(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 030 049 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
07.08.2024 Bulletin 2024/32

(21) Application number: **21151470.8**

(22) Date of filing: **14.01.2021**

(51) International Patent Classification (IPC):
F02M 63/02 *(2006.01)* ***F02M 55/02*** *(2006.01)*
F02M 55/04 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F02M 63/027; F02M 55/025; F02M 55/04;
F02M 2200/40

(54) **A COMMON RAIL FUEL INJECTION SYSTEM FOR A MULTICYLINDER INTERNAL COMBUSTION PISTON ENGINE, METHOD OF UPGRADING A FUEL INJECTION SYSTEM IN A MULTICYLINDER INTERNAL COMBUSTION PISTON ENGINE AND AN INTERNAL COMBUSTION PISTON ENGINE**

COMMON-RAIL-KRAFTSTOFFEINSPRITZSYSTEM FÜR EINEN MEHRZYLINDER-VERBRENNUNGSKOLBENMOTOR, VERFAHREN ZUM NACHRÜSTEN EINES KRAFTSTOFFEINSPRITZSYSTEMS IN EINEM MEHRZYLINDER-VERBRENNUNGSKOLBENMOTOR UND VERBRENNUNGSKOLBENMOTOR

SYSTÈME D'INJECTION DE CARBURANT À RAMPE COMMUNE POUR UN MOTEUR À PISTON À COMBUSTION INTERNE MULTICYLINDRES, PROCÉDÉ DE MISE À NIVEAU D'UN SYSTÈME D'INJECTION DE CARBURANT DANS UN MOTEUR À PISTON À COMBUSTION INTERNE MULTICYLINDRES ET MOTEUR À PISTON À COMBUSTION INTERNE

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(43) Date of publication of application:
20.07.2022 Bulletin 2022/29

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Description

Technical field

[0001] The present invention relates to a common rail fuel injection system for a multicylinder internal combustion piston engine according to the preamble of claim 1.

[0002] The present invention relates to a method of upgrading a fuel injection system in a multicylinder internal combustion piston engine comprising fuel delivering high-pressure parts including fuel injector in each one of the cylinders of the engine, fuel pressure accumulators and fuel supply line connecting the pressure accumulators to the injectors, high-pressure fuel pumps connected to the fuel supply line.

[0003] The present invention relates to an internal combustion piston engine comprising a common rail fuel injection system.

Background art

[0004] A so called common rail fuel injection system is commonly used in internal combustion piston engines for use with various types of fuels. The common rail fuel injection systems have been used particularly in connection with diesel engines, but are applicable to piston engines configured to operation using also other types of cycles. The common rail fuel injection system has independently operable fuel pressure generation and injection timing control for each cylinder of the engine, and therefore it provides very versatile and precise control of the fuel injection and combustion of the fuel.

[0005] Some arrangements of such a common rail fuel injection system are described in the following prior art documents.

[0006] GB2341637 A discloses a common rail fuel injection system in which the injectors are provided with a dedicated pressure accumulator which is arranged immediately upstream to the injector. The accumulators are connected with each other and to a high-pressure injection pump.

[0007] WO9842978A1 discloses a common rail fuel injection system where each injector is provided with a dedicated accumulator in the fuel feed pipe and the accumulators are arranged parallel to each other having a volume of 80 - 300 times the maximal fuel injection amount.

[0008] EP1612405 A1 discloses a fuel injection system which comprises a tank for the fuel; a compressor assembly for making available the fuel at a high-pressure to a storage volume; a plurality of electro-injectors fluidically connected to the storage volume for taking in the fuel at a high-pressure from the storage volume itself and injecting it into respective combustion chambers of the engine. There is also a pressure regulator for correcting the value of the injection pressure with respect to the operating conditions of the engine i.e., for adjusting the pressure of the fuel inside the storage volume given the same pressure of the fuel delivered by the compressor assembly to the storage volume itself. The storage volume is split into a plurality of distinct elementary storage volumes, which are fluidically connected to one another and which supplies fuel to a respective electro-injector. The storage volumes may also be arranged in the respective electro-injector.

[0009] EP0959245 A2 discloses a fuel feeding system for an engine with several cylinders in which the fuel is fed from a fuel tank by means of high-pressure pumps into two separate accumulators, from which it is fed further by means of injectors into the cylinders of the engine. Each one of the accumulators is connected to at least two injectors and the accumulators are provided with a high-pressure pump of their own. The pressure spaces of the pressure accumulator units also are continuously in connection with each other. In addition, one of the pressure accumulator units of the system is provided with a valve, by means of which a pressure space of the accumulator and at the same time the pressure spaces connected thereto can be connected to the fuel tank.

[0010] WO2012107633 A2 discloses a fuel injection system for a reciprocating engine. The fuel injection system comprises injectors for injecting pressurized fuel into the cylinders of the engine, a high-pressure pump for pressurizing fuel to be injected, a supply pipe for feeding fuel from the high-pressure pump towards the injectors and feed pipes for feeding fuel from the supply pipe to the injectors, wherein the first ends of the feed pipes are connected to the injectors, the second ends of the feed pipes are connected to the supply pipe, and each fuel injector is provided with a pressure accumulator, which is an integral part of the injector. This kind of an arrangement may lead to increase size of the injector because the accumulation volume is mainly, if not solely, in the injectors. Document EP 0 711 914 A discloses a fuel injection system.

[0011] An object of the invention is to provide a common rail fuel injection system in which the performance, particularly with regard to stable pressure conditions, is considerably improved compared to the prior art solutions.

Disclosure of the Invention

[0012] Objects of the invention can be met substantially as is disclosed in the independent claims and in the other claims describing more details of different embodiments of the invention.

[0013] According to an embodiment of the invention a common rail fuel injection system for a multicylinder internal combustion piston engine, comprising at least two fuel injectors, wherein each one of the injectors is provided with a first accumulator space,

a fuel supply line arranged in flow communication with each one of the first accumulator spaces,
at least two high-pressure pump units, wherein
each one of the high-pressure pump units comprises

a high-pressure pump and a second accumulator space, the high-pressure fuel pump having its high-pressure outlet connected to the second accumulator space,

the second accumulator spaces being in flow connection with each other, forming an array of second accumulator spaces such that the first one of the second accumulator spaces is at a first end of the array and a last one of the second accumulator spaces is at a second end of the array, and wherein the array of second accumulator spaces is in flow communication with the fuel supply line.

[0014] By means of the common rail fuel injection system for a multicylinder internal combustion piston engine, a compact and effective design is obtained which dampens and stabilizes the pressure waves in the common rail fuel injection system. Furthermore, the presented common rail fuel injection system for multicylinder internal combustion piston engine stabilizes the fuel injection quantities between injectors, thus beneficially effecting on the stability of the combustion process.

[0015] According to an embodiment of the invention the array of second accumulator spaces is in connection with the fuel supply line through only one of the second accumulator spaces.

[0016] According to an embodiment of the invention the array of second accumulator spaces is in connection with the fuel supply line through only one of the second accumulator spaces at the end in the array of second accumulator spaces.

[0017] According to an embodiment of the invention the array of second accumulator spaces is in connection with each one of the first accumulator spaces via a connection from its second end.

