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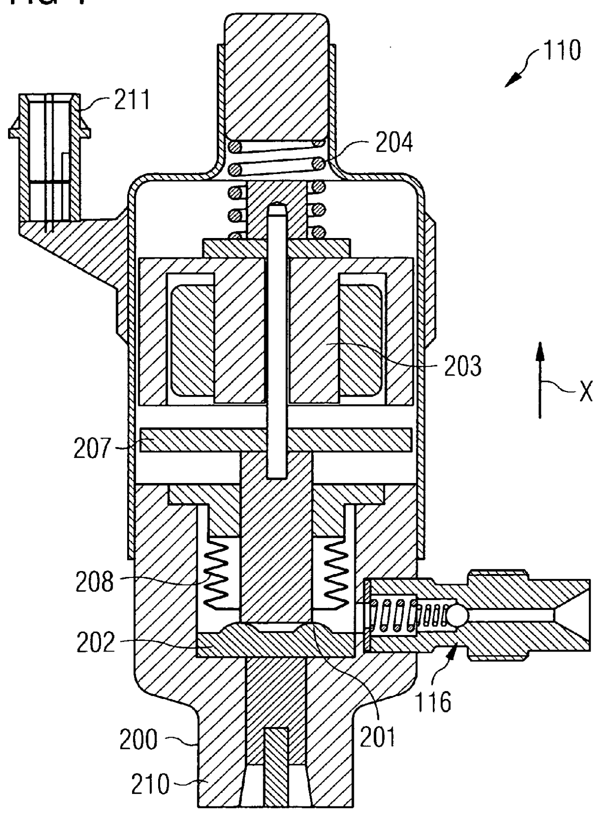
(54) **Fuel pump for delivering fuel to a fuel injector and system comprising a multitude of such fuel pumps**

(57) A fuel pump for delivering fluid to a fuel injector of a combustion engine comprises a pump housing (200) with a pump chamber (201) and a piston (202) . The piston (202) is arranged in the fuel pump such that it is axially moveable in pump chamber (201) in order to provide a pressurisation of the fluid within the pump chamber (201). The fuel pump comprises an electromagnetic or piezoelectric actuator (203) for driving the piston (202) . A fuel supply system comprising a multitude of such fuel pumps.

FIG 1



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Description

[0001] The invention relates to a fuel pump for delivering fuel to a fuel injector of a combustion engine. Furthermore, the invention relates to a fuel supply system that comprises a multitude of such fuel pumps.

[0002] Conventional fuel supply systems in vehicles comprise a high-pressure fuel pump that is connected to a high-pressure rail. The fuel rail is hydraulically connected to a multitude of fuel injectors. The high-pressure fuel pump conventionally is driven by the camshaft of the combustion engine of the vehicle. Accordingly, the fuel pressure is only generated when the combustion engine is running, which is critical in particular during engine cranking. Conventionally, the fuel pressure is also a function of the revolutions per minute of the combustion engine because of the coupling of the high-pressure fuel pump with the camshaft of the combustion engine. Furthermore, the fuel injectors are all hydraulically coupled to one common high-pressure rail. Therefore, pressure waves are transmitted between the fuel injectors.

[0003] A further aspect of the conventional system is that the components such as the fuel pumps or the common fuel rail are relatively expensive components because they must handle high-pressure fuel and be properly sealed.

[0004] Additional engine management requirements like stop/start are look for a quick pressure build inside the injector to allow a quick injection to restart the engine. Also, engine cranking at low temperature requires high-pressure operating conditions to reduce engine emissions.

[0005] It is desirable to create a fuel pump for delivering fuel to a fuel injector of a combustion engine that works reliably and is cost-effective. Furthermore, it is desirable to create fuel supply system that works reliably and is cost-effective.

[0006] According to one embodiment of the invention, a fuel pump for delivering fuel to a fuel injector of a combustion engine comprises a pump housing with a pump chamber. The fuel pump further comprises a piston which is arranged in the pump such that it is axially movable in the pump chamber in order to provide a pressurization of the fluid within the pump chamber. The fuel pump further comprises an electromagnetic or piezoelectric actuator for driving the piston.

