in Figures 2 and 5.

Detailed Description

[0011] According to Figure 1, a low-pressure pump 2 pressurizes fuel from a fuel tank 1, and delivers it to a high pressure pump through an inlet fitting 40. The fuel then passes under the influence of an accumulator 4 to a normally closed control valve 5. A normally open control valve 5 is also applicable to such a fuel system. Once the fuel passes through the control valve 5 the fuel is drawn into a pumping chamber 10, where an engine camshaft 9 drives a pumping piston or plunger 8 in an upward motion, pressurizing the fuel.

[0012] The control valve 5 is acted upon by a control valve spring 7 and a solenoid 6 to control the quantity of fuel delivered by the high pressure pump. This is accomplished by coordinating the action of the control valve 5 and the motion of the pumping piston 8, such that the control valve 5 closes when the pumping piston 8 is driven in an upward motion by the engine camshaft 9. When the fuel is thus pressurized, it travels through an outlet check valve 11, a high pressure line 14, and into a common rail 16 that feeds engine fuel injectors 15. Because the injectors 15 are fed from a common rail 16, injector timing is flexible.

[0013] Desired rail pressure is controlled by a closed feedback loop in the Electronic Control Unit (ECU) 18 including control of the high pressure fuel output via the solenoid 6 and control valve 5 compared to the rail pressure sensor 17 output signal to the ECU 18. A primary pressure relief valve 12 is required to protect the high pressure system in case of a system malfunction. The outlet check valve 11 and primary pressure relief valve 12 are preferably contained in a common fitting assembly 13, but this is not required for the present invention.

[0014] As shown in Figures 2 and 5, a fuel system in accordance with the present disclosure incorporates the features and function of the prior art fuel system of Figure 1, and includes an auxiliary pressure relief valve 19. The auxiliary pressure relief valve 19 relieves excess pressure in the pumping

chamber caused by system malfunction before the excess pressure may reach the high pressure line 14 or common rail 16. Alternately, the auxiliary relief valve 19 may be in fluid communication with the high pressure line 14 instead of the pumping chamber 10; however there are advantages to direct fluid connection to the pumping chamber 10. Firstly, the peak chamber pressure and resulting cam loading is minimized by eliminating the added pressure drop across the outlet check valve 11. Secondly, a high degree of sealing integrity is not required for the auxiliary relief valve 19 when pressure from the common rail 16 does not act on the auxiliary relief valve 19 (as depicted in Figure 2) during normal operation such as during a hot soak.

[0015] With reference to Figure 3, the lower portion of the graph shows the plunger lift S and pumping and charging ramps defined by the camshaft, while the upper graph shows the normally functioning pumping chamber pressure profile P_{ch} (solid line) and high pressure line pressure profile P_L (dashed line). The primary pressure relief valve 12 (Figure 2) is set to open at pressure P_{R1} with a margin “a”, to avoid unwanted opening. The auxiliary pressure relief valve is set to open at pressure P_{R2} with a margin “b” over the peak normal chamber pressure and margin “c” over the stabilized pumping chamber pressure. The auxiliary relief valve 19 can operate for brief periods when the peak pumping chamber pressure exceeds P_{R2} ($b < 0$) or for extended durations, when $c < 0$.

[0016] As shown in Figure 4, the primary pressure relief valve 12 (Figure 2) operates during time T_{R1} when P_L is at or slightly above the opening pressure P_{R1} . As pump speed is increased, the line pressure P_L increases due to the higher pump flow rate and restricted flow through the primary pressure relief valve 12. When pump speed is increased the primary pressure relief valve also operates for less time T_{R1b} , which is determined by the difference between the line pressure P_L and pumping chamber pressure P_{ch} (designated ΔP_{R1b}) when ΔP_{R1b} is greater than or equal to P_{R1} . The auxiliary pressure relief valve 19 (Figure 2) operates for a maximum time T_{R2} whenever the

pumping chamber pressure is above the set point P_{R2} . P_{ch} Normal is the pumping chamber pressure profile during normal pump operation as depicted in Figure 3.

[0017] As shown in Figure 5, the auxiliary pressure relief valve 19 comprises a cylindrical valve body 20 having an inlet side 35 in hydraulic communication with the common rail 16 downstream of the outlet check valve 11 and primary pressure relief valve 12. An outlet side 36 of the valve body 20 is in hydraulic communication with a fuel passage 37. The fuel passage 37 is in hydraulic communication with a low pressure feed annulus 38 which is in communication with the low pressure side of the pump assembly, upstream of the control valve 5.

[0018] A relief valve sealing seat 21 having a through bore 25 is configured at the inlet side 35 of the valve body 20. A ball 22, a spring seat 23 and a spring 24, are configured intermediate the sealing seat 21 and an outlet bore 26. The outlet bore 26 is at the outlet side 36 of the valve body, and configured in hydraulic communication with the fuel passage 37. In an alternate embodiment (not shown), the various components may be assembled separately into a bore in the pump housing 3 which comprises the valve body 20.