[0018] According to an embodiment of the invention a second end of the fuel supply line is provided with a safety valve, by means of which the fuel supply line is connectable in flow connection with a fuel tank.

[0019] According to an embodiment of the invention a second end of the fuel supply line is provided with circulation valve by means of which the fuel supply line is connectable in flow connection with a fuel tank.

[0020] According to an embodiment of the invention the common rail fuel injection system the number of high-pressure pump units is at least half of the number of the fuel injectors.

[0021] According to an embodiment of the invention the common rail fuel injection system the number of high-pressure pump units is half of the number of the fuel injectors.

[0022] According to an embodiment of the invention the volume of the first accumulator space is 10 - 30 times the maximum injection quantity of the injector. It has been found out by the inventors that this range results in effective wave dampening in the fuel injection system, yet simultaneously making possible to effectively utilize the available space in and in vicinity of cylinder heads of the engine.

[0023] According to an embodiment of the invention the first accumulator space is 18 - 22 times the maximum injection quantity of the injector.

[0024] According to an embodiment of the invention the volume of the second accumulator space is 0,1 - 0,2 times the volume of the first accumulator space. According to the studies this range is the most feasible for pressure wave dampening of the fuel when size and complexity of the components are considered.

[0025] According to an embodiment of the invention the common rail fuel injection system comprises a low-pressure pump configured to supply fuel to each one of the high-pressure pumps, fuel inlets of which high-pressure pumps are coupled parallel to each other and to the low-pressure pump by a fuel transfer line.

[0026] According to an embodiment of the invention the common rail fuel injection system is configured such that the volume flow of fuel which exits from a specific second fuel accumulator space 34 consist of fuel volume flow from each one of the preceding high-pressure pump units 30.2 in the array, and the fuel volume flow from the high-pressure pump of the specific high-pressure pump unit.

[0027] According to an embodiment of the invention second accumulator space comprises cylindrical volume having a diameter and a length, and the length/diameter ratio of the second accumulator space is 7,5 to 8,5. This provides effective pressure wave dampening with straightforward structure and manufacturing process of the second accumulator space.

[0028] According to an embodiment of the invention second accumulator space comprises cylindrical volume having a diameter and a length, and that the length/diameter ratio of the second accumulator space is 7,5 to 8,5, and the first accumulator space is 18 - 22 times the maximum injection quantity of the injector, and the volume of the second accumulator space is 0,1 - 0,2 times the volume of the first accumulator space.

[0029] According to an embodiment of the invention the cylindrical second accumulator space comprises a first end and a second end, and comprising a first flow port at the first end, a second flow port at the second and a third flow port between the first end and the second end and the first flow port is a fuel outlet connected to either to a second flow port of another cylindrical second accumulator space, or to the fuel supply line, and that second flow port is a first fuel inlet, and the third flow port is a second fuel inlet connected to the high-pressure outlet of the high-pressure fuel pump.

[0030] Method of upgrading a fuel injection system in a multicylinder internal combustion piston engine, the engine comprising fuel delivering high-pressure parts including fuel injector in each one of the cylinders of the engine, fuel pressure accumulators and fuel supply line connecting the pressure accumulators to the injectors, high-pressure fuel pumps connected to the fuel supply line, comprising:

disassembling at least following fuel supply high-pressure parts from the engine:

fuel injectors from each one of the cylinders of the engine,
fuel supply lines connected to the injectors,
high-pressure fuel accumulators connected to the fuel supply line and thereafter
assembling fuel injectors provided with a first accumulator space,
assembling accumulators, each provided with a second accumulator space, in flow connection with each one of the high-pressure pumps,
connecting the second accumulators in flow communication with each other forming an array of second accumulator spaces, and
connecting the array of second accumulator spaces in flow communication by means the fuel supply line first accumulator spaces.

[0031] By means of the invention it is possible to effectively replace a bulky, old common rail accumulators of the first generation in the hotbox of the engine. The retrofit injectors provided with major part of the needed accumulator volume as the first accumulator space, can be installed to replace the old ones in easy way while the old single plunger pumps of the common rail first generation are complemented with accumulators with a second accumulator space.

[0032] According to an embodiment of the invention the method further comprising:

assembling the fuel injector provided with a first accumulator space, having volume which is 10 - 30 times the maximum injection quantity of the injector to each one of the cylinders,
assembling the accumulators, provided with the second accumulator space, having volume which is 0,1 - 0,2 times the volume of the first accumulator space.

[0033] According to an embodiment of the invention the method comprising: disassembling high-pressure pumps connected to the fuel supply line, assembling a common rail fuel injection system to the engine, by assembling at least two high-pressure pumps and connecting each high-pressure fuel pump to one second accumulator space.

[0034] According to an embodiment of the invention the method comprising assembling accumulators, each provided with a cylindrical second accumulator space, in flow connection with each one of the high-pressure pumps, wherein the cylindrical volume having a diameter and a length, and the length/diameter ratio of the second accumulator space is 7,5 to 8,5.

[0035] Internal combustion piston engine comprising a fuel injection system according to anyone of the claims 1 - 9.

[0036] By means of various embodiments of the invention, following advantageous effects can be obtained: a compact and effective design which dampens and stabilizes the pressure waves in the common rail fuel injection system in a hotbox of the engine, more economical design for pump connection as regards to accumulators, better serviceability and easier maintenance, improved stability on fuel injection quantities between injectors and thus more stable combustion process.

[0037] The exemplary embodiments of the invention presented in this patent application are not to be interpreted to pose limitations to the applicability of the appended claims. The verb "to comprise" is used in this patent application as an open limitation that does not exclude the existence of also unrecited features. The features recited in depending claims are mutually freely combinable unless otherwise explicitly stated. The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims.

Brief Description of Drawings

[0038] In the following, the invention will be described with reference to the accompanying exemplary, schematic drawings, in which

Figure 1 illustrates a common rail fuel injection system according to an embodiment of the invention,

Figure 2 illustrates a common rail fuel injection system according to another embodiment of the invention, and

Figure 3 illustrates a high-pressure pump unit according to an embodiment of the invention.

Detailed Description of Drawings

[0039] Figure 1 depicts schematically a common rail fuel injection system 10 for an internal combustion piston engine 11, of which a sections of cylinder heads 12 are depicted, for clarity reasons. The internal combustion piston engine is well known to a skilled person in the art. The common rail fuel injection system 10 for a multicylinder internal combustion piston engine 11 according to the embodiment shown in the figure 1 comprise at least two fuel injectors 14, one injector per each cylinder of the engine. In this connection the injector 14 comprises necessary means, including valve needle and injection orifice(s) (not shown), for metering fuel into a combustion chamber of the engine under control of a computer, often referred to as electronic controller unit ECU. In some practical application the injector 14, more precisely, the same injector body may include second means for metering (injection valve assembly) second fuel to the combustion chamber, separated from the present invention. The injectors are provided with leak fuel conduits for returning so called leak fuel back to a source of fuel 20,

such as a fuel tank. The leak fuel conduits are not shown here for clarity reasons. Number of cylinders in the engine may vary and therefore also the number of injectors vary accordingly.

