



- | | |
|---|--|
| <p>(51) International Patent Classification:
 <i>F02M 59/46</i> (2006.01) <i>F02D 41/38</i> (2006.01)
 <i>F02M 63/02</i> (2006.01)</p> | <p>(72) Inventors: LLOYD, James; The Old Surgery, East Street, Harrietsham, Maidstone KENT ME17 1HJ (GB).
 FULLER, Trevor; 14 Plantation Lane, Bearsted, Maidstone Kent ME14 4BH (GB).</p> |
| <p>(21) International Application Number:
 PCT/EP2018/057792</p> | <p>(74) Agent: DELPHI FRANCE SAS; c/o Delphi Technologies, Campus Saint Christophe, Bâtiment Galilée 2, 10, avenue de l'Entreprise, 95863 Cergy Pontoise CEDEX (FR).</p> |
| <p>(22) International Filing Date:
 27 March 2018 (27.03.2018)</p> | |
| <p>(25) Filing Language: English</p> | |
| <p>(26) Publication Language: English</p> | |
| <p>(30) Priority Data:
 1705178.0 31 March 2017 (31.03.2017) GB</p> | |
| <p>(71) Applicant: DELPHI TECHNOLOGIES IP LIMITED [BB/BB]; Erin Court, Bishop's Court Hill, St. Michael (BB).</p> | |
| <p>(71) Applicant (for GH only): DELPHI FRANCE SAS [FR/FR]; Bâtiment le Raspail - ZAC Paris Nord 2 22 avenue des Nations CS65059 Villepinte, 95972 Roissy CDG Cedex (FR).</p> | <p>(81) Designated States (<i>unless otherwise indicated, for every kind of national protection available</i>): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.</p> |

(54) Title: HIGH PRESSURE FUEL PUMP

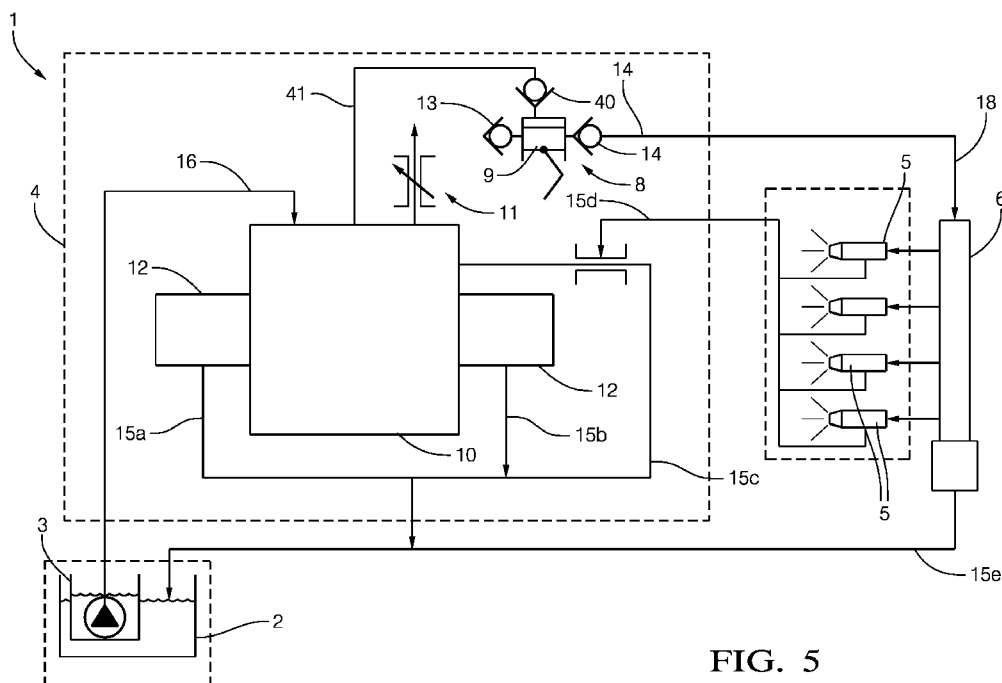


FIG. 5

(57) Abstract: A high pressure fuel pump, said pump including a low pressure fuel inlet and a cam-driven plunger and cylinder arrangement, said cylinder including a low pressure fuel inlet and a high pressure fuel outlet, and said plunger adapted to reciprocate in a cylinder so as to draw fuel from said inlet and to provide pressurised fuel via said high pressure fuel outlet, and characterised wherein said cylinder further includes an outlet to a depressurisation path via depressurization valve, adapted to provide a pathway for fuel to allow depressurisation of fuel in said cylinder.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