[0019] The relief valve spring 24 is placed within the valve body 20 to apply a load through the spring seat 23 and force the ball 22 sealingly against the relief valve sealing seat 21, which is press-fit into the valve body 20. The opening pressure may be adjusted by pressing the relief valve sealing seat 21 deeper into the valve body bore 20 until the spring 24 is adequately compressed. Once the relief pressure is set, the auxiliary relief valve assembly 19 is installed into the pump housing 3 by press-fitting the valve body 20 into the pump housing 3.

[0020] During auxiliary relief valve operation, fluid flows from the pumping chamber 10 and passes through bore 25 and around the ball 22. Once fluid

passes around the ball 22, fluid passes around the spring seat 23 and through the bore 26. Once fluid passes through the bore 26 it can then pass into the low pressure side of the pump upstream of the control valve 5.

[0021] Figure 6 depicts an outlet fitting assembly 39 for use with an alternate embodiment of the pump assembly. In the alternate embodiment, the outlet check valve 11 and primary pressure relief valve 12 are replaced by the outlet fitting assembly of Figure 6. The outlet fitting assembly 39 is in hydraulic communication with the pumping chamber 10 at one end, and the high pressure line 14 at the other end. An outlet/pressure relief seat 27 is affixed and sealed to the outlet fitting 39 by an interference fit. An outlet check valve 28 is biased closed against the outlet/pressure relief seat 27 by an outlet check spring 29 and guided by an outlet check stop 30.

[0022] A pressure relief spring 32 imparts a biasing force upon spring seat 33, which biases and seals a pressure relief ball 31 against the outlet/pressure relief seat 27. Adjustment cup 34 is interference fit into the end of the fitting assembly in hydraulic communication with the pumping chamber 10, bearing against spring 32 until the desired opening pressure of ball 31 is reached.

[0023] During normal pump operation, the fuel flow follows the arrows toward the right during the pumping phase of the operational cycle. During the charging phase the outlet check valve 28 closes, preventing any backflow through the fitting into the pumping chamber 10. If the pressure in the system during the charging phase exceeds the biasing force provided by the pressure relief spring 32, the pressure relief ball 31 will be forced toward the pumping chamber 10, allowing fuel to flow in the direction of the leftward directed arrows, into the pumping chamber 10.

Claims:

1. A fuel pump having a low pressure fuel inlet (40) and a single piston pumping chamber (10) for supplying high pressure fuel through a pump outlet to an inlet side of a common rail (16), comprising: a primary pressure relief valve (12) having an inlet side in hydraulic communication with the inlet side of the common rail (16) and an outlet side in fluid communication with the pumping chamber (10); and an auxiliary pressure relief valve (19) having an inlet side (35) in hydraulic communication with the pumping chamber (10) and an outlet side (36) in direct fluid communication with a fuel passage (37) at the low pressure of the pump inlet.
2. The pump of claim 1 wherein the primary pressure relief valve (12) has a static opening pressure (P_{R1}) that is less than a static opening pressure (P_{R2}) of the auxiliary pressure relief valve (19).
3. The pump of claim 1 wherein the primary pressure relief valve (12) is located in a fitting (13) attached to the pump housing (3) at the pump outlet and the auxiliary pressure relief valve (19) is located entirely within the pump housing (3).
4. The pump of claim 3, wherein an outlet check valve (11) in hydraulic communication with a high pressure fuel line (14) is also located in the fitting (13).
5. The pump of claim 3, wherein an outlet check valve (11) in hydraulic communication with a high pressure fuel line (14) is contained in a separate fitting from the primary pressure relief valve (12), and both the outlet check valve (11) and primary pressure relief valve (12) are in hydraulic communication with a high pressure fuel line (14).

6. The pump of claim 1 wherein both the primary pressure relief valve (12) and the auxiliary pressure relief valve (19) are located within the pump housing (3).

7. The pump of claim 1, wherein the pump includes a control valve (5) that allows low pressure fuel from the fuel inlet (40) to the pumping chamber (10) during a charging stroke of the pump, and the outlet side (36) of the auxiliary pressure relief valve (19) is in direct hydraulic communication with a low pressure feed annulus (38) upstream of the control valve (5).

8. The pump of claim 7, wherein an electronic control unit (18) controls high pressure fuel output, the electronic control unit (18) configured to open or close the control valve (5) via a solenoid (6), upon receiving an output signal from a rail pressure sensor (17) in hydraulic communication with the common rail (16).

9. The pump of claim 1, wherein

the pump includes a control valve (5) that allows low pressure fuel from the fuel inlet (40) to the pumping chamber (10) during a charging stroke of the pump, and the outlet side (36) of the auxiliary pressure relief valve (19) is in direct hydraulic communication with a low pressure passage (37) upstream of the control valve (5);

the auxiliary pressure relief valve (19) is located entirely within the pump housing (3) with the inlet side (35) of the auxiliary valve (19) in direct fluid communication with the pumping chamber (10); and

the primary pressure relief valve (12) static opening pressure (P_{R1}) is less than the auxiliary pressure relief valve (19) static opening pressure (P_{R2}).