[0007] The fuel pump is arranged to deliver fuel out of a fuel reservoir to exactly one fuel injector. Since the fuel pump is electrically driven, it is cost-effective. The fuel pump is arranged to be operated independent of the combustion engine since it is electrically driven and not driven by the camshaft of the combustion engine. The fuel pump is arranged to provide the fuel with a pressure of about 50 to 200 bar.

[0008] According to further aspects, the electromagnetic or piezoelectric actuator is arranged to drive the piston in a first direction to suck in the fluid into the pump chamber. The pump further comprises a spring coupled to the piston for driving the piston in a second direction opposite to the first direction in order to provide the pressurization to the fluid. The spring is arranged to apply a force to the piston that is as strong as needed to provide the high pressure to the fuel in the pump chamber.

[0009] According to further aspects, the pump comprises a magnet that is coupled with the pump housing for driving the piston in the second direction in order to provide the pressurization of the fluid. The magnet supports the spring in moving the piston in the second direction. According to further embodiments, the magnet is a permanent magnet.

[0010] According to one embodiment of the invention, a fuel supply system for a combustion engine comprises a multitude of fuel injectors for providing fuel to the combustion engine. The fuel supply system further comprises a multitude of fuel pumps as described above. Each fuel pump of the multitude of fuel pumps is hydraulically coupled with one fuel injector for providing fuel to the respective fuel injector.

[0011] Reference will now be made in detail to embodiments of the invention, examples of which are illustrated in the accompanying drawings. Elements of the same design and function that appear in different figures are identified by the same reference signs.

Figure 1 schematically shows a pump according to an embodiment,

Figure 2 schematically shows a pump according to a further embodiment,

Figure 3 schematically shows a fuel supply system according to an embodiment, and

Figure 4 schematically shows a fuel supply system according to a further embodiment.

[0012] Figure 1 schematically shows a fuel pump 110. The fuel pump 110 comprises a pump housing 200. The pump housing surrounds a pump chamber 201. A piston 202 is movably arranged in the pump chamber.

[0013] The piston 202 is coupled to an actuator 203. The piston 202 is further coupled to a spring 204. The pump housing 200 has a spring rest and the piston 202 comprises a spring rest. The spring 204 is arranged between the two spring rests. In particular, the piston 202 is coupled to an armature 207. The armature 207 is arranged to interact with the actuator 203. A bellow 208 surrounds the piston as to separate the piston 202 from the magnetic circuit and accordingly the actuator 203 to protect the magnetic circuit from the fuel. The pump 210 further comprises an inlet valve 116 through which fuel is sucked into the pump chamber 201 during operation. The fuel is ejected out of the pump chamber 201 through an outlet 210. The inlet valve 116 and the outlet 210 are hydraulically coupled with the pump chamber. The fuel pump 110 further comprises a connector 211 for connecting the pump with an engine control unit 115 (Figures 3 and 4).

[0014] For delivering fuel to a fuel connector 106 (Figures 3 and 4), the engine control unit 115 controls the pump 110, especially the actuator 203, to move the piston axially in the pump chamber 201 in the x-direction of Figure 1. This movement is against the force of the spring 204. Due to the movement of the piston in the x-direction, fuel that may be provided by a low-pressure pump 114 (Figures 3 and 4) is sucked into the pump chamber 201 via the inlet valve 116. The inlet valve 116 is a one-way valve which prevents fluid from flowing out of the pump chamber 201 into the regions of the fluid supply system upstream the pump 110.

[0015] The fuel in the pump chamber 201 is pressurized by the piston due to the force of the spring 204 which applies a force in the direction opposite the x-direction to the piston 202. When there is enough fuel for one injection of a fuel injector in the pump chamber 201, the actuator 203 is stopped. The engine control unit stops energizing the actuator 203.

[0016] The fuel in the pump chamber 201 is not able to leave the pump chamber 201 as long as the fuel injector 106 that is hydraulically coupled with the outlet 210 of the pump 110 opens and injects the fuel into a combustion chamber 102 of the combustion engine 101 (Figures 3 and 4). When the fuel injector opens, the fuel is ejected out of the pump chamber 201 by a movement of the piston 202 in the x-direction forced by the spring 204. Between the sucking in of the fuel into the pump chamber and the ejecting when the fuel injector opens, pressurized fuel is stored in the pump chamber 201.