[0040] Each one of the injectors is provided with a first accumulator space 16 within the body of the injector, which facilitates fuel delivery for each injection, such that adequate amount of fuel with adequate injection pressure is available for each injection occurrence. The injectors are connected with each other by a fuel supply line 18, which runs along the length of a row of cylinders in an engine, when the injectors and the fuel supply line 18 are assembled to the engine. High-pressure fuel is supplied by means of the fuel supply line 18 to each one of the injectors 14 and therefore also to the first accumulator spaces 16 of the injectors. The injectors are connected successively one after the other to the fuel supply line 18, such that the fuel for each one of the injectors is introduced at a first end of the fuel supply line 18. The fuel supply line 18 comprises pipe sections 26 which are connected with each other by a connector piece 24. Or, in other words, the connector pieces 24 are connected with each other by the pipe sections 26. The first accumulator spaces 16 in the injectors 14 are connected to the fuel supply line 18 by a branch line 22, which may be referred to as quill pipe delivering fuel to the injector through a cylinder head of the engine (not shown in the figure 1). The branch line 22 is connected to a respective connector piece 24. There is preferably a flow fuse 28 arranged to the branch line 22 or to the connector piece 24, effecting to the flow of fuel into the branch line 22 and to the injector 14. The flow fuse 28 prevents excess amount of fuel (more than a predetermined amount of fuel) flow from the fuel supply line 18 to the injector at a time, in case of malfunction of the injector, for example when the valve needle fails to close properly. Flow fuse and its operation is known to a skilled person in the art as such, a reference is made for example to WO2016024038 A1, paragraphs [0022] and [0023].

[0041] At the second end of the fuel supply line 18, that is, after the last connector piece 24 in the fuel supply line 18, in the flow direction of the fuel, there is a fuel return line 40 arranged, which connects the last connector piece to the tank 20, or other source of fuel. The fuel injection system comprises a safety valve 46 in flow connection with the second end of the fuel supply line 18, which is configured to open at a predetermined pressure and relief excess pressure to the return line 40. The fuel injection system comprises also a circulation valve 52 in flow connection with the second end of the fuel supply line 18, by means of which fuel may be arranged to flow, i.e., circulate in the fuel injection system.

[0042] For the safety valve 46 and the circulation valve 52, the return line 40 comprises a section having two parallel flow lines 42, 44. The safety valve 46 is arranged to the first flow line 42 and the circulation valve 52 is arranged to the second flow line 44 such that the valves can be operated independently from each other. The first flow line 42 is provided also with an expansion tank 48 downstream to the safety valve 46, to allow rapid decrease of the pressure in the fuel supply line 18, when needed. There is also an orifice 50 for limiting the flow rate of the fuel in the return line 40 back to the tank 20. Typically, the circulation valve 52 provides a proportional control of the fuel flow, whereas the safety valve may be of on-off type valve.

[0043] The common rail fuel injection system 10 comprises further at least two high-pressure pump units, here there are a first high-pressure pump unit 30.1 and a second high-pressure pump unit 30.2. Each one of the high-pressure pump units 30 comprises a high-pressure pump 32 and a second accumulator space 34. The high-pressure fuel pump 32 has its high-pressure fuel outlet 36 connected to the second accumulator space 34 via a connection pipe 35. Thus, advantageously the high-pressure pump 32 and the second accumulator space 34 are separate parts but fluidly connected with each other. Still further, in the common rail fuel injection system 10 the second accumulator spaces 34 are in direct flow connection with each other, forming an array of second accumulator spaces 38. The array 38 is formed such that the first one of the second accumulator spaces 34 is at a first end 38.1 of the array 38 and a last one of the second accumulator spaces 34 is at a second end 38.2 of the array 38. The array 38 of second accumulator spaces is in flow communication with the fuel supply line 18 at its end.

[0044] In the array 38 of second accumulator spaces, the second accumulator spaces 34 are connected with each other by a connection lines 31, and in the figure1 there is only shown the first connection line 31.1. The first high-pressure pump unit 30.1 feeds the fuel from the second accumulator space 34 to the first connection line 31.1 via which the fuel is fed to the second accumulator space 34 of the second high-pressure pump unit 34. In the embodiment shown in the figure 1 the fuel supply line18 is configured, and connected so as, to transfer the total fuel flow generated by all of the high-pressure pump units 30.1, 30.2 to the injectors 14.

[0045] The common rail fuel injection system comprises a fuel transfer line 54 which is configured to transfer fuel from the fuel tank 20 or a source of fuel, to the inlet side of the high-pressure pumps 32. The fuel transfer line 54 comprises a delivery line 56 which has its first end arranged in the tank 20. The delivery line 56 is provided with a low-pressure pump 58 as a fuel feed pump. The low-pressure pump 58 is configured to supply fuel to each one of the high-pressure pumps 32, fuel inlets of which high-pressure pumps are coupled parallel to each other and to the low-pressure pump by the fuel transfer line 54.

[0046] There is also a return line 60 provided, which is connected to the delivery line 56 by a pressure regulating valve 62 via which the delivery line is optionally connectable back to a source of the fuel 20. When the common rail fuel injection system is in use, the high-pressure pumps 32, when pressurizing and pumping the fuel, tend

to generate pressure pulsation into the system. This is the case because the high-pressure pump 32 is advantageously a jerk pump, in its simplest form a single plunger jerk pump.

[0047] In the system, pressure pulsation is attenuated firstly by the second accumulator space 34 associated with the specific pump, which is connected to the second accumulator space 34 via the in the connection pipe 35. This way the high-pressure unit 30.2 attenuates pressure pulsation near to the origin of the pulsation. It is important to the function of the common rail fuel injection system according to the invention that the total volume flow of the fuel is divided to be produced by several high-pressure pump units 30 and thus created pulsation is attenuated at the proximity to the origin of the pulsation. In the common rail fuel injection system, the number of high-pressure pump units is at least half of the number of the fuel injectors, even if in the figure 1 the number of high-pressure pump units is equal to the number of the fuel injectors 14. In fact, it is also important that a total fuel accumulator space in the system is divided to several partial volumes, which are partly located in the injectors 14, at immediate proximity to the injection valve and in the high-pressure pump units 30, at immediate proximity to the high-pressure pump. In terms of the maximum fuel injection quantity during one injection, that is, during one combustion occurrence in the cylinder, the volume of the first accumulator space is 10 - 30 times the maximum injection quantity of the injector, preferably the first accumulator space is 18 - 22 times the maximum injection quantity of the injector. Respectively, the volume of the second accumulator space is 0,1 - 0,2 times the volume of the first accumulator space.

[0048] As can be seen in the figure 1 the array 38 of second accumulator spaces is in connection with the fuel supply line 18 through only one of the second accumulator spaces 34, which is here the second accumulator space of the second high-pressure pump unit 30.2, at the end of the array. The second accumulator space 34 of the second high-pressure pump unit 30.2 is configured to receive fuel from the second accumulator space of the first high-pressure pump unit 30.1 and from the high-pressure pump 32 of the second high-pressure pump unit 30.2, and to deliver the fuel further to the fuel supply line 18. This way the array 38 of second accumulator spaces is in connection with each one of the first accumulator spaces 16 via a connection from its second end 38.2 only. The second accumulator space 34 is thus connected to a first end of the fuel supply line 18.