10. The pump of claim 1, wherein

the pump includes an outlet fitting (39) having an outlet check spring (29) at a first end biasing an outlet check valve (28) closed against an

outlet/pressure relief seat (27) interference fit within the outlet fitting (39), the outlet check spring abutting an outlet check stop at an end axially opposite the outlet check valve (30), and a pressure relief spring (32) at a second end of the outlet fitting (39) biasing a spring seat (33) and pressure relief ball (31) against the outlet/pressure relief seat (27), the pressure relief spring abutting an adjustment cup (34) at an end axially opposite the spring seat (33) and pressure relief ball (31); and

the first end of the outlet fitting (39) is in hydraulic communication with the high pressure fuel line (14), and the second end of the outlet fitting (39) is in hydraulic communication with the pumping chamber (10).

11. A fuel pump having a low pressure fuel inlet (40), a single piston pumping chamber (10); a control valve (5) that allows low pressure fuel from the fuel inlet (40) to the pumping chamber (10) during a charging stroke of the piston (8), a pump outlet for discharging high pressure fuel from the pumping chamber (10) during a pumping stroke of the piston (8); and a primary pressure relief valve (12) having an inlet side outside the pump and an outlet side in fluid communication with the pumping chamber (10);

wherein the improvement comprises an auxiliary pressure relief valve (19) having an inlet side (35) in hydraulic communication with the pumping chamber (10), an outlet side (36) in direct hydraulic communication with a low pressure passage (37) upstream of the control valve (5); and wherein the primary pressure relief valve (12) has a static opening pressure (P_{R1}) that is less than a static opening pressure (P_{R2}) of the auxiliary pressure relief valve (19).

12. A fuel pump having a low pressure fuel inlet (40) and a single piston pumping chamber (10) for supplying high pressure fuel through a pump outlet to an inlet side of a common rail (16), comprising: a primary pressure relief valve (12) having an inlet side in hydraulic communication with the inlet side of the common rail (16) and an outlet side in fluid communication with the

pumping chamber (10); and an auxiliary pressure relief valve (19) having an inlet side (35) in hydraulic communication with the inlet side of the common rail (16) and an outlet side (36) in direct fluid communication with a fuel passage (37) at the low pressure of the pump inlet.

13. The pump of claim 12 wherein the primary pressure relief valve (12) has a static opening pressure (P_{R1}) that is less than a static opening pressure (P_{R2}) of the auxiliary pressure relief valve (19).

14. The pump of claim 12 wherein the primary pressure relief valve (12) is located in a fitting (13) attached to the pump housing (3) at the pump outlet and the auxiliary pressure relief valve (19) is located entirely within the pump housing (3).

15. The pump of claim 14, wherein an outlet check valve (11) in hydraulic communication with a high pressure fuel line (14) is also located in the fitting (13).

16. The pump of claim 14, wherein an outlet check valve (11) in hydraulic communication with a high pressure fuel line (14) is contained in a separate fitting from the primary pressure relief valve (12), and both the outlet check valve (11) and primary pressure relief valve (12) are in hydraulic communication with a high pressure fuel line (14).

17. The pump of claim 12 wherein the primary pressure relief valve (12) is located in a fitting (13) attached to the pump housing (3) at the pump outlet and the auxiliary pressure relief valve (19) is located entirely within the pump housing (3) with the inlet side (35) of the auxiliary valve (19) in direct fluid communication with a high pressure line (14) in hydraulic communication with the inlet side of the common rail (16).

18. The pump of claim 17, wherein an outlet check valve (11) in hydraulic communication with a high pressure fuel line (14) is also located in the fitting (13).

19. The pump of claim 17, wherein an outlet check valve (11) in hydraulic communication with a high pressure fuel line (14) is contained in a separate fitting from the primary pressure relief valve (12), and both the outlet check valve (11) and primary pressure relief valve (12) are in hydraulic communication with a high pressure fuel line (14).

20. The pump of claim 12 wherein both the primary pressure relief valve (12) and the auxiliary pressure relief valve (19) are located within the pump housing (3).

21. The pump of claim 12, wherein the pump includes a control valve (5) that allows low pressure fuel from the fuel inlet (40) to the pumping chamber (10) during a charging stroke of the pump, and the outlet side (36) of the auxiliary pressure relief valve (19) is in direct hydraulic communication with a low pressure feed annulus (38) upstream of the control valve (5).

22. The pump of claim 21, wherein an electronic control unit (18) controls high pressure fuel output, the electronic control unit (18) configured to open or close the control valve (5) via a solenoid (6), upon receiving an output signal from a rail pressure sensor (17) in hydraulic communication with the common rail (16).