HIGH PRESSURE FUEL PUMP

5

TECHNICAL FIELD

This invention relates to high pressure fuel pumps. It has particular application to plunger or piston operated pumps used to provide high pressure fuel to an accumulator volume such as a common rail, for supply to fuel injectors.

BACKGROUND OF THE INVENTION

Typically fuel is supplied to fuel injectors via e.g. a common rail from a high pressure pump. Low pressure fuel is supplied to the high pressure pump via e.g. an inlet metering valve. Typically a high pressure pump comprises a cam driven plunger (piston) adapted to reciprocate in a cylinder to pressurize the fuel. Typically there are four phases; an inlet/filling phase where on the down stroke of the plunger fuel is drawn into the cylinder. Following this on the upstroke, there is a pressurization phase. At a certain pressure an outlet valve located between the cylinder and the common rail opens, and during the subsequent delivery phase pressurized fuel is allowed to flow to the common rail. Following this is a depressurization phase.

A problem particularly at high pump speeds, low inlet pressures and high delivery pressures is a reduction on volumetric efficiency. It is an object of the invention to overcome this problem and to provide a method to reduce the duration of the depressurization phase.

SUMMARY OF THE INVENTION

In one aspect is provided a high pressure fuel pump, said pump including a low pressure fuel inlet and a cam-driven plunger and cylinder arrangement, said cylinder including a low pressure fuel inlet and a high pressure fuel outlet, and said plunger adapted to reciprocate in a cylinder so as to draw fuel from said inlet

and to provide pressurised fuel via said high pressure fuel outlet, and characterised wherein said cylinder further includes an outlet to a depressurisation path via a depressurization valve, adapted to provide a pathway for fuel so as to allow depressurisation of fuel in said cylinder.

5

The pump may include an inlet or head cap valve located between a low pressure fuel supply and said cylinder.

10 The pump may include an outlet valve located downstream of the high pressure outlet.

Said depressurisation valve may be adapted to be controlled by an engine control unit (ECU).

15 Said depressurisation valve may be a solenoid or piezo-controlled.

Said depressurisation path may be connected or provide a flow to the pump cambox.

20 Said depressurisation valve may be adapted to be operated dependent on a demand or actual rail pressure and/or the speed of the pump.

.

25 Said depressurisation valve may be activated at a start point in relation to the plunger travel and/or duration dependent on a desired or actual rail pressure or the speed of the pump.

In another aspect is provided a high pressure fuel pump system for a vehicle including a pump as claimed above an ECU, said ECU adapted to control said depressurisation valve.

30

In methodology activation of the pump may be dependent on a desired or actual rail pressure or the speed of the pump.

The start point in terms of plunger position and/or the duration of the activation may be variable.

BRIEF DESCRIPTION OF THE DRAWINGS

5

The present invention is now described by way of example with reference to the accompanying drawings in which:

- Figure 1 shows a schematic figure of a typical fuel delivery system;
- Figure 2 shows the a chart of the pumping cycle;
- 10 - Figure 3 shows the effect of inlet pressure on the volumetric efficiency;
- Figure 4 shows the simulated effect of rail pressure of depressurization duration;
- Figure 5 shows an arrangement according to one embodiment of the current invention.

15

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows a schematic figure of a typical fuel delivery system (hydraulic circuit) 1 for a vehicle engine. Fuel is supplied from a tank 2 via a low pressure pump 3 to a high pressure pumping arrangement including a high pressure pump shown generally by box 4 which supplies high pressure fuel to injectors 5 via a common rail 6. Backflow paths are shown with reference numeral 5.