[0017] The fuel pressure value that the pump provides depends on the spring 204 and a predefined compression amount which is selectable by calibrating the spring 204. The fuel pump provides the fuel with a constant fuel pressure value.

[0018] The pump 110, which is electronically driven by the electromagnetic or piezoelectric actuator 203, is only driven by electric energy during the fuel intake phase and only a predetermined amount of fuel that will be injected in one single injection by the fuel injector is pressurized by one single pump stroke. The energy to pressurize and eject the fuel is coming from the spring 204. To reload fuel into the pump chamber after a single pumping stroke, the actuator 203 is again energized to perform the next pump cycle. The energy stored in the spring 204 is the only energy to perform the fuel compression and ejecting. No additional energy is needed to deliver the high-pressure fuel to the fuel injector. Electronic energy by the actuator 203 is only required to fill the pump chamber 201. Therefore, energy is saved and efficiency is improved.

[0019] In the pump 110, no pressure pulsations are generated during the ejecting phase due to the force of the spring 204. Further, the pump 210 with the electric actuator 203 is arranged to provide pressurized fuel to the fuel injector independent from the combustion engine 101, especially independent from the revolutions per minute of the combustion engine. The pump 110 is not coupled to the camshaft of the combustion engine and therefore is arranged to provide pressurized fuel also when the camshaft is not turning.

[0020] During cranking of the combustion engine or by a stop/start function of the combustion engine, the pump 110 is arranged to pressurize the fuel without engine rotation since the electrical signal to control the pump 110 can be sent to the pump by the engine control unit 115 at any time regardless of the engine rotation speed. The pump 110 is also arranged to pressurize only the fuel required by the fuel injector 106 by the next injection and there is no large waste or inefficiency as per the conventional mechanically driven high-pressure pumps.

[0021] Once the pump 110 has sucked in the fuel into the pump chamber 201 and is loaded with fuel, the spring energy always keeps the fuel in the pump chamber 201 under pressure until the fuel injector 106 opens and the fuel is injected into the combustion chamber of the combustion engine. Since the fuel pressure is stable, the minimum deliverable fuel quantity is lower. There is no need for an overpressure operating like with conventional mechanically driven pumps.

[0022] Figure 2 schematically shows the pump 110 according to a further embodiment. In contrast to the embodiment of Figure 1, the pump according to Figure 2 comprises two springs, the spring 204 and a further spring 209, which is coupled to the piston 202.

[0023] Further, in contrast to Figure 1, the pump according to the embodiment of Figure 2 comprises a magnet 205 which is coupled to the pump housing 200. According to embodiments, the magnet 205 is a permanent magnet. The magnet 205 supports the movement of the piston in the x-direction when sucking in fuel into the pump chamber 201. When the solenoid of the actuator 203 is energized, the magnet 205 exerts a force in the x-direction to move the piston into the x-direction. This also allows to have a stronger spring 204 which acts against the movement in the x-direction. This leads to a higher fuel pressure when ejecting the fuel.

[0024] When the energizing of the actuator 203 is stopped, the magnet 205 supports the spring 204 in moving the piston in the opposite direction to the x-direction when ejecting the fuel out of the pump chamber 201. The second spring 209 is a calibration spring for calibrating the pressure that is provided by the pump 110.

[0025] Figure 3 schematically shows a fuel supply system 100. The fuel supply system 100 comprises the combustion engine 101. The combustion engine 101 is an internal combustion engine of a vehicle, in particular a diesel gasoline combustion engine.

[0026] The system 100 further comprises a fuel reservoir 118 in which fuel 120 is stored. In particular, the fuel is diesel gasoline. The fuel reservoir 118 is hydraulically coupled via a pipe 117 to a multitude of fuel pumps 110, 111, 112, and 113 as explained with respect to Figures 1 and 2. The fuel pumps are electrically driven by the electronic actuator 203. The electronic actuator is arranged to move the piston 202 of the fuel pump in response to an electrical signal received by the fuel pump. The movement of the piston of the fuel pump forced by the electric actuator delivers fuel out of the reservoir 118 to the respective fuel injector. In particular the electronic actuator is an electromagnetic actuator. The electromagnetic actuator comprises the solenoid that interacts with the piston 202 of the fuel pump. According to further embodiments, the electronic actuator is a piezoelectric actuator.