[0049] In general terms, the common rail fuel injection system is configured such that the volume flow of fuel which exits from a specific second fuel accumulator space 34 consist of fuel volume flow from each one of the preceding high-pressure pump units 30.2 in the array, and the fuel volume flow from the high-pressure pump of the specific high-pressure pump unit.

[0050] Figure 2 discloses a common rail fuel injection system according to another embodiment of the invention configured for a multicylinder engine. Figure 2 depicts schematically a common rail fuel injection system 10 which is practically similar to that shown in the figure 1, with the exception that in the figure 2 the common rail fuel injection system engine is adapted to deliver fuel to six cylinders. In other respect, all features disclosed and explained in connection with the figure 1 are applicable to the system in the figure 2. As is often the case, large piston engines configured to produce power for generating electricity or propulsion power have more than six cylinders, in which case a row of cylinders having more than six cylinders is provided with more than one of the common rail fuel injection system according to embodiment of the figure 2. In the embodiment shown in the figure 2 the number of high-pressure pump units 30 is half of the number of the fuel injectors 14. There are six injectors and three high-pressure pump units 30 in the system. Practically each one of the second accumulator spaces 34 effect on the pulsation of the fuel pressure in each one of the first accumulator spaces 16.

[0051] A high-pressure pump unit 30 according to an embodiment of the invention is illustrated in the figure 3 in more detailed manner. The high-pressure pump unit 30 in the figure 3 is a detailed presentation of the one shown in the figures 1 and 2. The second accumulator space 34 is arranged to a fuel accumulator body 33 which encloses the second accumulator space 34. The body 33 is preferably an assembly of more than one parts. The second accumulator space 34 is a cylindrical volume having a diameter D and a length L. The length/diameter ratio of the second accumulator space is 7,5 to 8,5. This alone provides a considerably attenuation of fuel pressure pulsation is obtained in the common rail fuel injection system according to the invention where at least two fuel injectors 14 provided with a first accumulator space are connected by the fuel supply line 18 with at least two high-pressure pump units 30 having the second accumulator spaces 34 in flow connection with each other, forming an array of second accumulator spaces.

[0052] The cylindrical second accumulator space 34 has a longitudinal axis and it has a first end 64 and a second end 66 opposite to each other. There is a first flow port 68 at the first end 64 of the second accumulator space 34, a second flow port 70 at the second end of the accumulator space, and a third flow port 72 between the first end 64 and the second end 66 of the cylindrical second accumulator space. The first flow port 68 is a fuel outlet connected to either to a second flow port 70 of another cylindrical second accumulator space 34 in a succeeding high-pressure pump units in the array 38, or if it the last one of the second accumulators 34 in the array 38, to the fuel supply line 18. The second flow port 70 is a first fuel inlet, connected to a first flow port 68 of another cylindrical second accumulator space 34 preceding in the array 38, to receive fuel flow from the preceding high-pressure pump units. And the third flow port 72 is a second fuel inlet connected to the high-pressure outlet 36 of the high-pressure fuel pump 32. Having the

flow ports arranged as described above, the second accumulator space 34 is a cylindrical volume having a diameter D and a length L, wherein the length/diameter ratio of the second accumulator space is 7,5 to 8,5. It has been found that usually the ratio value of substantially 8 provides goods results. Advantageously the volume of the first accumulator space 34 is 10 - 30 times the maximum injection quantity of the and the volume of the second accumulator space is 0,1 - 0,2 times the volume of the first accumulator space. Particularly, when applied to the system described in the figure 2 there is provided one distinct second accumulator space 34 for two first accumulator spaces 16 in the injector.

[0053] This way even more effective attenuation of fuel pressure pulsation is obtained in the common rail fuel injection system according to the invention where at least two fuel injectors 14 provided with a first accumulator space are connected by the fuel supply line 18 with at least two high-pressure pump units 30 having the second accumulator spaces 34 in flow connection with each other, forming an array of second accumulator spaces.

[0054] In the figure 3 the high-pressure pump unit 30 comprises a jerk pump 32. Even if a jerk pump is prone to produce pressure waves in the system, the common rail fuel injection system according to the invention attenuates such pressure waves effectively. The jerk pump 32 has a plunger 32.1 assembled to a cylinder 32.2 where a pumping space 32.3 is arranged above/behind an end of the plunger 32.1. The pumping space 32.3 is connected to a fuel inlet 35 via a check valve 32.4 and to the fuel outlet 36 via a second check valve 35.5 which facilitates the flow of pressurized fuel to only one direction and filling of the space with low-pressure fuel and preventing back and forth flow of the fuel, while the plunger 32.1 is reciprocating in the cylinder. The plunger 32.1 of the pump is driven by an accessory shaft, which usually is a cam shaft of the engine, directly or indirectly.

[0055] While the invention has been described herein by way of examples in connection with what are, at present, considered to be the most preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but is intended to cover various combinations or modifications of its features, and several other applications included within the scope of the invention, as defined in the appended claims. The details mentioned in connection with any embodiment above may be used in connection with another embodiment when such combination is technically feasible.

Claims

1. A common rail fuel injection system (10) for a multi-cylinder internal combustion piston engine (11), comprising

a low-pressure pump (58) configured to supply fuel to each one of high-pressure pumps in the system,

characterized by

at least two fuel injectors (14), wherein each one of the injectors (14) is provided with a first accumulator space (16) within the body of the injector,

a fuel supply line (18) arranged in flow communication with each one of the first accumulator spaces (16),

at least two high-pressure pump units (30), wherein

a. each one of the high-pressure pump units (30) comprises a high-pressure pump (32) and a second accumulator space (34), the high-pressure fuel pump having its high-pressure outlet (36) connected to the second accumulator space (34),

b. the second accumulator spaces (34) being in direct flow connection with each other, forming an array (38) of second accumulator spaces (34) such that the first one of the second accumulator spaces (34) is at a first end (38.1) of the array (38) and a last one of the second accumulator spaces (34) is at a second end (38.2) of the array (38), and

wherein the array (38) of second accumulator spaces (34) is in flow communication with the fuel supply line (18).

2. A common rail fuel injection system (10) according to claim 1, **characterized in that** the array (38) of second accumulator spaces (34) is in connection with the fuel supply line (18) through only one of the second accumulator spaces (34).

3. A common rail fuel injection system (10) according to claim 1 or 2, **characterized in that** the array (38) of second accumulator spaces (34) is in connection with the fuel supply line (18) through only one of the second accumulator spaces (34) at the end in the array (38) of second accumulator spaces (34).

4. A common rail fuel injection system (10) according to claim 1, **characterized in that** in the common rail fuel injection system (10) the number of high-pressure pump units (30) is at least half of the number of the fuel injectors (14).

5. A common rail fuel injection system (10) according to claim 4, **characterized in that** in the common rail fuel injection system (10) the number of high-pressure pump units (30) is half of the number of the fuel injectors (14).

6. A common rail fuel injection system (10) according

to anyone of the preceding claims **characterized in that** the volume of the first accumulator space (16) is 10 - 30 times the maximum injection quantity of the injector (14), and the volume of the second accumulator space (34) is 0,1 - 0,2 times the volume of the first accumulator space (16).

