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

(11) **EP 3 088 725 A1**

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
02.11.2016 Bulletin 2016/44

(21) Application number: **16167581.4**

(22) Date of filing: **28.04.2016**

(51) Int Cl.:
F02M 59/10 $^{(2006.01)}$ ***F04B 53/16*** $^{(2006.01)}$
F04B 1/04 $^{(2006.01)}$ ***F02M 63/02*** $^{(2006.01)}$
F02M 59/06 $^{(2006.01)}$ *F02M 59/44* $^{(2006.01)}$

(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
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **28.04.2015 IT BO20150210**

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(54) FUEL PUMP FOR A DIRECT INJECTION SYSTEM WITH A REDUCED STRESS ON THE BUSHING OF THE PISTON

(57) Fuel pump (4) having: a pumping chamber (14); a piston (15) slidingly mounted within the pumping chamber (14); a cylindrical containing seat (26) which is defined below the pumping chamber (14), has a diameter larger than the one of the pumping chamber (14) and is delimited on top by an annular abutment (28) which externally has the diameter of the containing seat (26) and internally has the diameter of the pumping chamber (14); and a guide bushing (27), which is housed in the containing seat (26) and has an upper surface (30) which abuts against the annular abutment (28); the upper surface (30) of the guide bushing (27) has a convex shape having an increasing height from outside to inside; and the annular abutment (28) has a step (31) against which the upper surface (30) of the guide bushing (27) rests.

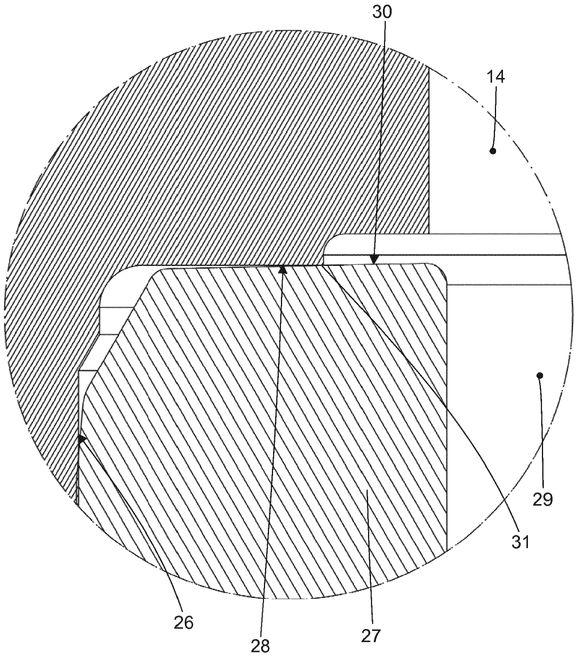

Fig. 5

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Description

TECHNICAL FIELD

[0001] The present invention relates to a fuel pump for a direct injection system; preferably, the direct injection system is used in an internal combustion engine with controlled ignition, and then supplied with petrol or similar fuels.

PRIOR ART

[0002] A direct injection system comprises a plurality of injectors, a common rail that supplies the pressurized fuel to the injectors, a high-pressure fuel pump, which supplies the fuel to the common rail by means of a high-pressure supply duct and is provided with a flow-regulating device, and a control unit which controls the flow-regulating device to maintain the fuel pressure inside the common rail at a desired value, generally variable over time as a function of the engine operating conditions.

[0003] The high-pressure fuel pump described in the patent application EP2236809A1 comprises a pumping chamber within which a piston slides with reciprocating motion, an intake channel controlled by an intake valve for supplying the low-pressure fuel within the pumping chamber, and a delivery channel regulated by a delivery valve for feeding the high-pressure fuel out of the pumping chamber and into the common rail through the supply duct.

[0004] The pressure of the intake valve is normally controlled and, in the absence of any external intervention, the intake valve is closed when the fuel pressure in the pumping chamber is higher than the fuel pressure in the intake channel, and is open when the fuel pressure in the pumping chamber is lower than the fuel pressure in the intake channel. The flow-regulating device is mechanically coupled to the intake valve to maintain, when necessary, the intake valve open during the pumping phase of the piston, thus allowing a fuel flow to come out of the pumping chamber through the intake channel. In particular, the flow-regulating device comprises a control rod, which is coupled to the intake valve and is movable between a passive position, where the rod allows the closing of the intake valve, and an active position, where the rod does not allow the closing of the intake valve. The flow-regulating device also comprises an electromagnetic actuator, which is coupled to the control rod to move the control rod between the active position and the passive position. The electromagnetic actuator comprises a spring, which keeps the control rod in the active position, and an electromagnet that moves the control rod into the passive position, magnetically attracting a ferromagnetic anchor integral with the control rod against a fixed magnetic armature.

[0005] The reciprocating sliding of the piston is guided by a guide bushing, which is arranged below the pumping chamber to delimit inferiorly the pumping chamber and inside which the piston slides. Normally, the guide bushing is fitted in a containing seat, which is formed below the pumping chamber. The piston guide bushing is subjected to high mechanical stresses, since it must withstand the hydraulic thrust generated during pumping, which acts on the circular crown-shaped surface defined between the inner diameter and the outer diameter of the guide bushing; in this regard, there is a significant difference between the inner diameter and the outer diameter of the guide bushing (approximately, the inner diameter is about 7-9 mm, while the outer diameter is about 14-16 mm), and therefore the hydraulic thrust on the guide bushing is significant.