[0027] The fuel pumps each are hydraulically connected to one single fuel injector 106, 107, 108, and 109. The fuel injectors are arranged to inject fuel into combustion chambers 102, 103, 104, and 105 of the combustion engine 101.

[0028] The system 100 further comprises a low pressure pump 114 that is hydraulically arranged upstream the fuel pumps 110 to 113 and that provides fuel out of the fuel reservoir 118 to the fuel pumps 110 to 113. Furthermore, an on/off valve 119 is arranged at the pipe 117. One inlet valve 116 is arranged upstream of each fuel pump 110 to 113.

[0029] The system 100 further comprises the engine control unit 115 for controlling the system. The engine controlling unit 115 is electrically coupled to each of the fuel pumps 110 to 113 and to each of the fuel injectors 106 to 109. The engine control unit is further coupled to the on/off valve 119.

[0030] The engine control unit 115 is arranged to control the fuel pumps 110 to 113 to deliver fuel out of the fuel reservoir 118 to the fuel injectors 106 to 109. The engine control unit 115 is further arranged to control the fuel injectors between a closed state and an open state. In the closed state, the fuel injectors prevent fuel from being injected into the combustion chambers 102 to 105 of the combustion engine 101. In the open state, fuel provided by the fuel pumps 110 to 113 is injected into the combustion chambers via the fuel injectors 106 to 109.

[0031] The system 100 comprises as much fuel injectors as combustion chambers, for example four combustions chambers and four fuel injectors. The system 100 comprises as much fuel pumps as fuel injectors, for example four fuel pumps and four fuel injectors. According to further embodiments, the system 100 comprises more than four fuel injectors, combustion chambers and fuel pumps respectively, such as six fuel injectors, combustion chambers and fuel pumps respectively. According to further embodiments, the system 100 comprises less than four fuel injectors, combustion chambers and fuel pumps respectively, such as two fuel injectors, combustion chambers and fuel pumps respectively.

[0032] One fuel pump 110 delivers fuel to exactly one fuel injector 106. Downstream the fuel pumps, the fuel injectors 106 to 109 are hydraulically independent from each other. Upstream of each fuel pump, the inlet valve 116 is arranged. There are as many inlet valves 116 as fuel pumps 110 to 113. The inlet valve 116 is a one-way valve and prevents fuel from returning in the direction to the fuel reservoir 118.

[0033] During operation, the engine control unit 115 controls the valve 119 to open. Fuel is delivered out of the fuel reservoir 118 to the fuel pumps 110 to 113 by the low pressure pump 114 via the valve 119, the pipe 117, and the respective valves 116.

[0034] The engine control unit 115 controls the fuel pump 110 to suck in fuel only when the respective fuel injector 106 is in its closed state. After sucking in fuel into the pump chamber 201 of the fuel pump 110, the fuel is provided under pressure in the pump chamber for being injected into the combustion chamber 102. The pump 110 does not eject the fuel out of the pump chamber as long as the fuel injector 106 is in its closed state.

[0035] When the engine control unit 115 controls the fuel injector 106 to open, the fuel is ejected under pressure out of the pump chamber and injected into the combustion chamber 102 via the fuel injector 106. Afterwards, the engine control unit 115 sets the fuel injector 106 again in its closed state and controls the pump 110 to suck in fuel.

[0036] There is only one sucking in and only one ejecting of fuel out of the pump 110 per one injection of fuel into the combustion chamber 102 via the fuel injector 106. Per one opening of the fuel injector 106 there is one ejecting of the fuel out of the pump chamber of the pump 110.

[0037] The functionality of the combination of the fuel pump 110, the fuel injector 106 and the combustion chamber 102 is transferable to the further combinations of the respective fuel pumps with the respective fuel injectors and combustion chambers, for example the combination of fuel pump 111, the fuel injector 107 and the combustion chamber 103.