7. A common rail fuel injection system (10) according to anyone of the preceding claims, **characterized in that** the common rail fuel injection system (10) is configured such that the volume flow of fuel which exits from a specific second fuel accumulator space (34) consist of fuel volume flow from each one of the preceding high-pressure pump units (30) in the array (38), and the fuel volume flow from the high-pressure pump (32) of the specific high-pressure pump unit.

8. A common rail fuel injection system (10) according to anyone of the preceding claims, **characterized in that** second accumulator space (34) comprises cylindrical volume having a diameter and a length, and that the length/diameter ratio of the second accumulator space (34) is 7,5 to 8,5.

9. A common rail fuel injection system (10) according to claim 8, **characterized in that** the cylindrical second accumulator space (34) comprises a first end (64) and a second end (66), and comprising a first flow port (68) at the first end, a second flow port (70) at the second and a third flow port (72) between the first end (64) and the second end (66), wherein the first flow port (68) is a fuel outlet connected to either to a second flow port (70) of another cylindrical second accumulator space (34), or to the fuel supply line (18), and that second flow port (70) is a first fuel inlet, and the third flow port (72) is a second fuel inlet connected to the high-pressure outlet (36) of the high-pressure fuel pump (32).

10. Method of upgrading a fuel injection system in a multicylinder internal combustion piston engine (11), the engine (11) comprising a low-pressure pump (58) configured to supply fuel to each one of high-pressure pumps in the system, fuel delivering high-pressure parts including fuel injector (14) in each one of the cylinders of the engine (11), fuel pressure accumulators and fuel supply line (18) connecting the pressure accumulators to the injectors (14), high-pressure fuel pumps connected to the fuel supply line (18),
the method comprising:

disassembling at least following fuel supply high-pressure parts from the engine (11):

- fuel injectors from each one of the cylinders of the engine (11),
- fuel supply lines connected to the injectors,
- high-pressure fuel accumulators connected to the fuel supply line and thereafter

- assembling fuel injectors (14) provided with a first accumulator space (16) within the body of the injector,
- assembling accumulators, each provided with a second accumulator space (34), in flow connection with each one of the high-pressure pumps (32),
- connecting the second accumulators in direct flow communication with each other forming an array (38) of second accumulator spaces (34),
- connecting the array (38) of second accumulator spaces (34) in flow communication by means of the fuel supply line (18) with the first accumulator spaces (16).

11. Method of upgrading a fuel injection system in a multicylinder internal combustion piston engine (11) according to the claim 10, the method comprising:

assembling the fuel injector (14) provided with a first accumulator space (16), having volume which is 10 - 30 times the maximum injection quantity of the injector (14) to each one of the cylinders,
assembling the accumulators, provided with the second accumulator space (34), having volume which is 0,1 - 0,2 times the volume of the first accumulator space (16).

12. Method of upgrading a fuel injection system in a multicylinder internal combustion piston engine (11) according to the claim 10 or 11, the method comprising:

- disassembling high-pressure fuel pumps connected to the fuel supply line,
assembling a common rail fuel injection system (10) to the engine (11), by assembling
- at least two high-pressure fuel pumps (32) and connecting each high-pressure fuel pump to one second accumulator space (34)

13. Method of upgrading a fuel injection system in a multicylinder internal combustion piston engine (11) according to claim 10 or 11, wherein the method comprising assembling accumulators, each provided with a cylindrical second accumulator space (34), in flow connection with each one of the high-pressure pumps (32), wherein the cylindrical volume having a diameter and a length, and the length/diameter ratio of the second accumulator space (34) is 7,5 to 8,5.

14. Internal combustion piston engine (11) comprising a common rail fuel injection system (10) according to anyone of the preceding claims 1 - 9.

Patentansprüche

1. Common-Rail-Kraftstoffeinspritzsystem (10) für einen Mehrzylinder-Verbrennungskolbenmotor (11), umfassend eine Niederdruckpumpe (58), die dazu konfiguriert ist, Kraftstoff zu jeder der Hochdruckpumpen in dem System zuzuführen,
gekennzeichnet durch

mindestens zwei Kraftstoffeinspritzdüsen (14), wobei jede der Einspritzdüsen (14) mit einem ersten Speicherraum (16) innerhalb des Körpers der Einspritzdüse versehen ist,
eine Kraftstoffzufuhrleitung (18), die mit jedem der ersten Speicherräume (16) in Strömungskommunikation steht,
mindestens zwei Hochdruckpumpeneinheiten (30), wobei

a. jede der Hochdruckpumpeneinheiten (30) eine Hochdruckpumpe (32) und einen zweiten Speicherraum (34) umfasst, wobei die Hochdruckkraftstoffpumpe ihren Hochdruckauslass (36) mit dem zweiten Speicherraum (34) verbunden hat,
b. die zweiten Speicherräume (34) in direkter Strömungsverbindung miteinander stehen, indem sie ein Array (38) aus zweiten Speicherräumen (34) derart bilden, dass der erste der zweiten Speicherräume (34) an einem ersten Ende (38.1) des Arrays (38) liegt, und ein letzter der zweiten Speicherräume (34) an einem zweiten Ende (38.2) des Arrays (38) liegt, und
wobei das Array (38) der zweiten Speicherräume (34) in Strömungskommunikation mit der Kraftstoffzufuhrleitung (18) steht.

2. Common-Rail-Kraftstoffeinspritzsystem (10) nach Anspruch 1, **dadurch gekennzeichnet, dass** das Array (38) der zweiten Speicherräume (34) mit der Kraftstoffzufuhrleitung (18) durch nur einen der zweiten Speicherräume (34) in Verbindung steht.

3. Common-Rail-Kraftstoffeinspritzsystem (10) nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** das Array (38) der zweiten Speicherräume (34) mit der Kraftstoffzufuhrleitung (18) durch nur einen der zweiten Speicherräume (34) an dem Ende in dem Array (38) der zweiten Speicherräume (34) in Verbindung steht.

4. Common-Rail-Kraftstoffeinspritzsystem (10) nach Anspruch 1, **dadurch gekennzeichnet, dass** in dem Common-Rail-Kraftstoffeinspritzsystem (10) die Anzahl von Hochdruckpumpeneinheiten (30) mindestens die Hälfte der Anzahl der Kraftstoffeinspritzdüsen (14) beträgt.

5. Common-Rail-Kraftstoffeinspritzsystem (10) nach Anspruch 4, **dadurch gekennzeichnet, dass** in dem Common-Rail-Kraftstoffeinspritzsystem (10) die Anzahl von Hochdruckpumpeneinheiten (30) die Hälfte der Anzahl der Kraftstoffeinspritzdüsen (14) beträgt.

6. Common-Rail-Kraftstoffeinspritzsystem (10) nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** das Volumen des ersten Speicherraums (16) das 10-bis 30-Fache der maximalen Einspritzmenge der Einspritzdüse (14) beträgt, und das Volumen des zweiten Speicherraums (34) das 0,1- bis 0,2-Fache des Volumens des ersten Speicherraums (16) beträgt.

7. Common-Rail-Kraftstoffeinspritzsystem (10) nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** das Common-Rail-Kraftstoffeinspritzsystem (10) derart konfiguriert ist, dass der Kraftstoffvolumenstrom, der aus einem spezifischen zweiten Speicherraum (34) austritt, aus Kraftstoffvolumenstrom aus jeder der vorangehenden Hochdruckpumpeneinheiten (30) in dem Array (38) und der Kraftstoffvolumenstrom aus der Hochdruckpumpe (32) der spezifischen Hochdruckpumpeneinheit besteht.