[0006] The patent application EP1275845 and the patent application DE102008002170 describe a high-pressure fuel pump provided with a piston sliding with a reciprocating motion within a guide bushing, which is arranged below the pumping chamber to delimit inferiorly the pumping chamber.

[0007] Recently, automobile manufacturers have started to design new petrol-fuelled internal combustion engines that operate with a petrol injection pressure over 400-500 bars (up to 800 bars) and consequently need high-pressure fuel pumps, capable of pumping the fuel under such pressures. The higher the pumping pressure, the stronger the hydraulic thrust on the piston guide bushing, and therefore the guide bushing must be accordingly secured in the corresponding containing seat to avoid that the guide bushing comes out of its seat during pumping. A side calking of the guide bushing in the corresponding containing seat has been proposed to improve the fastening of the piston guide bushing; however, even with this expedient, the fuel pump is not able to operate under pumping pressures higher than 500-600 bars. Consequently, a further increase of the pumping pressure of the fuel pump necessarily requires some further processing (e.g. welding) to enhance the fastening of the piston guide bushing; however, such further processing results in a remarkable cost increase.

DESCRIPTION OF THE INVENTION

[0008] The object of the present invention is to provide a fuel pump for a direct injection system, said fuel pump being able to pump fuel at high pressures and being at the same time easy and economical to produce.

[0009] The present invention accordingly provides a fuel pump for a direct injection system according to what claimed by the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The present invention will now be described with reference to the accompanying drawings showing a non-limiting embodiment, in which:

- Figure 1 is a schematic view, with parts removed for clarity's sake, of a fuel direct injection system of the common rail type;

- Figure 2 is a longitudinal section view, schematic and with parts removed for clarity's sake, of a high-pressure fuel pump for a direct injection system of Figure 1;
- Figure 3 is a cross-section view, schematic and with parts removed for clarity's sake, of the high-pressure fuel pump of Figure 2;
- Figure 4 is an enlarged view of a detail of Figure 2 showing a piston guide bushing; and
- Figure 5 is an enlarged view of a detail of Figure 4.

PREFERRED EMBODIMENTS OF THE INVENTION

[0011] In Figure 1, the number 1 indicates in its entirety a fuel direct injection system of the common rail type for an internal combustion engine.

[0012] The direct injection system 1 comprises a plurality of injectors 2, a common rail 3 that supplies the pressurized fuel to the injectors 2, a high-pressure pump 4, which feeds the fuel to the common rail 3 by means of a supply duct 5 and is provided with a flow-regulating device 6, a control unit 7 that maintains the fuel pressure inside the common rail 3 at a desired value, generally variable over time as a function of the engine operating conditions, and a low-pressure pump 8 which feeds the fuel from a tank 9 to the high-pressure pump 4 through a supply duct 10.

[0013] The control unit 7 is coupled to the flow-regulating device 6 to control the flow of the high-pressure pump 4, to supply, instant by instant, to the common rail 3 the amount of fuel required to obtain the desired pressure value in the common rail 3. In particular, the control unit 7 regulates the flow rate of the high-pressure pump 4 by means of a feedback control using as a feedback variable the value of the fuel pressure in the common rail 3, the pressure value being detected in real time by a pressure sensor 11.

[0014] As shown in Figure 2, the high-pressure pump 4 comprises a main body 12, which has a longitudinal axis 13 and defines inside it a cylindrical pumping chamber 14. A piston 15 is slidably mounted inside the pumping chamber 14. Moving with a reciprocating motion along the longitudinal axis 13, the piston 15 causes a cyclic variation of the volume of the pumping chamber 14. A lower portion of the piston 15 is coupled on one side to a spring 16, which tends to push the piston 15 toward a position of maximum volume of the pumping chamber 14, and on the other side to a cam (not shown) that is brought in rotation by an engine crankshaft to cyclically move upwards the piston 15, thus compressing the spring 16.

[0015] A side wall of the pumping chamber 14 originates an intake channel 17 that is connected to the low-pressure pump 8 via the supply duct 10 and is regulated by an intake valve 18 arranged at the pumping chamber 14. The pressure of the intake valve 18 is normally controlled and, in the absence of any external intervention, the intake valve 18 is closed when the fuel pressure in the pumping chamber 14 is higher than the fuel pressure in the intake channel 17, and is open when the fuel pressure in the pumping chamber 14 is lower than the fuel pressure in the intake channel 17.

[0016] As shown in Figure 3, a delivery channel 19 originates on a side wall of the pumping chamber 14 and on the opposite side with respect to the intake channel 17, said channel being connected to the common rail 3 by means of the supply duct 5 and being regulated by a unidirectional delivery valve 20 which is arranged at the pumping chamber 14 and allows only a flow of fuel out of the pumping chamber 14. The pressure of the delivery valve 20 is controlled and the valve is opened when the fuel pressure in the pumping chamber 14 is higher than the fuel pressure in the delivery channel 19, and is closed when the fuel pressure in the pumping chamber 14 is lower than the fuel pressure in the delivery channel 19.