[0038] Since each fuel pump 110 to 113 provides fuel to only one fuel injector 106 to 109 respectively, the fuel injectors 106 to 109 are hydraulically independent from each other downstream the fuel pumps 110 to 113. Therefore, no pressure waves are generated that impact other fuel injectors. Furthermore, since the fuel pumps each comprise an electromagnetic or piezoelectric actuator, they are cost-effective. Each fuel pump 110 to 113 is arranged to provide the fuel with a pressure of about 50 to 200 bar. Furthermore, due to the coupling of one fuel pump to one single fuel injector, there is no need for a common high-pressure rail that is coupled to a multitude of fuel injectors.

[0039] Figure 4 schematically shows the system 100 of Figure 3 according to a further embodiment. In contrast to the embodiment of Figure 3, according to the embodiment of Figure 4, the pumps 110 to 113 are hydraulically coupled to the respective fuel injectors 106 to 109 via respective fuel pipes 121.

[0040] The system 100 according to the exemplary embodiments of Figure 3 and Figure 4 with the fuel pumps 110 to 113 according to Figure 1 and/or Figure 2 allows having the fuel pressure on demand and not only when the combustion engine 101 is running. Therefore, engine cranking is reliable because fuel pressure is readily available to allow proper storing conditions without turning the engine. This operation condition also supports a reliable stop/start function of the engine. The common high-pressure fuel rail is no longer required and the system 100 has a reduced number of components compared to conventional fuel supply systems. No fuel return line from the fuel pump to the fuel reservoir 118 is required. Since each fuel pump is responsible to supply high-pressure fuel to exactly one fuel injector, there are no or less pressure pulsations transmitted between the fuel pumps 110 to 113 and the fuel injectors 106 to 109. There is no influence from one fuel injector to the other fuel injectors. No pressure waves are transmitted between the fuel injectors due to any injection event.

[0041] The system 100 is reliable especially when there are multiple injections of fuel into one combustion chamber during one engine cycle. Since the fuel pumps 110 to 113 each are electrically driven, there is no longer a need for providing an overpressure of 30% of additional injector P-Max performance as in conventional systems with a common fuel high-pressure rail. By the fuel pumps according to the system 100, there is the fuel provided at the pressure needed without a redundant additional pressure for balancing pressure pulsations. If the system 100 includes the ballistic operating condition function, the complete flow range could be obtained with one pressure value only.

Claims

1. Fuel pump for delivering fluid to a fuel injector of a combustion engine, comprising a pump housing (200) with a pump chamber (201) and a piston (202), with the piston (202) being arranged in the fuel pump such that it is axially moveable in pump chamber (201) in order to provide a pressurisation of the fluid within the pump chamber (201) and an electromagnetic or piezoelectric actuator (203) for driving the piston (202).

2. Fuel pump according to claim 1, wherein the actuator (203) is arranged to drive the piston (202) in a first direction to suck in the fluid into the pump chamber (201) and wherein the fuel pump comprises a spring (204) coupled to the piston (202) for driving the piston (202) in a second direction opposite to the first direction in order to provide the pressurisation of the fluid.

3. Fuel pump according to claim 2, comprising a magnet (205) that is coupled with the pump housing for driving the piston (202) in the second direction in order to provide the pressurisation of the fluid.

4. Fuel pump according to one of claims 1 to 3, comprising a one way inlet valve (116) upstream the pump chamber (201) that is coupled with the pump housing (200).

5. Fuel pump according to one of claims 1 to 4, the fuel pump being arranged for directly delivering the fluid to one single fuel injector (106).

6. Fuel pump according to one of claims 1 to 5, the fuel pump being arranged to be operated independent of the combustion engine (101) .

7. Fuel supply system for a combustion engine (101), comprising:

   - a multitude of fuel injectors (106, 107, 108, 109) for providing fuel to the combustion engine (101),
   - a multitude of fuel pumps (110, 111, 112, 113) according to one of claims 1 to 6, each fuel pump of the multitude of fuel pumps (110, 111, 112, 113) being hydraulically coupled with one fuel injector (106, 107, 108, 109) for providing fuel to the respective fuel injector (106, 107, 108, 109).