Regarding the high pressure fuel pump 4, fuel is supplied from low pressure supply to the cylinder 7 of a plunger/cylinder pump arrangement 8 which includes a plunger (piston) 9. The fuel here is supplied via a high pressure pump cambox 10 and an Inlet Metering valve 11. Fuel is pressurised by the plunger reciprocating in the cylinder, driven by a cam. The cam bearings (shown with the cam box with reference numerals 12) are lubricated via paths 15a and 15b. The high pressure pump systems in the art typically, include with respect to the cylinder, an inlet valve 13 (head or cap valve) and an outlet valve 14, the latter of which is located between the pump high pressure outlet (cylinder and the common rail). Backflow paths 15a-e as shown. Inlet path 16 is at the inlet

pressure. Pressure at path 17 is the head cap pressure, and 18 the high pressure system pressure.

Figure 2 shows the a chart of the pumping cycle for a typical or simulated system showing pumping chamber (cylinder 7) pressure 20 as well plunger lift 21 on a plunger type fuel pump operating at 2000 RPM and 2000bar and a 100% Inlet Metering Valve condition. Phase A is the pressurization phase. Here fuel is compressed and the pumping chamber pressure increases. The outlet valve opens at start of delivery phase B and delivery of fuel to the rail begins. Pumping pressure is maintained at roughly the rail pressure rail pressure. At the end of phase B, Top Dead Centre (TDC) is reached, the outlet valve shuts and delivery stops. As the plunger moves down the pumping chamber the pumping chamber dead volume is depressurised during phase C.

Once de-pressuring of the pumping chamber has occurred and the required pressure difference across the inlet valve is achieved then the inlet valve will open and filling will start during filling phase D. The filling period lasts until Bottom Dead Centre (BDC) and phase A commences again.

Figure 3 shows the effect of inlet pressure on the volumetric efficiency of a common rail high pressure pump with speed, for different pressures; it shows a typical HP pump volumetric efficiency curves at pump full load. Reference numerals 22, 23, 24, 25, 26 shows the plots of pressures of 2.5, 3, 4, 5, and 6 bar respectively. Except at 6bar, the volumetric efficiency reduces at high speed. This would be true for 6 bar if speed increased further. As would be expected, lower inlet pressure results in a reduced volumetric efficiency at a lower speed than with a higher inlet pressure. As speed increases, time available for fuel to fill the pumping chamber is reduced, volumetric efficiency reduces. Also, at high speed, plunger leakage in depressurising phase is lower than at low speed. This means high speed depressurising requires greater angular duration and reduces the filling phase. As inlet pressure reduces, flow rate from across inlet valve reduces, volumetric efficiency reduces. Also the filling phase reduces due to later valve opening.

Figure 4 shows the simulated effect of rail pressure of depressurization duration, and in particular shows pumping chamber pressure at different (initial) pumping chamber pressures) against cam driveshaft angle (this can be equated to plunger lift) over a relatively small phase interval of 95 to 115 degrees. Plots 30, 31, 32, 33 shows the plots of pumping chamber pressure for initial pumping chamber pressures of 2000, 2200, 2400 and 2600 bar respectively. Plot 34 shows the plunger lift. Depressurisation takes place over about 17° from TDC.

Regarding the rail pressure effect on volumetric efficiency (due to filling phase effect); as rail pressure increases, depressurising phase increases, in combination with high speeds filling phase will reduce in turn reducing volumetric efficiency. The more hydraulically efficient the hydraulic head (often linked to small plunger clearance), the longer the depressurising phase will be.

15

Figure 5 shows an arrangement according to one embodiment of the current invention. The figure is similar to figure 1 with like reference numerals but also includes a depressurisation valve 40, which provides an depressurisation outlet (path), via flow from the cylinder. In the example is provided a depressurisation path 41 allowing the fuel to return to the cambox.