[0017] As shown in Figure 2, the flow-regulating device 6 is mechanically coupled to the intake valve 18 to allow the control unit 7, when necessary, keeping the intake valve 18 open during a pumping phase of the piston 15 and then to allow a fuel flow going out of the pumping chamber 14 through the intake channel 17. The flow-regulating device 6 comprises a control rod 21, which is coupled to the intake valve 18 and is movable between a passive position, where it allows the closing of the intake valve 18, and an active position, where it does not allows the closing of the intake valve 18. The flow-regulating device 6 also comprises an electromagnetic actuator 22, which is coupled to the control rod 21 to move the control rod 21 between the active position and the passive position.

[0018] As shown in Figure 3, a side wall of the pumping chamber 14 originates an exhaust channel 23, which connects the pumping chamber 14 with the delivery channel 19 and is regulated by a unidirectional maximum pressure valve 24 allowing only a flow of fuel entering the pumping chamber 14. The function of the maximum pressure valve 24 is to allow a fuel outlet in the case where the fuel pressure in the common rail 3 exceeds a maximum value set at the design stage (typically in case of control errors made by the control unit 7); in other words, the maximum pressure valve 24 is calibrated to automatically open when the pressure jump at its ends is higher than a threshold value set in the design phase, and thus prevent the fuel pressure in the common rail 3 from exceeding the maximum value set in the design phase.

[0019] As shown in Figure 2, a cylindrical containing seat 26 housing a guide bushing 27 of the piston 15 is formed in the main body 12 and below the pumping chamber 14. The guide bushing 27 inferiorly delimits the pumping chamber 14 (i.e. forms a bottom wall of the pumping chamber 14), and drives the reciprocating axial sliding. The guide bushing 27 is made of a material having a suitable hardness and a surface finish to facilitate the axial sliding of the piston 15. The guide bushing 27 is fastened in the containing seat 26 by fitting the guide bushing 27 in the containing seat 26 or by a side caulking of the guide bushing 27 in the containing seat 26.

[0020] As shown in Figure 4, the containing seat 26 has a diameter (significantly) larger than the pumping chamber 14 so that the guide bushing 27 inserted in the containing seat 26 can inferiorly delimit the pumping chamber 14. In correspondence of the pumping chamber 14, the containing seat 26 is delimited on top by an annular abutment 28, which externally has the diameter of the containing seat 26 and internally has the diameter of the pumping chamber 14. The guide bushing 27 has a tubular shape and is internally provided with a through hole 29 slidingly housing the piston 15; the through hole 29 of the guide bushing 27 substantially has the same diameter of the piston 15 housing the piston 15 with no appreciable clearance, and therefore has a diameter smaller than the one of the pumping chamber 14. On top (namely towards the pumping chamber 14), the guide bushing 27 has an annular surface 30 which abuts against the annular abutment 28 of the containing seat 26 and forms the lower delimitation of the pumping chamber 14.

[0021] As shown more clearly in Figure 5, the upper surface 30 of the guide bushing 27 has a convex shape having an increasing height from outside to inside; in other words, the upper surface 30 of the guide bushing 27 is not perfectly parallel to the annular abutment 28 of the containing seat 26, but has an increasing height from outside to inside. Therefore, the upper surface 30 of the guide bushing 27 is bent to be externally lower and internally higher. Moreover, the annular abutment 28 of the containing seat 26 has a centrally arranged step 31, against which a central portion of the upper surface 30 of the guide bushing 27 rests. In other words, the convex shape of the upper surface 30 of the guide bushing 27 and the step 31 of the annular abutment 28 of the containing seat 26 determine that the contact between the upper surface 30 of the guide bushing 27 and the annular abutment 28 of the containing seat 26 occurs always and only at the step 31 (i.e. at the edge of the step 31) for a clear geometric constraint.

[0022] This ensures that the hydraulic sealing area of the guide bushing 27 is always at the step 31 of the shoulder 28 rather than at the outer surface of the guide bushing 27; accordingly, the hydraulic thrust generated during pumping (i.e. the fuel pressure in the pumping chamber 14) acts on the circular crown-shaped surface defined between the step 31 of the shoulder 28 and the through-hole 29 instead of, as in a known fuel pump, on the circular crown-shaped surface defined between the outer diameter and the through hole 29. This causes a substantial reduction (even larger than 50%) of the surface of the guide bushing 27 on which the hydraulic thrust (i.e. the fuel pressure in the pumping chamber 14) generated during pumping acts with an analogous reduction of the hydraulic thrust on the guide bushing 27 of the piston 15. In other words, moving the hydraulic sealing area to the inside (i.e. near the inner diameter of the guide bushing 27 of the piston 15) significantly reduces the surface exposed to the fuel pressure, analogously reducing the hydraulic thrust on the guide bushing 27 of the piston 15; in this way, thanks to a configuration very similar to the known fuel pumps, the working pressure of the fuel pump 4 can be increased up to very high values (of the order of magnitude of 1000 bars). According to a preferred embodiment, to guarantee a better hydraulic sealing at the step 31 of the annular abutment 28 (i.e. to ensure that the hydraulic sealing completely corresponds to the step 31 of the annular abutment 28 with no significant leakage), the guide bushing 27 is fitted in the containing seat 26 and is pushed against the annular abutment 28 with a force sufficient to cause a plastic deformation in the contact area of the annular abutment 28 or the upper surface 30 of the guide bushing 27. Preferably, the guide bushing 27 is made of a metallic material harder than the metal material forming the annular abutment 28 (or forming the main body 12 having a housing seat 26) so that a plastic deformation of the annular abutment 28 (at the step 31) against the upper surface 30 of the guide bushing 27 occurs in the contact area. Alternatively, the guide bushing 27 is made of a metallic material less hard than the metal material forming the annular abutment 28 (or forming the main body 12 having a housing seat 26) so that a plastic deformation of the guide bushing 27 (at the step 31) against the annular abutment 28 occurs in the contact area.