FIG 1

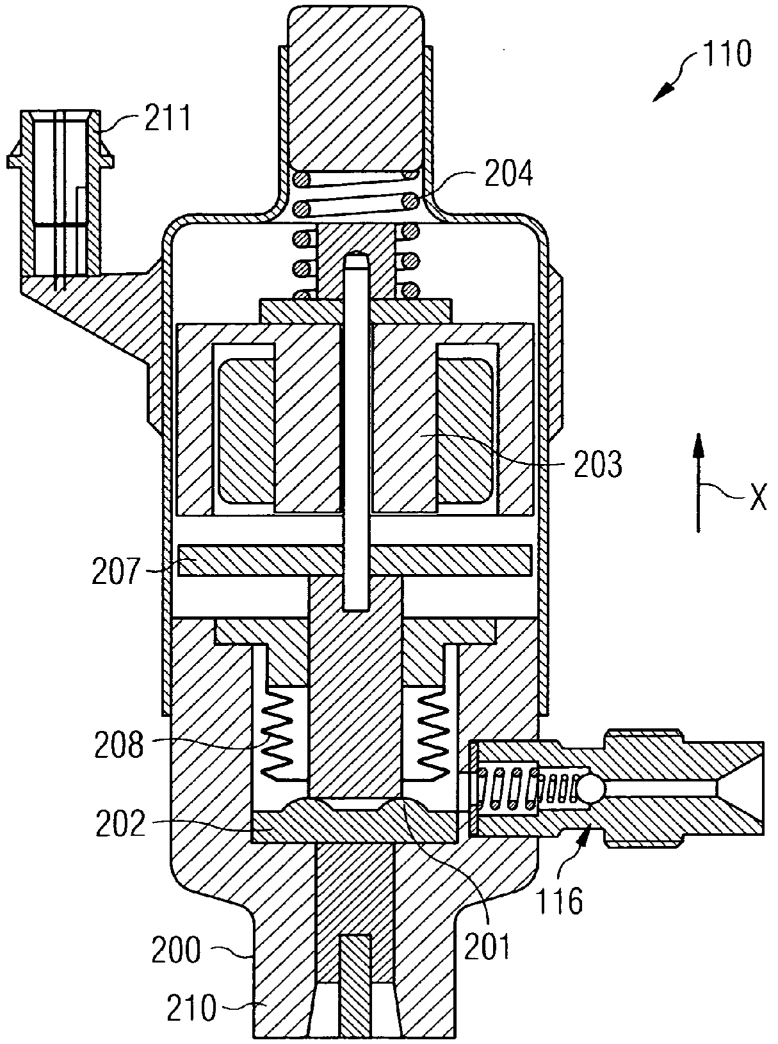

FIG 2

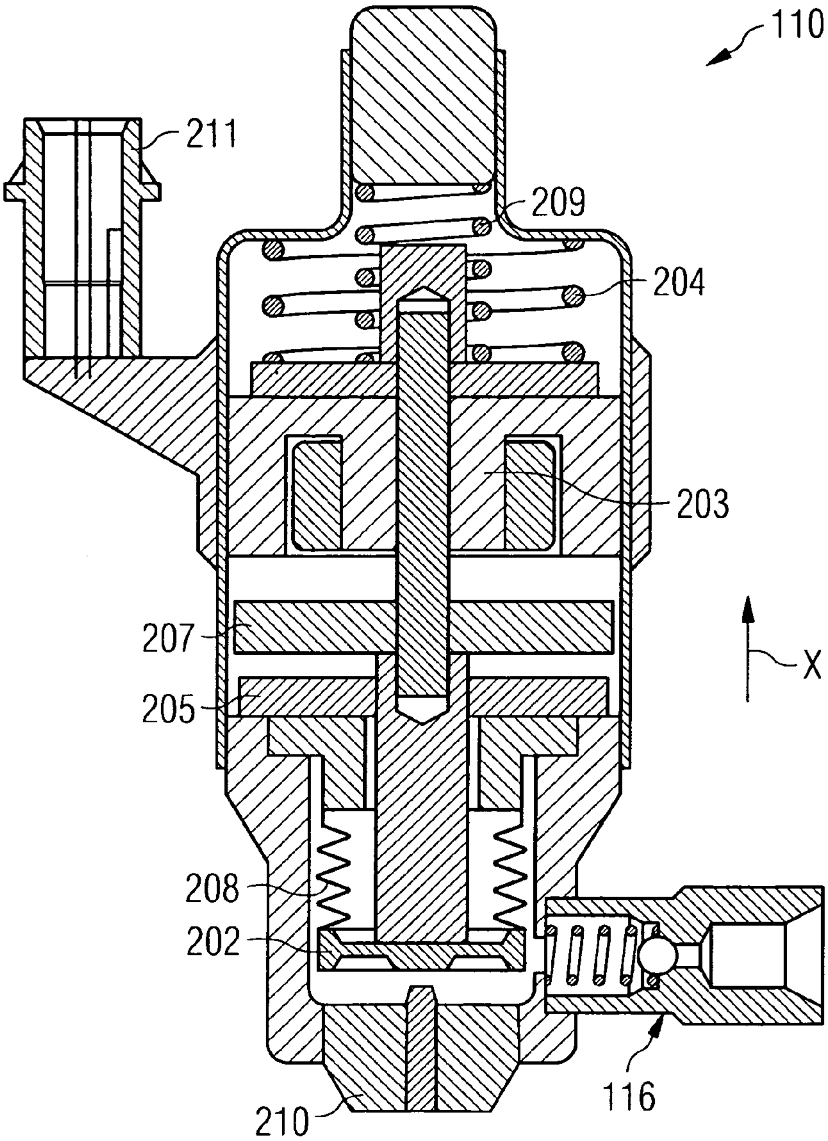

FIG 3

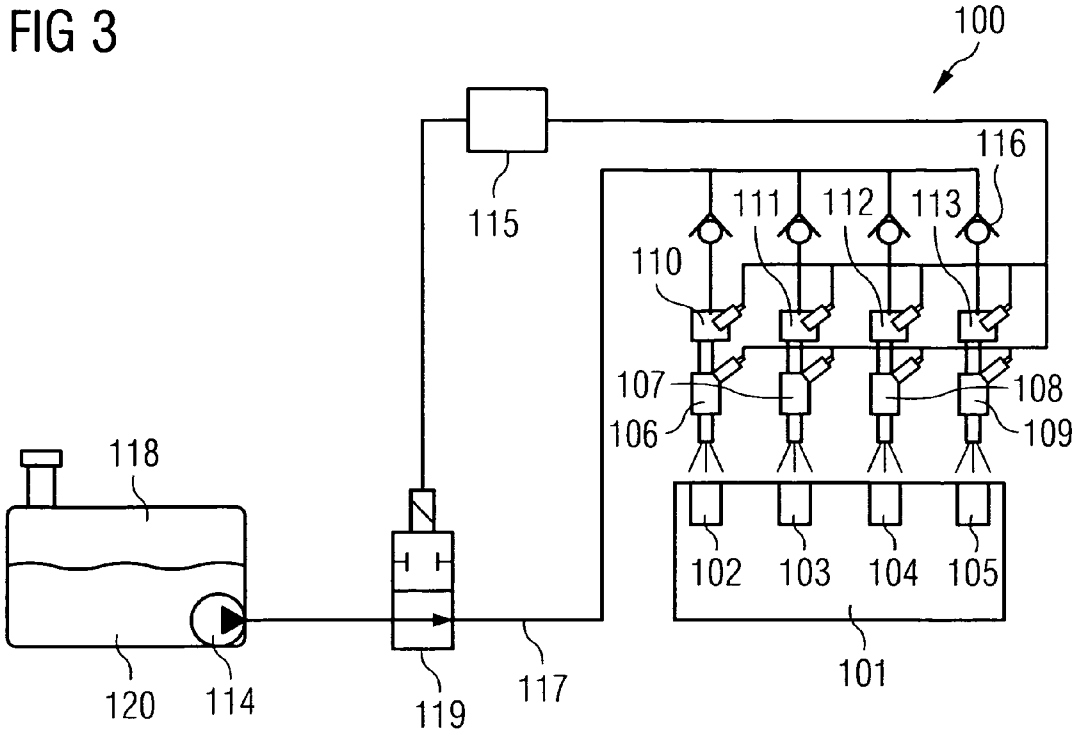