23. The pump of claim 12, wherein

the pump includes a control valve (5) that allows low pressure fuel from the fuel inlet (40) to the pumping chamber (10) during a charging stroke of the pump, and the outlet side (36) of the auxiliary pressure relief valve (19) is in direct hydraulic communication with a low pressure passage (37) upstream of the control valve (5);

the auxiliary pressure relief valve (19) is located entirely within the pump housing (3); and

the primary pressure relief valve (12) static opening pressure (P_{R1}) is less than the auxiliary pressure relief valve (19) static opening pressure (P_{R2}).

24. The pump of claim 12, wherein

the pump includes an outlet fitting (39) having an outlet check spring (29) at a first end biasing an outlet check valve (28) closed against an outlet/pressure relief seat (27) interference fit within the outlet fitting (39), the outlet check spring abutting an outlet check stop at an end axially opposite the outlet check valve (30), and a pressure relief spring (32) at a second end of the outlet fitting (39) biasing a spring seat (33) and pressure relief ball (31) against the outlet/pressure relief seat (27), the pressure relief spring abutting an adjustment cup (34) at an end axially opposite the spring seat (33) and pressure relief ball (31); and

the first end of the outlet fitting (39) is in hydraulic communication with the high pressure fuel line (14), and the second end of the outlet fitting (39) is in hydraulic communication with the pumping chamber (10).

25. In a fuel pump having a low pressure fuel inlet (40), a single piston pumping chamber (10); a control valve (5) that allows low pressure fuel from the fuel inlet (40) to the pumping chamber (10) during a charging stroke of the piston (8), a pump outlet for discharging high pressure fuel from the pumping chamber (10) during a pumping stroke of the piston (8) into a common rail (16); a primary pressure relief valve (12) having an inlet side in hydraulic communication with the common rail (16) and an outlet side in fluid communication with the pumping chamber (10); an auxiliary pressure relief valve (19) located entirely within the pump housing (3) with an inlet side in direct hydraulic communication with the pumping chamber (10) an outlet side in direct hydraulic communication with a low pressure passage (37) upstream of the control valve (5); a method of overpressure protection comprising:

when the pressure in the common rail (16) exceeds a first limit (P_{R1}), opening the primary relief valve (12), thereby flowing fuel in a direction from the common rail (16), through the primary pressure relief valve (12), and to the pumping chamber (10); and

when the pressure (P_{ch}) in the pumping chamber exceeds a second limit (P_{R2}), opening the auxiliary pressure relief valve (19), thereby flowing fuel from the pumping chamber (10) to the low pressure passage (37) upstream of the control valve (5) during the pumping stroke .

26. The method of claim 25, wherein

the primary pressure relief valve (12) static opening pressure (P_{R1}) is less than the auxiliary pressure relief valve (19) static opening pressure (P_{R2});

the flow of fuel into the pumping chamber (10) begins when the primary relief valve (12) opens during the charging stroke of the piston (8); and

the flow of fuel from the pumping chamber (10) begins when the auxiliary relief valve (19) opens during the pumping stroke of the piston (8).

27. The method of claim 26, wherein a closed feedback loop comprising an electronic control unit (18) controls the pressure in the common rail (16) via control of the high pressure fuel output, the method further comprising a rail pressure sensor (17) sensing a pressure in the common rail (16) and sending an output signal to the electronic control unit (18), upon receiving the output signal from the rail pressure sensor (17) the electronic control unit (18) controlling a solenoid (6) to open or close the outlet control valve (5).