[0023] The plastic deformation occurring at the step 31 allows to obtain a perfect contact (i.e. with no cracks, however small) between the upper surface 30 of the guide bushing 27 28 and the annular abutment of the containing seat 26. This guarantees an optimal hydraulic sealing, showing no leakage even at very high fuel pressures (even higher than 1000 bars).

[0024] According to a possible embodiment, the guide bushing 27 and/or the piston 15 can be made of a ceramic material, which can have a considerable hardness and favourable frictional characteristics. In other words, when the guide bushing 27 and the piston 15 are made of a ceramic material, the guide bushing 27 is easily harder than the annular abutment 28 so that a plastic deformation of the shoulder 28 against the upper annular surface 30 of the guide bushing 27 occurs in the contact area. Furthermore, when the guide bushing 27 and the piston 15 are made of a ceramic material, a very low friction between the bushing 27 and the driving piston 15 can be obtained.

[0025] The high-pressure pump 4 as described above has numerous advantages.

[0026] First, the aforesaid high-pressure pump 4 can pump fuel at a pressure above 600-700 bars. Among other things, this result is obtained thanks to the fact that the hydraulic thrust on the guide bushing 27 of the piston 15 is significantly limited by moving to the inside the contact point (i.e., the hydraulic sealing area) between the upper surface 30 of the guide bushing 27 and the annular abutment 28 of the containing seat 26.

[0027] Moreover, the aforesaid high-pressure pump 4 is economic and easy to implement, because the changes, compared to a similar known fuel pump, are limited to two simple mechanical machining steps; substantially, the upper surface 30 of the guide bushing 27 must be machined to give a convex shape to the upper surface 30 and the shoulder 28 of the containing seat 26 must be machined to create the step 31 (both of these machining steps are simple and, above all, are mainly carried out on the single parts before they are assembled).

Claims

1. A fuel pump (4) for a direct injection system provided with a common rail (3); the fuel pump (4) comprises:

a pumping chamber (14) defined in a main body (12);
a piston (15), which is slidingly mounted inside the pumping chamber (14) to cyclically vary the volume of the pumping chamber (14);
an intake channel (17), which originates from a wall of the pumping chamber (14);
an intake valve (18), which is arranged along the intake channel (17);
a delivery channel (19), which originates from a wall of the pumping chamber (14);
a delivery valve (20), which is arranged along the delivery channel (19);
a cylindrical containing seat (26), which is defined in the main body (12) under the pumping chamber (14), has a diameter larger than the diameter of the pumping chamber (14), and is delimited, on the upper side, by an annular abutment (28), which has, on the outside, the diameter of the containing seat (26) and, on the inside, the diameter of the pumping chamber (14); and
a guide bushing (27), which is housed in the containing seat (26), is centrally provided with a through hole (29) where the piston (15) is slidingly arranged, and has an upper surface (30), which abuts against the annular abutment (28) of the containing seat (26);
wherein the upper surface (30) of the guide bushing (27) and the annular abutment (28) of the containing seat (26) are shaped so as to create, between them, a hydraulic sealing, which is formed at a central area of the annular abutment (28);
the fuel pump (4) being **characterized in that**:

the upper surface (30) of the guide bushing (27) has a convex shape having an increasing height from outside to inside; and
the annular abutment (28) of the containing seat (26) has a step (31), which is centrally arranged and against which a central portion of the upper surface (30) of the guide bushing (27) rests.

2. A fuel pump (4) according to claim 1, wherein the guide bushing (27) is fitted in the containing seat (26) and is pushed against the annular abutment (28) with a force that is sufficient to determine a plastic deformation in the contact area of the annular abutment (28) or of the upper surface (30) of the guide bushing (27).

3. A fuel pump (4) according to claim 2, wherein the guide bushing (27) is made of a material harder than the material forming the annular abutment (28), so that, in the contact area, there is a plastic deformation of the annular abutment (28) against the upper surface (30) of the guide bushing (27).

4. A fuel pump (4) according to claim 3, wherein the guide bushing (27) is made of a material less hard than the material forming the annular abutment (28), so that, in the contact area, there is a plastic deformation of the upper surface (27) of the guide bushing (28) against the annular abutment (30).