8. Common-Rail-Kraftstoffeinspritzsystem (10) nach einem der vorstehenden Ansprüche, **dadurch gekennzeichnet, dass** der zweite Speicherraum (34) ein zylindrisches Volumen umfasst, das einen Durchmesser und eine Länge aufweist, und dass das Längen-/Durchmesserverhältnis des zweiten Speicherraums (34) 7,5 bis 8,5 beträgt.

9. Common-Rail-Kraftstoffeinspritzsystem (10) nach Anspruch 8, **dadurch gekennzeichnet, dass** der zweite zylindrische Speicherraum (34) ein erstes Ende (64) und ein zweites Ende (66) umfasst, und eine erste Strömungsöffnung (68) an dem ersten Ende, eine zweite Strömungsöffnung (70) an dem zweiten und eine dritte Strömungsöffnung (72) zwischen dem ersten Ende (64) und dem zweiten Ende (66) umfasst, wobei die erste Strömungsöffnung (68) ein Kraftstoffauslass ist, der entweder mit einer zweiten Strömungsöffnung (70) eines anderen zweiten zylindrischen Speicherraums (34) oder mit der Kraftstoffzufuhrleitung (18) verbunden ist, und dass die zweite Strömungsöffnung (70) ein erster Kraftstoffeinlass ist, und die dritte Strömungsöffnung (72) ein zweiter Kraftstoffeinlass ist, der mit dem Hochdruckauslass (36) der Hochdruckkraftstoffpumpe (32) verbunden ist.

10. Verfahren zum Nachrüsten eines Kraftstoffeinspritzsystems in einen Mehrzylinder-Verbrennungskolbenmotor (11), wobei der Motor (11) eine Nieder-

druckpumpe (58) umfasst, die dazu konfiguriert ist, zu jeder der Hochdruckpumpen in dem System Kraftstoff zuzuführen, Kraftstoffzufuhr-Hochdruckteile eine Kraftstoffeinspritzdüse (14) in jedem der Zylinder des Motors (11) beinhalten, Kraftstoffdruckspeicher und die Kraftstoffzufuhrleitung (18) die Hochdruckspeicher mit den Kraftstoffeinspritzdüsen (14) verbinden, die Hochdruckkraftstoffpumpe mit der Kraftstoffzufuhrleitung (18) verbunden sind, wobei das Verfahren Folgendes umfasst:

Ausbauen mindestens der folgenden Kraftstoffzufuhr-Hochdruckteile aus dem Motor (11):

- Kraftstoffeinspritzdüse aus jedem der Zylinder des Motors (11),
- Kraftstoffzufuhrleitungen, die mit den Einspritzdüsen verbunden sind,
- Hochdruckkraftstoffspeicher, die mit der Kraftstoffzufuhrleitung verbunden sind,

und danach

- Einbauen der Kraftstoffeinspritzdüsen (14), die mit einem ersten Speicherraum (16) versehen sind, innerhalb des Körpers der Einspritzdüse,
- Einbauen von Speichern, die jeweils mit einem zweiten Speicherraum (34) verbunden sind, in Strömungsverbindung mit jeder der Kraftstoffhochdruckpumpen (32),
- Verbinden der zweiten Speicher in direkter Strömungskommunikation miteinander, indem ein Array (38) aus zweiten Speicherräumen (34) gebildet wird,
- Verbinden des Arrays (38) aus zweiten Speicherräumen (34) in Strömungskommunikation mittels der ersten Kraftstoffzufuhrleitung (18) mit den ersten Speicherräumen (16).

11. Verfahren zum Nachrüsten eines Kraftstoffeinspritzsystems in einen Mehrzylinder-Verbrennungskolbenmotor (11) nach Anspruch 10, wobei das Verfahren Folgendes umfasst:

- Einbauen der Kraftstoffeinspritzdüse (14), die mit einem ersten Speicherraum (16) versehen ist, der ein Volumen aufweist, der das 10- bis 30-Fache der maximalen Einspritzmenge der Einspritzdüse (14) beträgt, an jedem der Zylinder,
- Einbauen der Speicher, die mit dem zweiten Speicherraum (34) versehen sind, der ein Volumen aufweist, das das 0,1- bis 0,2-Fache des Volumens des ersten Speicherraums (16) aufweist.

12. Verfahren zum Nachrüsten eines Kraftstoffeinspritzsystems in einen Mehrzylinder-Verbrennungskolbenmotor (11) nach Anspruch 10 oder 11, wobei das Verfahren Folgendes umfasst:

- Ausbauen von Hochdruckkraftstoffpumpen, die mit der Kraftstoffzufuhrleitung verbunden sind,
- Einbauen eines Common-Rail-Kraftstoffeinspritzsystems (10) an dem Motor (11) durch Einbauen
- von mindestens zwei Kraftstoffhochdruckpumpen (32) und Verbinden jeder Kraftstoffhochdruckpumpe mit einem zweiten Speicherraum (34).

13. Verfahren zum Nachrüsten eines Kraftstoffeinspritzsystems in einen Mehrzylinder-Verbrennungskolbenmotor (11) nach Anspruch 10 oder 11, wobei das Verfahren das Einbauen von Speichern umfasst, die jeweils mit einem zweiten zylindrischen Speicherraum (34) versehen sind, in Strömungsverbindung mit jeder der Hochdruckpumpen (32), wobei das zylindrische Volumen einen Durchmesser und eine Länge aufweist, und das Längen-/Durchmesserverhältnis des zweiten Speicherraums (34) 7,5 bis 8,5 beträgt.

14. Verbrennungskolbenmotor (11), der ein Common-Rail-Kraftstoffeinspritzsystem (10) nach einem der Ansprüche 1-9 umfasst.

Revendications

1. Système d'injection de carburant à rampe commune (10) pour un moteur à piston à combustion interne multicylindre (11), comprenant

une pompe à basse pression (58) configurée pour alimenter en carburant chacune des pompes à haute pression du système,
caractérisé par au moins deux injecteurs de carburant (14), dans lequel chacun des injecteurs (14) est pourvu d'un premier espace d'accumulateur (16) à l'intérieur du corps de l'injecteur,
une conduite d'alimentation en carburant (18) disposée en communication d'écoulement avec chacun des premiers espaces d'accumulateur (16),
au moins deux unités de pompe à haute pression (30), dans lequel

a. chacune des unités de pompe à haute pression (30) comprend une pompe à haute pression (32) et un deuxième espace d'accumulateur (34), la pompe à carburant à

haute pression ayant sa sortie à haute pression (36) raccordée au deuxième espace d'accumulateur (34),
b. les deuxièmes espaces d'accumulateurs (34) étant en communication d'écoulement directe les uns avec les autres, en formant un réseau (38) de deuxièmes espaces d'accumulateurs (34) de telle sorte que le premier des deuxièmes espaces d'accumulateurs (34) se trouve à une première extrémité (38.1) du réseau (38) et un dernier des deuxièmes espaces d'accumulateurs (34) se trouve à une deuxième extrémité (38.2) du réseau (38), et dans lequel le réseau (38) de deuxièmes espaces d'accumulateurs (34) est en communication d'écoulement avec la conduite d'alimentation en carburant (18).