20

The depressurisation valve may be controlled by a vehicle ECU and may be solenoid or piezo-operated.

At conditions where pumping chamber filling is negatively impacted, filling duration can be increased by using the depressurising valve, to decrease the depressurisation duration, thus improving volumetric efficiency.

The depressurisation valve is thus, in examples, operated (i.e. opened) on the down-stroke, e.g. from or shortly after TDC to allow depressurisation to be effected more quickly, depending on conditions. The start time and or duration the de-pressurisation valve is opened may be varied, and be dependent on various

30

conditions such as rail pressure inlet pressures pump speed, cam profiles and such like as explained below.

This overcomes the problems listed below, which would otherwise become more
5 of a problem with current trends for higher speed, rail pressures and such like:

i) At high speed, the filling duration is reduced. The greater the angular duration
of depressurising at high speed, due to less depressurising due to plunger
clearance flow, the filling angular duration decreases.

10

ii) The higher the rail pressure, it is preferable to have a longer depressurising
phase and therefore the shorter the filling phase.

iii) At a low enough reduction in inlet pressure, the flow across the inlet valve will
15 be reduced in the filling phase thus reducing volumetric efficiency. It is desirable
to reduce for reduced leakage in pumping phase.

iv) As plunger clearance reduces, the depressurising phase will increase, reducing
the filling duration.

20

v) Cam profile – it is desirable to increase pumping duration for high pressure
pump peak torque reduction. However increased pumping duration requires
decreased filling duration.

25 The use of the de-pressurisation valve may not be desirable for continuous
operation under all pumping conditions. When the pump depressurises naturally,
energy is put back into the engine. If we depressurise with the valve energy is lost
as heat and wasted.

30 The depressurisation valve is preferably only used under specific operating
conditions at high speed where under normal driving cycles for a short duration.
Therefore, the energy lost at these conditions is tolerated due to the advantageous

use of features such as lower inlet pressure and high pumping duration cam profiles at low speeds where the depressurising valve is not used.

- 5 If an applications HP pump capacity is based on pump HP flow margin at high speed, the use of the depressurising valve may allow a lower capacity pump to be used. A lower capacity pump will have a greater overall efficiency than a high capacity pump for the same operating condition.

- 10 If HP pump negative torque interacts with the engine drive system in an undesirable fashion within a specific speed range, it may be optimised by use of the depressurising valve.

CLAIMS

1. A high pressure fuel pump, said pump including a low pressure fuel inlet and a cam-driven plunger and cylinder arrangement, said cylinder including a
5 low pressure fuel inlet and a high pressure fuel outlet, and said plunger adapted to reciprocate in a cylinder so as to draw fuel from said inlet and to provide pressurised fuel via said high pressure fuel outlet, and characterised wherein said cylinder further includes an outlet to a depressurisation path via a depressurization valve, adapted to provide a pathway for fuel so as to allow
10 depressurisation of fuel in said cylinder; characterised where said depressurisation valve is adapted to be controlled by an engine control unit (ECU) so as to be opened on the down-stroke to aid depressurisation.
2. A pump as claimed in claim 1 including an inlet or head cap valve located
15 between a low pressure fuel supply and said cylinder.
3. A pump as claimed in claim 1 or 2 including an outlet valve located downstream of the high pressure outlet.
20
4. A pump as claimed in claims 1 to 3 wherein said depressurisation valve is solenoid or piezo-controlled.
5. A pump as claimed in claims 1 to 4 wherein said depressurisation path is
25 connected or provide a flow to the pump cambox.
6. A pump as claimed in claims 1 to 5 wherein said depressurisation valve is adapted to be operated dependent on a demand or actual rail pressure and/or the speed of the pump.
30 .
7. A pump as claimed in claim 6 wherein said depressurisation valve is adapted to be activated at a start point in relation to the plunger travel and/or duration dependent on a desired or actual rail pressure or the speed of the pump.

8. A pump as claimed in any previous claim wherein said depressurisation valve is adapted to be activated dependent on a desired or actual rail pressure or
- 5 the speed of the pump.
9. A pump as claimed in any previous claim wherein the start point in terms of plunger position and/or the duration of the activation is variable.