5. A fuel pump (4) according to any one of claims 1-4, wherein the guide bushing (27) is made of a ceramic material.

6. A fuel pump (4) according to any one of claims 1-5, wherein the piston (15) is made of a ceramic material.

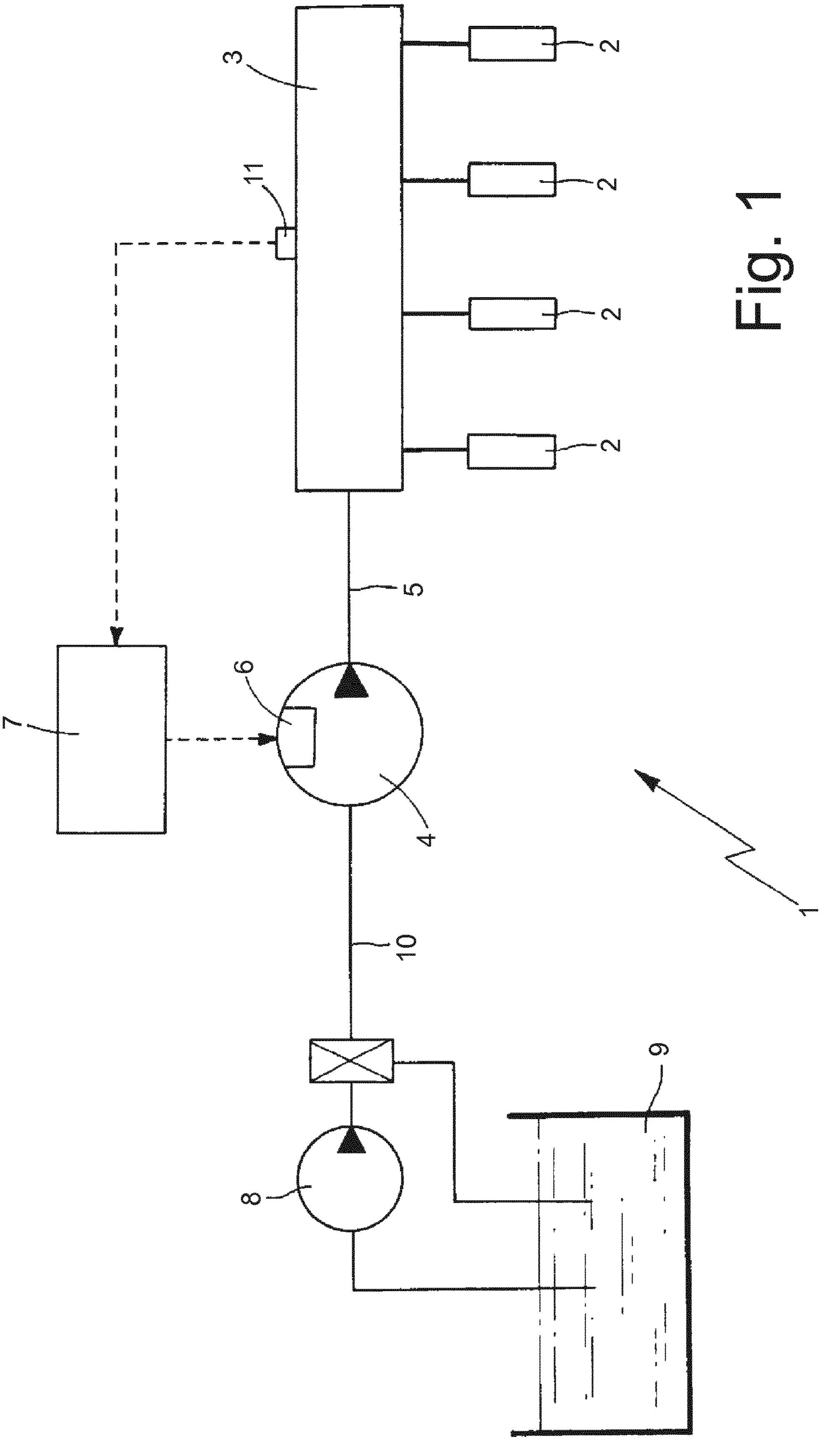

Fig. 1

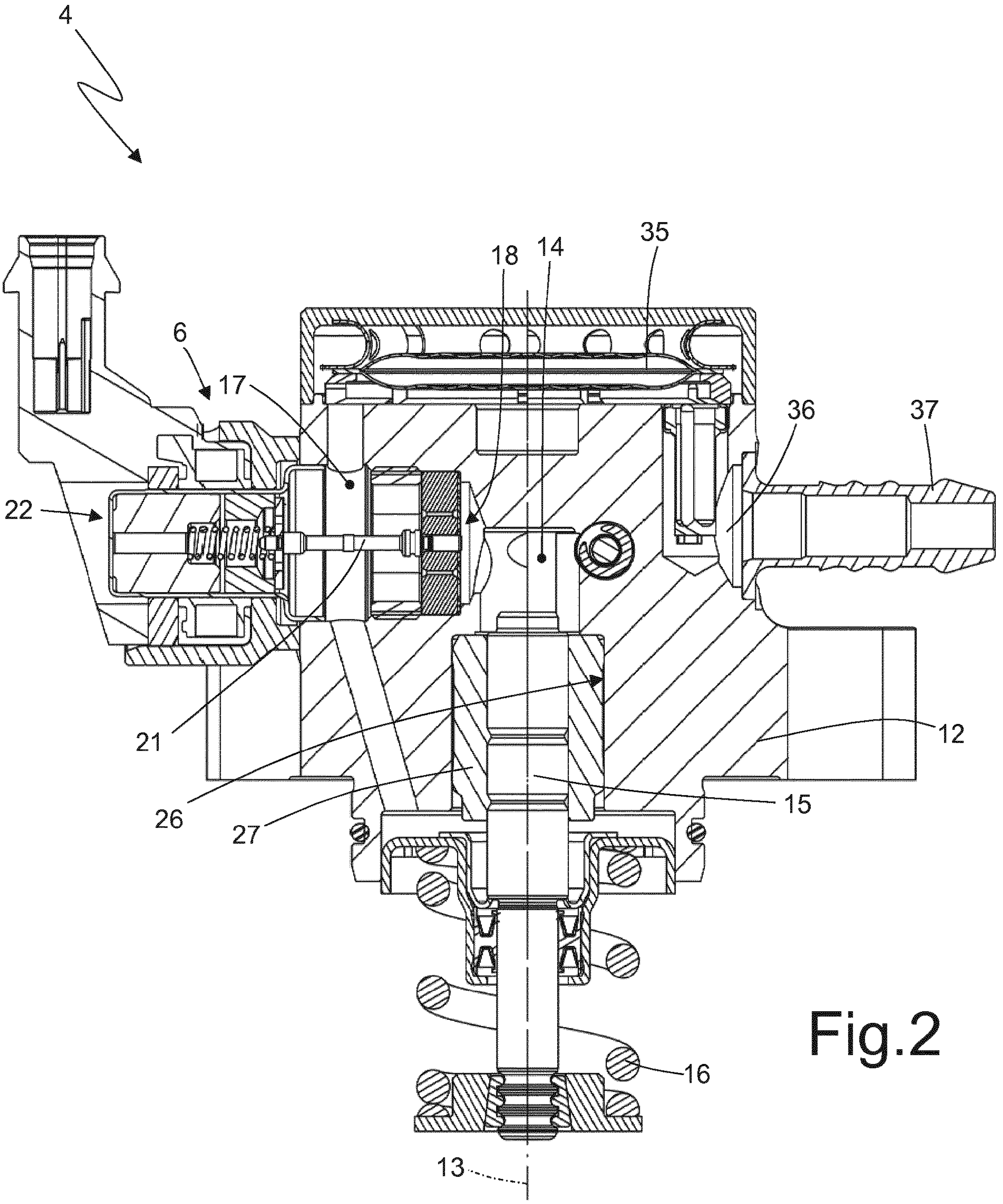

Fig.2

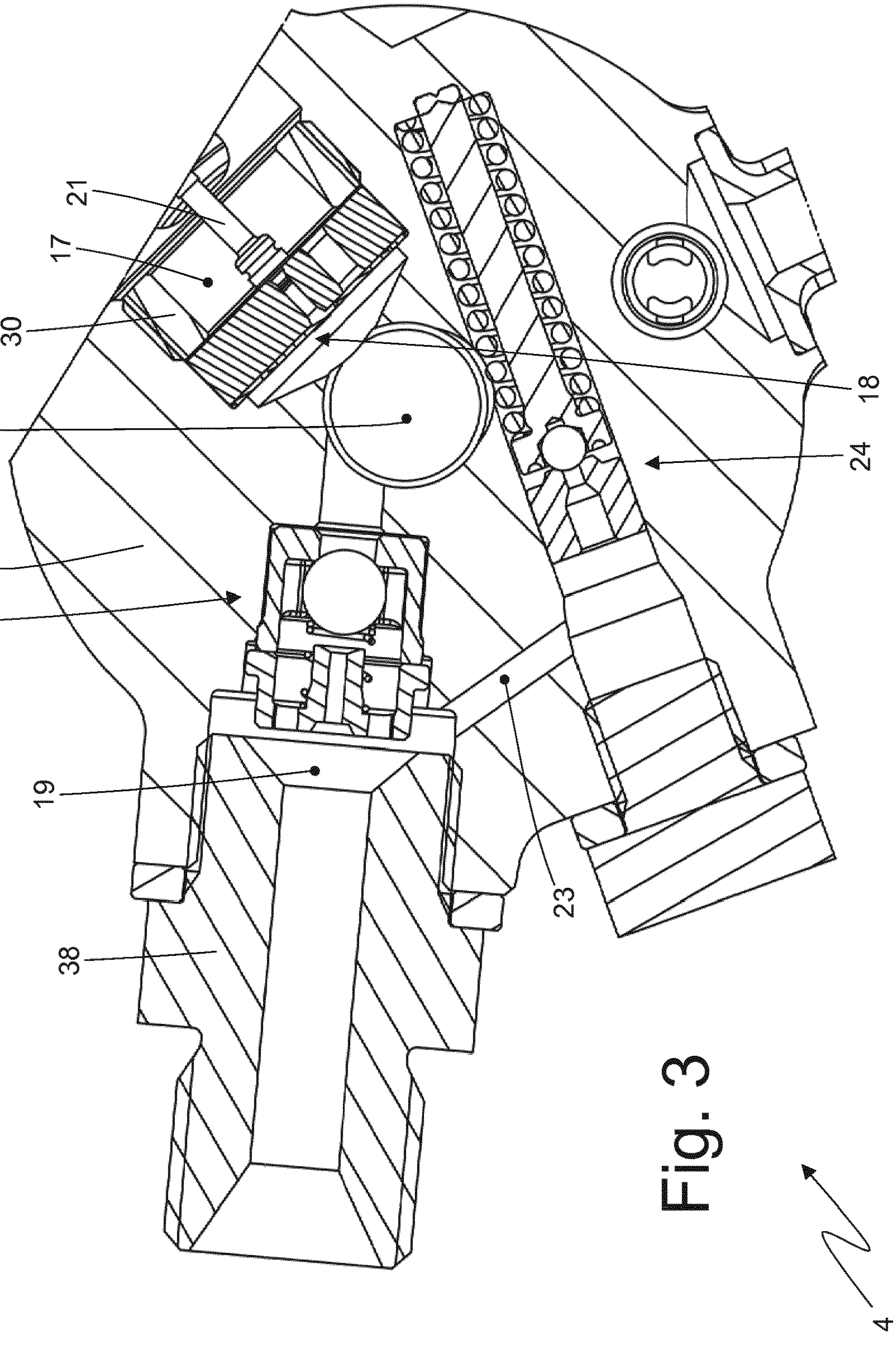

Fig. 3

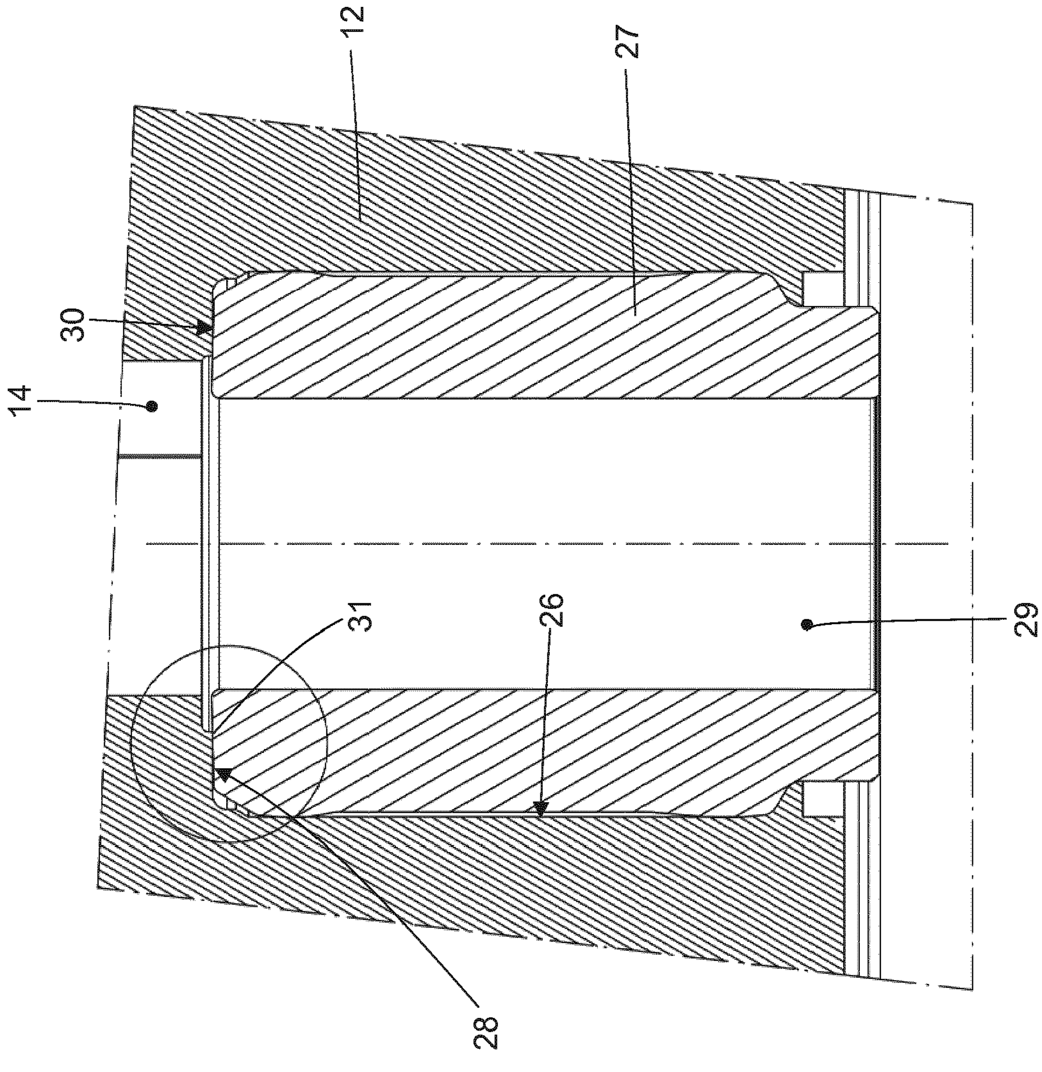

Fig. 4

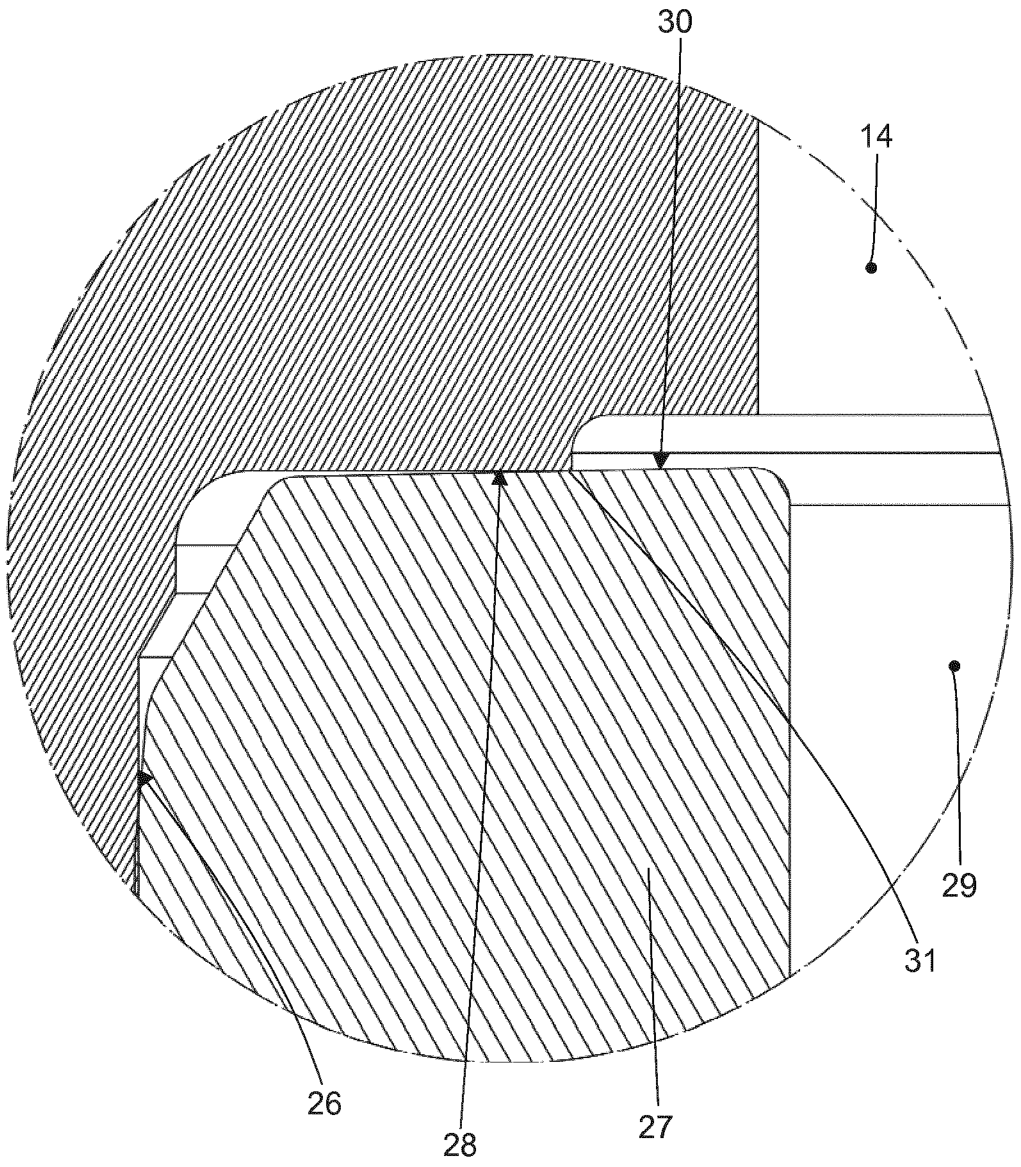

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 16 16 7581

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A,D	EP 2 236 809 A2 (MAGNETI MARELLI SPA [IT]) 6 October 