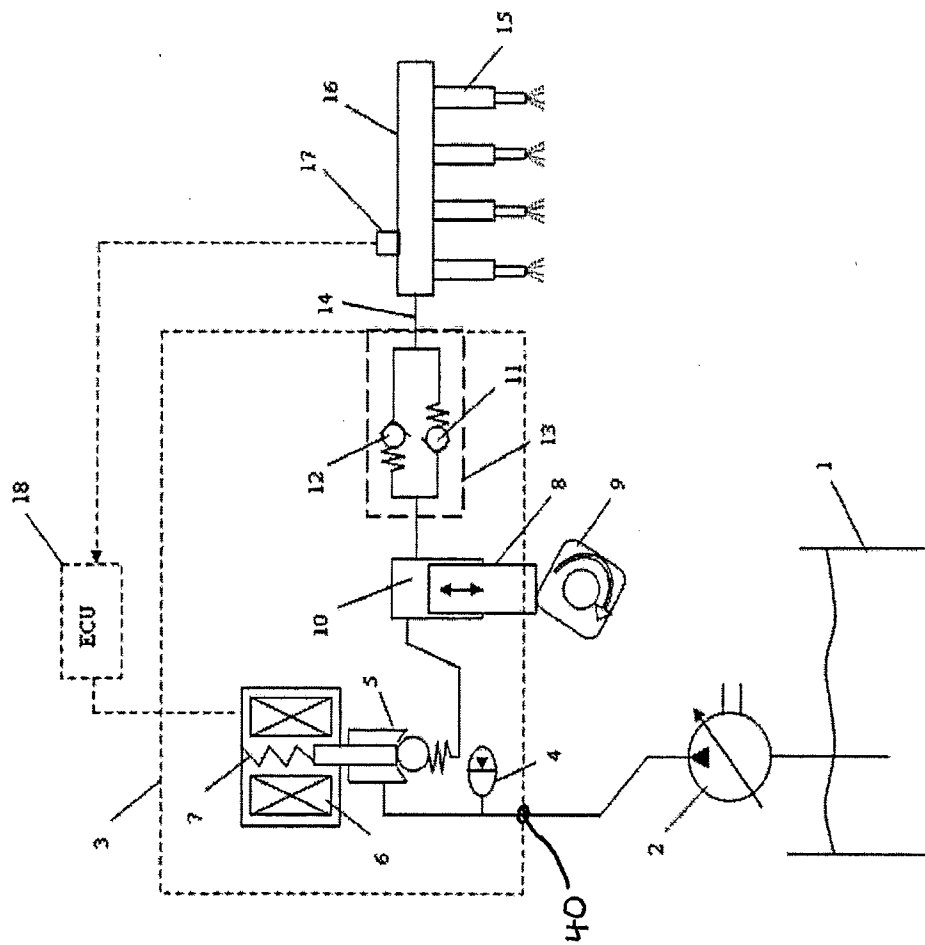


Figure 1

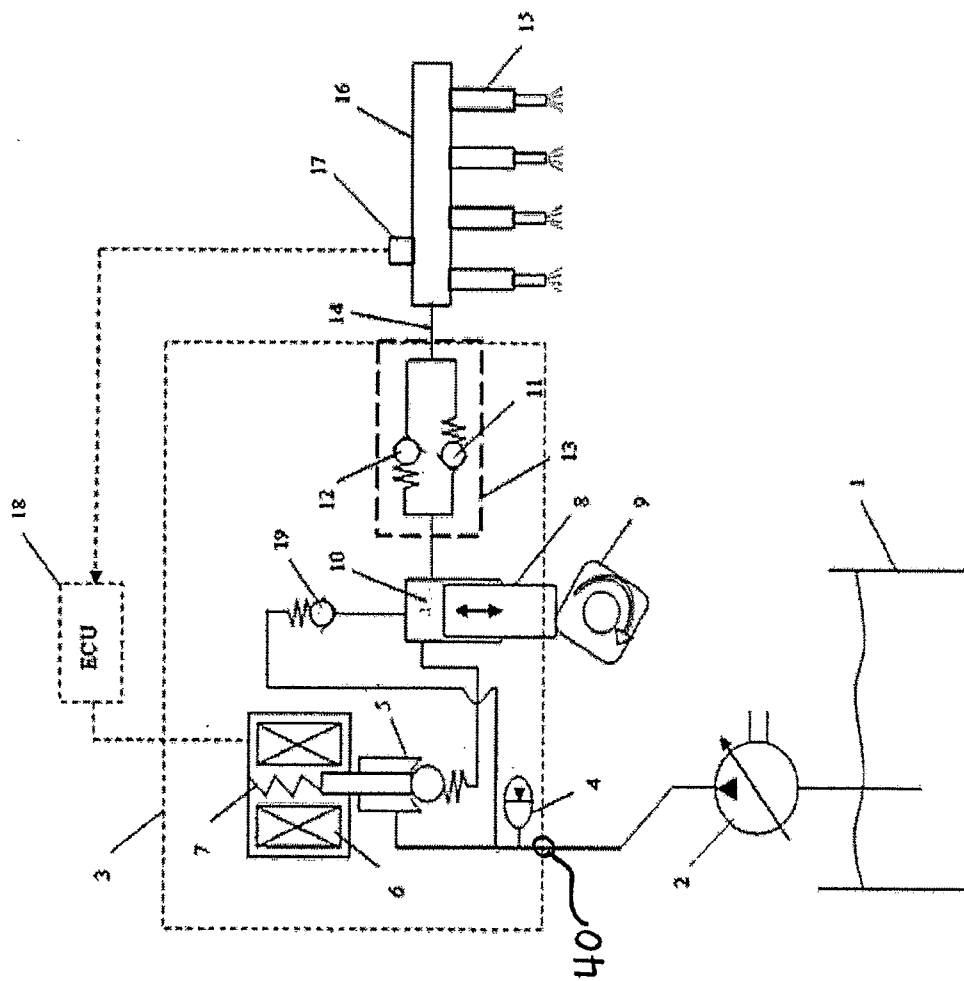


Figure 2

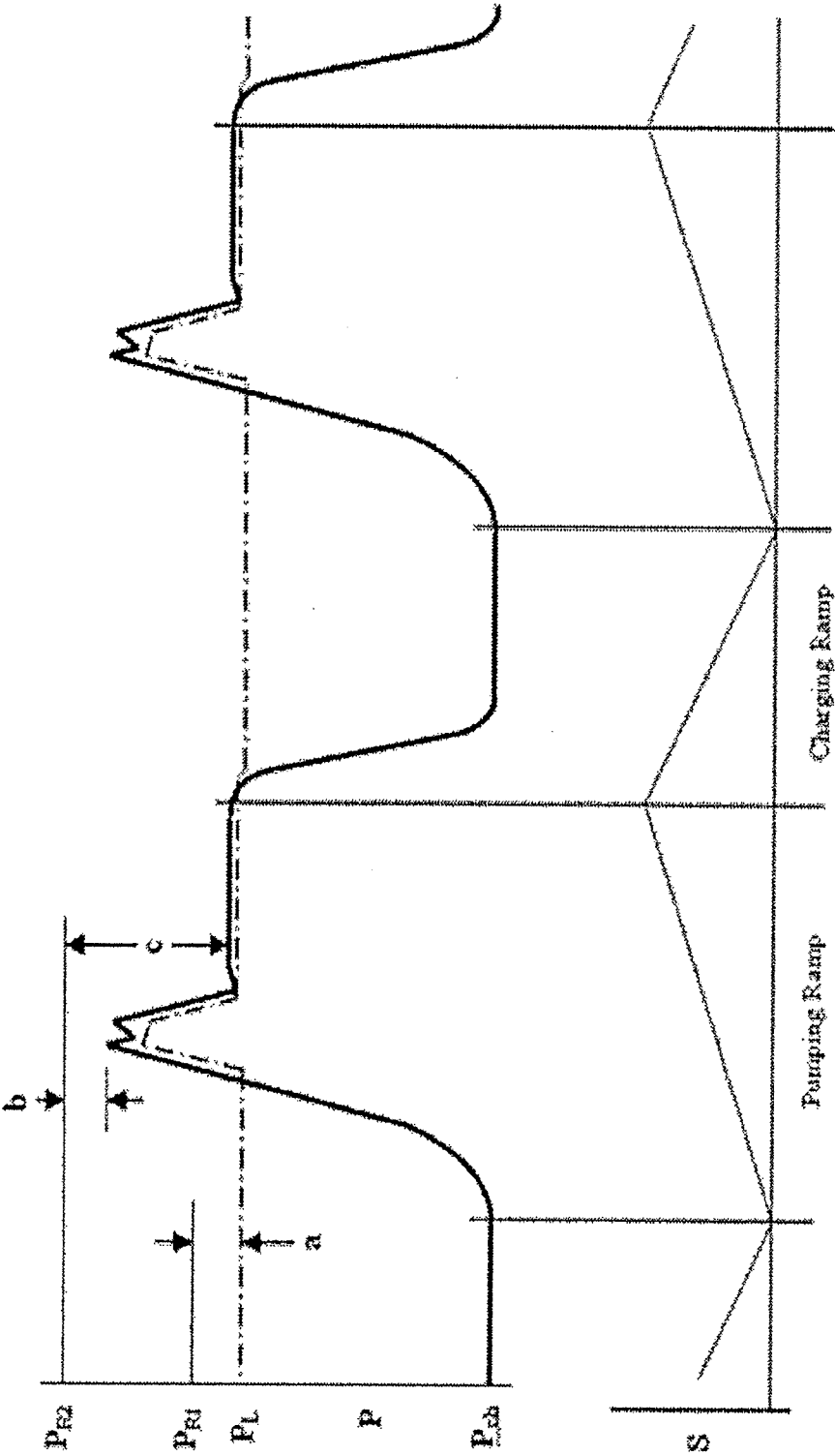


Figure 3

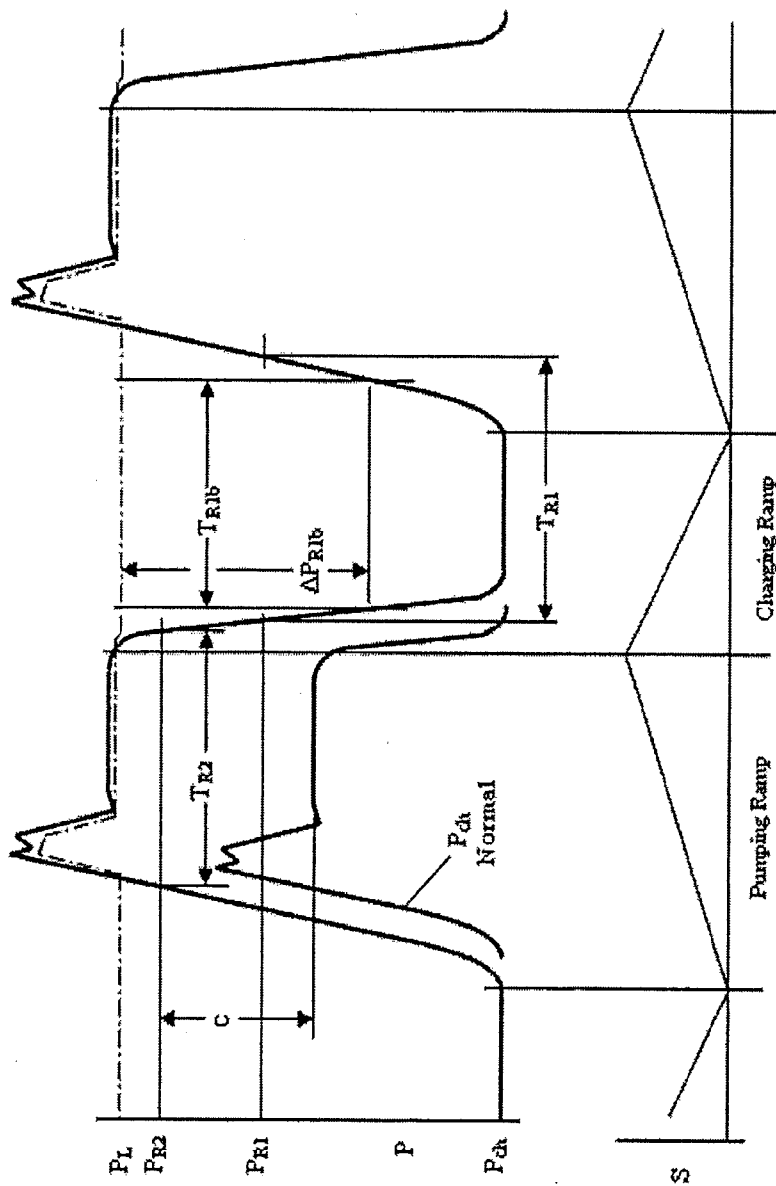


Figure 4

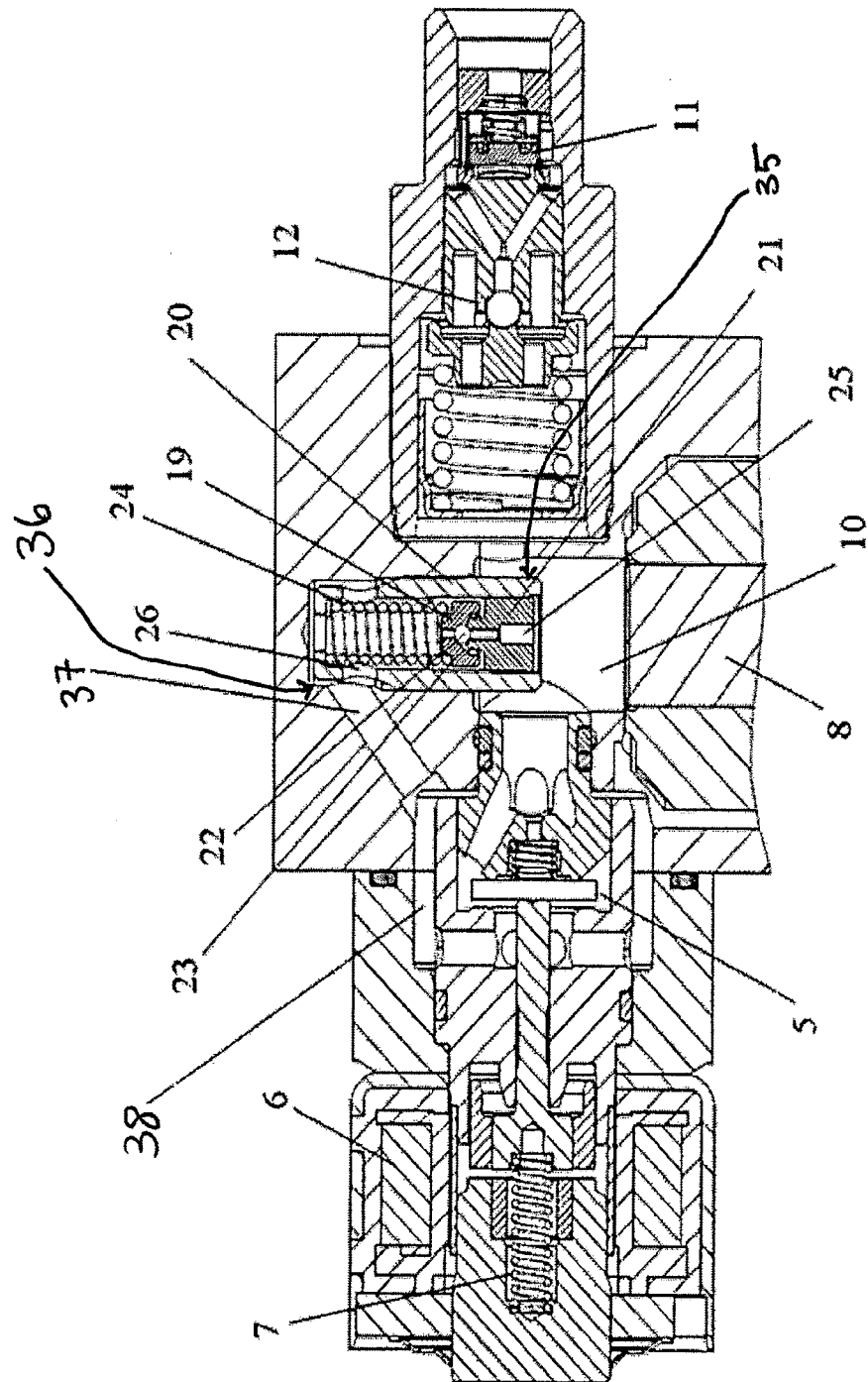


Figure 5

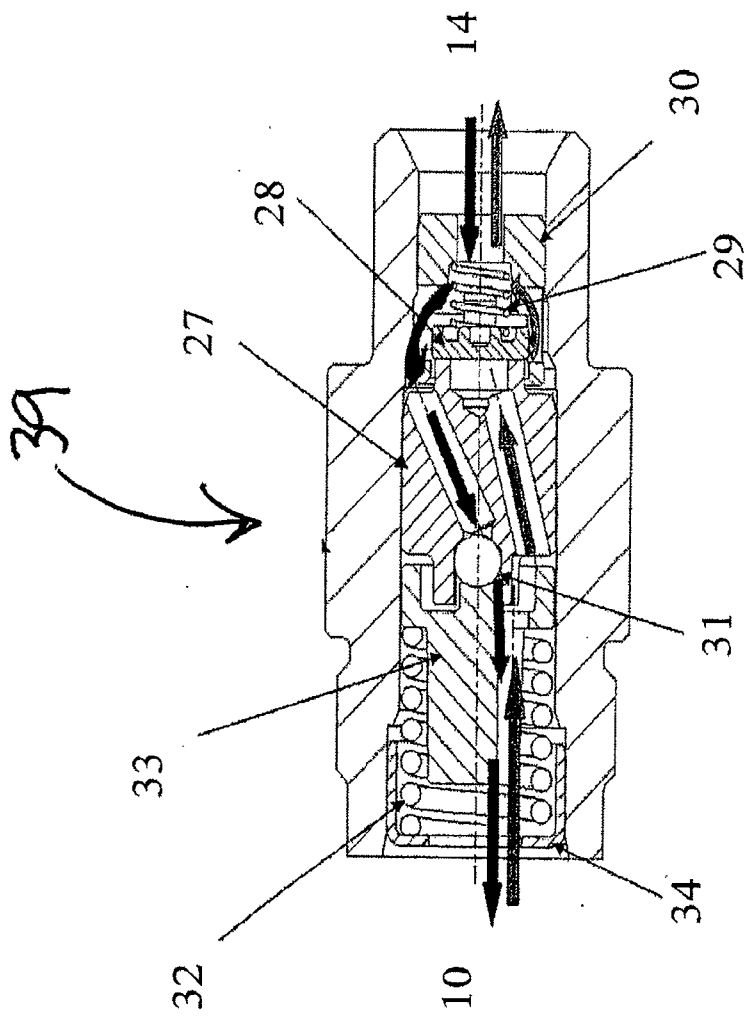


Figure 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 12/64963

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F02M 59/02, 59/46 (2012.01)