2. Système d'injection de carburant à rampe commune (10) selon la revendication 1, **caractérisé en ce que** le réseau (38) de deuxièmes espaces d'accumulateurs (34) est en communication d'écoulement avec la conduite d'alimentation en carburant (18) par l'intermédiaire d'un seul des deuxièmes espaces d'accumulateurs (34).

3. Système d'injection de carburant à rampe commune (10) selon la revendication 1 ou 2, **caractérisé en ce que** le réseau (38) de deuxièmes espaces d'accumulation (34) est en liaison avec la conduite d'alimentation en carburant (18) par l'intermédiaire d'un seul des deuxièmes espaces d'accumulation (34) à l'extrémité du réseau (38) de deuxièmes espaces d'accumulation (34).

4. Système d'injection de carburant à rampe commune (10) selon la revendication 1, **caractérisé en ce que** dans le système d'injection de carburant à rampe commune (10), le nombre d'unités de pompe à haute pression (30) est au moins égal à la moitié du nombre des injecteurs de carburant (14).

5. Système d'injection de carburant à rampe commune (10) selon la revendication 4, **caractérisé en ce que** dans le système d'injection de carburant à rampe commune (10), le nombre d'unités de pompe à haute pression (30) est égal à la moitié du nombre des injecteurs de carburant (14).

6. Système d'injection de carburant à rampe commune (10) selon une quelconque des revendications précédentes, **caractérisé en ce que** le volume du premier espace d'accumulateur (16) est de 10 à 30 fois la quantité d'injection maximale de l'injecteur (14), et le volume du deuxième espace d'accumulateur (34) est de 0,1 à 0,2 fois le volume du premier espace d'accumulateur (16) .

7. Système d'injection de carburant à rampe commune (10) selon une quelconque des revendications précédentes, **caractérisé en ce que** le système d'injection de carburant à rampe commune (10) est configuré de telle sorte que le débit volumique de carburant qui sort d'un deuxième espace d'accumulateur de carburant spécifique (34) se compose du débit volumique de carburant de chacune des unités de pompe à haute pression (30) précédentes dans le réseau (38), et du débit volumique de carburant de la pompe à haute pression (32) de l'unité de pompe à haute pression spécifique.

8. Système d'injection de carburant à rampe commune (10) selon une quelconque des revendications précédentes, **caractérisé en ce que** le deuxième espace d'accumulateur (34) comprend un volume cylindrique ayant un diamètre et une longueur, et **en ce que** le rapport longueur/diamètre du deuxième espace d'accumulateur (34) est de 7,5 à 8,5.

9. Système d'injection de carburant à rampe commune (10) selon la revendication 8, **caractérisé en ce que** le deuxième espace d'accumulateur cylindrique (34) comprend une première extrémité (64) et une deuxième extrémité (66), et comprend un premier orifice d'écoulement (68) à la première extrémité, un deuxième orifice d'écoulement (70) à la deuxième et un troisième orifice d'écoulement (72) entre la première extrémité (64) et la deuxième extrémité (66), dans lequel le premier orifice d'écoulement (68) est une sortie de carburant raccordée soit à un deuxième orifice d'écoulement (70) d'un autre deuxième espace d'accumulateur cylindrique (34), soit à la conduite d'alimentation en carburant (18), et ce deuxième orifice d'écoulement (70) est une première entrée de carburant, et le troisième orifice d'écoulement (72) est une deuxième entrée de carburant raccordée à la sortie à haute pression (36) de la pompe à carburant à haute pression (32).

10. Procédé de mise à niveau d'un système d'injection de carburant dans un moteur à piston à combustion interne multicylindre (11), le moteur (11) comprenant une pompe à basse pression (58) configurée pour alimenter en carburant chacune des pompes à haute pression du système, des pièces à haute pression d'alimentation en carburant comprenant un injecteur de carburant (14) dans chacun des cylindres du moteur (11), des accumulateurs de pression de carburant et une conduite d'alimentation en carburant (18) raccordant les accumulateurs de pression aux injecteurs (14), des pompes à carburant à haute pression raccordées à la conduite d'alimentation en carburant (18), le procédé comprenant :

le démontage d'au moins les pièces à haute pression d'alimentation en carburant suivantes

du moteur (11) :

- des injecteurs de carburant de chacun des cylindres du moteur (11),
- des conduites d'alimentation en carburant raccordées aux injecteurs,
- des accumulateurs de carburant à haute pression raccordés à la conduite d'alimentation en carburant

et ensuite

- l'assemblage des injecteurs de carburant (14) pourvus d'un premier espace d'accumulateur (16) à l'intérieur du corps de l'injecteur,
- l'assemblage des accumulateurs, pourvus chacun d'un deuxième espace d'accumulateur (34), en communication d'écoulement avec chacune des pompes à haute pression (32),
- le raccordement des deuxièmes accumulateurs en communication d'écoulement directe les uns avec les autres en formant un réseau (38) de deuxièmes espaces d'accumulateur (34),
- le raccordement du réseau (38) de deuxièmes espaces d'accumulateur (34) en communication d'écoulement au moyen de la conduite d'alimentation en carburant (18) avec les premiers espaces d'accumulateur (16).

11. Procédé de mise à niveau d'un système d'injection de carburant dans un moteur à piston à combustion interne multicylindre (11) selon la revendication 10, le procédé comprenant :

l'assemblage de l'injecteur de carburant (14) pourvu d'un premier espace d'accumulateur (16), dont le volume est de 10 à 30 fois la quantité maximale injectée par l'injecteur (14) dans chacun des cylindres,
l'assemblage des accumulateurs, pourvus du deuxième espace d'accumulateur (34), dont le volume est de 0,1 à 0,2 fois le volume du premier espace d'accumulateur (16) .

12. Procédé de mise à niveau d'un système d'injection de carburant dans un moteur à piston à combustion interne multicylindre (11) selon la revendication 10 ou 11, le procédé comprenant :

- le démontage de pompes à carburant à haute pression raccordées à la conduite d'alimentation en carburant,
- l'assemblage d'un système d'injection de carburant à rampe commune (10) au moteur (11),
- en assemblant au moins deux pompes à carburant à haute pression (32) et en raccordant chaque pompe à carburant à haute pression à un deuxième espace d'accumulateur (34).

13. Procédé de mise à niveau d'un système d'injection de carburant dans un moteur à piston à combustion interne multicylindre (11) selon la revendication 10 ou 11, le procédé comprenant l'assemblage d'accumulateurs, chacun pourvu d'un second espace d'accumulateur cylindrique (34), en communication d'écoulement avec chacune des pompes à haute pression (32), dans lequel le volume cylindrique a un diamètre et une longueur, et le rapport longueur/diamètre du deuxième espace d'accumulateur (34) est de 7,5 à 8,5.

14. Moteur à piston à combustion interne (11) comprenant un système d'injection de carburant à rampe commune (10) selon une quelconque des revendications précédentes 1 à 9.