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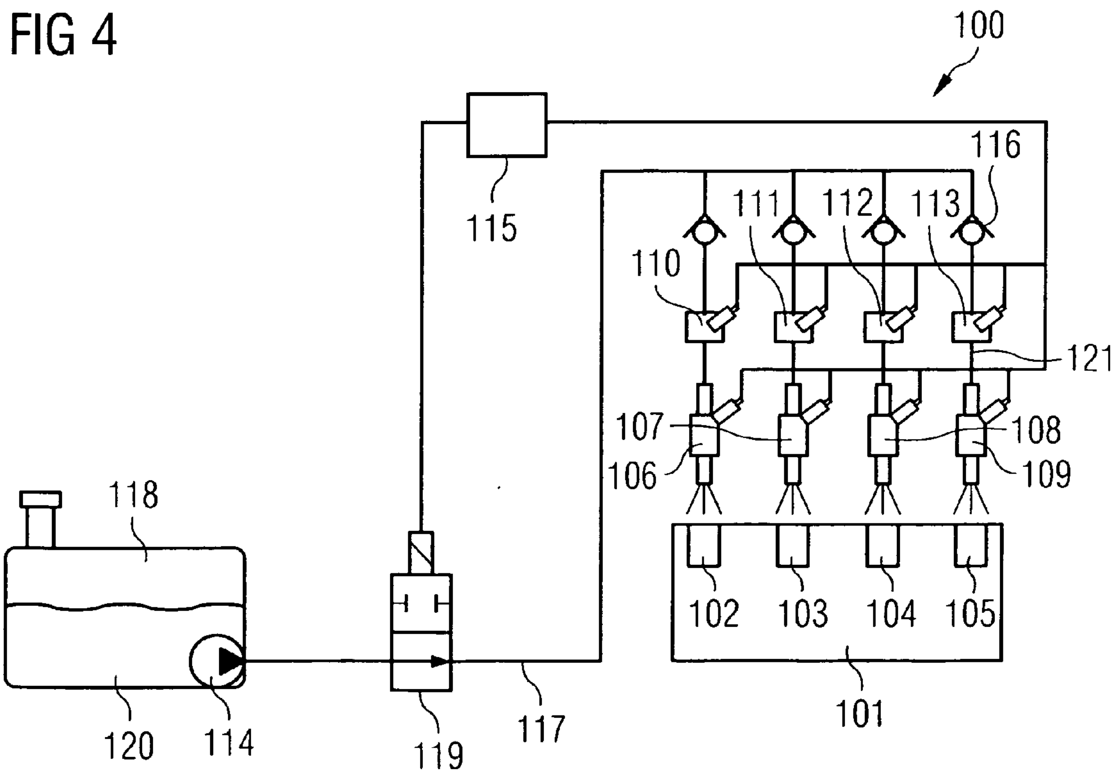
FIG 4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EUROPEAN SEARCH REPORT