USPC - 123/506; 417/308

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

USPC:123/506; 417/308

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC:123/445, 446, 456, 457, 459, 495, 506; 137/511, 512; 417/299, 302, 304, 307, 308, 443; F02M 59/02, 59/46

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatBase; Google Patents; Google Scholars.

Search Terms: fuel, pump, piston, rail, relief, check, valve, pressure, inlet, outlet, passage, chamber, auxiliary, second, two, dual, pair, double, additional

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2011/0126804 A1 (Lucas et al.) 02 June 2011 (02.06.2011) entire document; fig 1a; para [0014], [0015]	1-27
Y	US 6,860,255 B2 (Yamaguchi et al.) 01 March 2005 (0103.2005) entire document; fig 2; col 8, ln 48 to col 9, ln 2; col 14, ln 3-11	1-27
A	US 7,757,663 B2 (Usui et al.) 20 July 2010 (20.07.2010) entire document.	1-27
A	US 7,464,697 B2 (Gray et al.) 16 December 2008 (16.12.2008) entire document.	1-27
A	US 2005/0126539 A1 (Okamoto) 16 June 2005 (16.06.2005) entire document.	1-27

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Date of the actual completion of the international search

13 January 2012 (13.01.2012)

Date of mailing of the international search report

05 FEB 2013

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