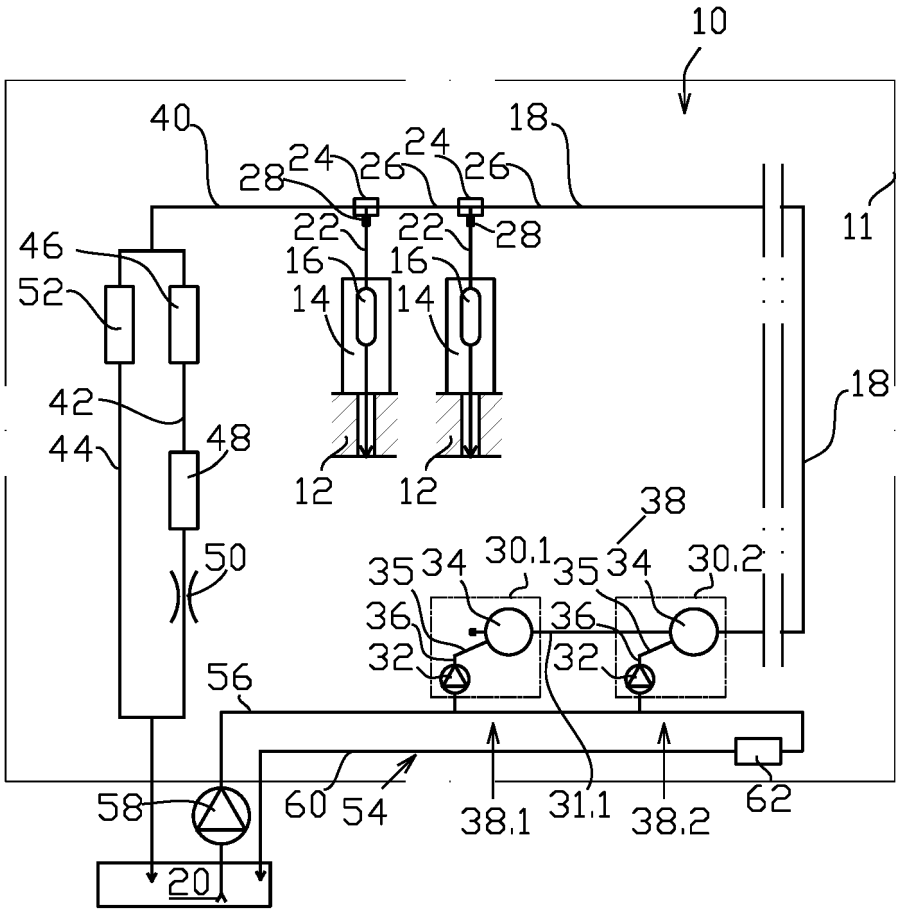
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Fig. 1

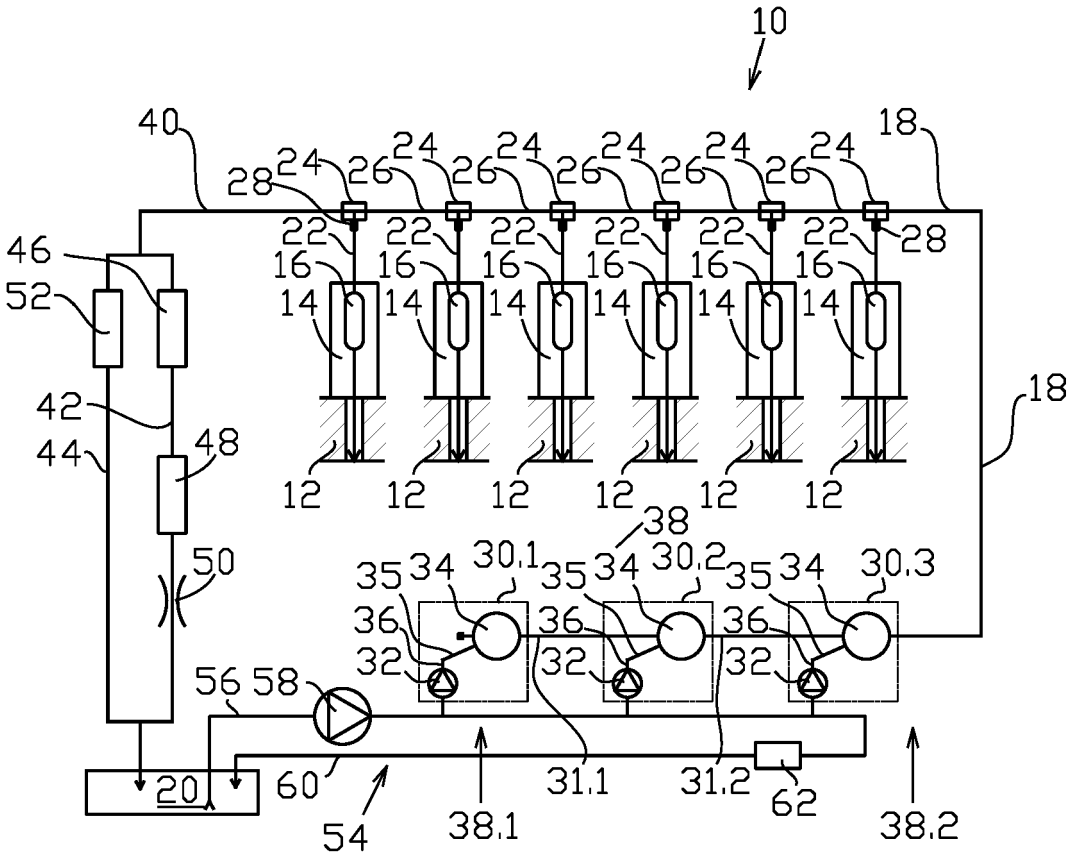
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Fig. 2

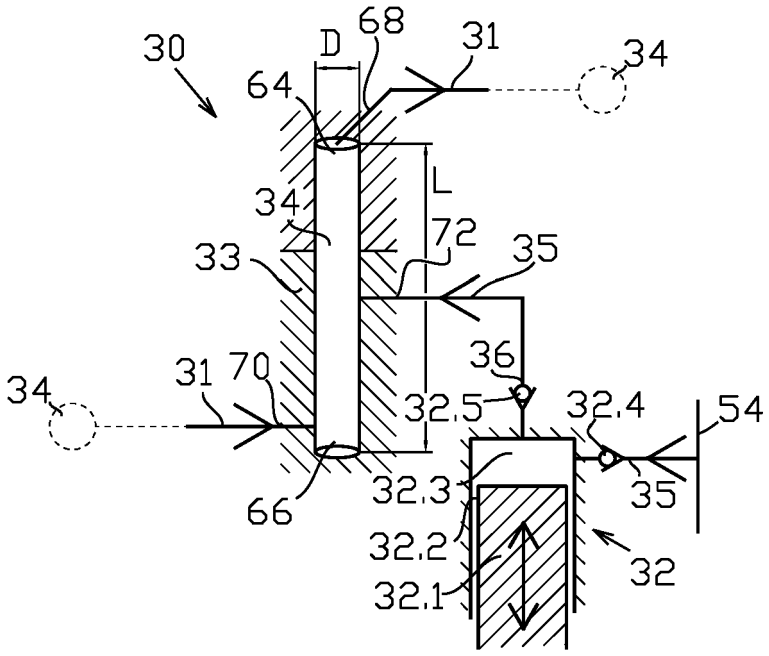
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Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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