2010 (2010-10-06) * figure 2 * -----	1	INV. F02M59/10 F04B53/16 F04B1/04 F02M63/02 ADD. F02M59/06 F02M59/44
A	WO 2014/069192 A1 (HITACHI AUTOMOTIVE SYSTEMS LTD [JP]) 8 May 2014 (2014-05-08) * figure 2 * -----	1	
A	DE 103 22 603 A1 (BOSCH GMBH ROBERT [DE]) 9 December 2004 (2004-12-09) * figures 8-10 * -----	1	
X	EP 1 275 845 A2 (BOSCH GMBH ROBERT [DE]) 15 January 2003 (2003-01-15)	1	
Y	* paragraph [0034]; figures 3,4 * -----	1-6	
Y	DE 10 2008 002170 A1 (BOSCH GMBH ROBERT [DE]) 10 December 2009 (2009-12-10) * paragraph [0009]; figures * -----	1-4	
Y	US 2008/224417 A1 (BENSON DONALD J [US] ET AL) 18 September 2008 (2008-09-18) * paragraph [0042]; figure 2 * -----	1,5,6	TECHNICAL FIELDS SEARCHED (IPC) F02M F04B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	30 August 2016	Landriscina, V

CATEGORY OF CITED DOCUMENTS

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L : document cited for other reasons
....
& : member of the same patent family, corresponding document

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EP 16 16 7581

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30-08-2016

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2236809 A2	06-10-2010	CN 101852156 A	06-10-2010
		EP 2236809 A2	06-10-2010
		IT 1396473 B1	14-12-2012
		US 2010242922 A1	30-09-2010
WO 2014069192 A1	08-05-2014	CN 104781543 A	15-07-2015
		EP 2915995 A1	09-09-2015
		JP 2014088838 A	15-05-2014
		US 2015300338 A1	22-10-2015
		WO 2014069192 A1	08-05-2014
DE 10322603 A1	09-12-2004	NONE	
EP 1275845 A2	15-01-2003	DE 10134066 A1	06-02-2003
		EP 1275845 A2	15-01-2003
		JP 2003065175 A	05-03-2003
DE 102008002170 A1	10-12-2009	NONE	
US 2008224417 A1	18-09-2008	CN 101688445 A	31-03-2010
		EP 2129869 A1	09-12-2009
		US 2008224417 A1	18-09-2008
		WO 2008115796 A1	25-09-2008

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- EP 2236809 A1 **[0003]**
- EP 1275845 A **[0006]**
- DE 102008002170 **[0006]**