Application Number
EP 11 15 7011

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	GB 2 469 078 A (SCION SPRAYS LTD [GB]) 6 October 2010 (2010-10-06)	1,2,4-6	INV. F02M57/02
Y	* abstract; figure 3 * * page 8, line 21 - page 9, line 26 * -----	3,7	
X	WO 2009/037486 A1 (SCION SPRAYS LTD [GB]; RAVENHILL PAUL BARTHOLOMEW [GB]; HOOLAHAN RICHA) 26 March 2009 (2009-03-26)	1,2,4-6	
Y	* page 5, lines 4-19; figures 1,13 * -----	3,7	
X	US 6 398 511 B1 (FRENCH MICHAEL J [US] ET AL) 4 June 2002 (2002-06-04)	1,4-7	
Y	* column 3, line 35 - column 6, line 36; figures 1,2 * -----	3,7	

TECHNICAL FIELDS SEARCHED (IPC)

F02M

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	26 May 2011	Etschmann, Georg

CATEGORY OF CITED DOCUMENTS

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26-05-2011

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 2469078 A	06-10-2010	WO 2010112856 A1	07-10-2010
WO 2009037486 A1	26-03-2009	CN 101802388 A	11-08-2010
		EP 2198149 A1	23-06-2010
		JP 2010540814 T	24-12-2010
		US 2010213287 A1	26-08-2010
US 6398511 B1	04-06-2002	US 2002141876 A1	03-10-2002

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