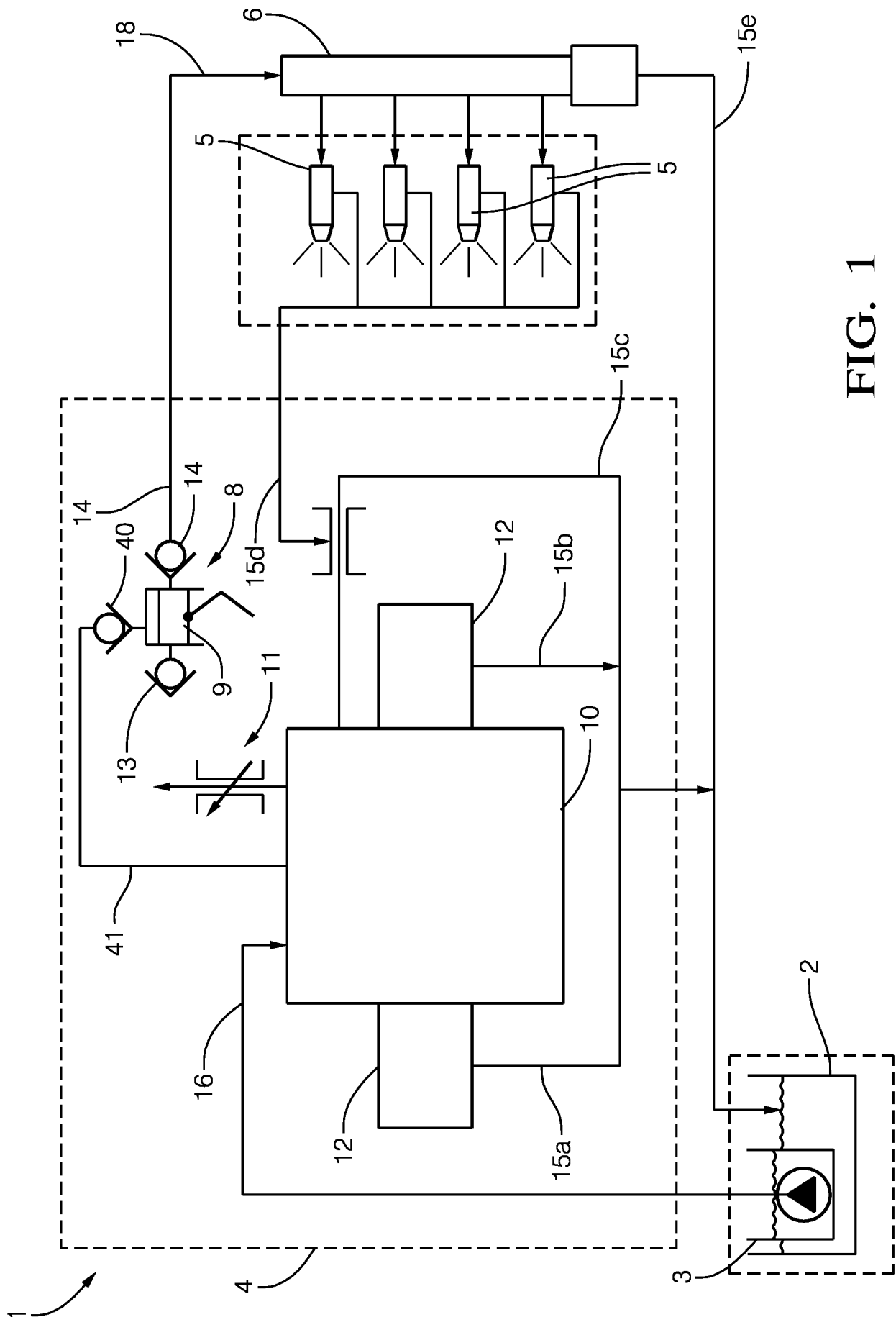


FIG. 1

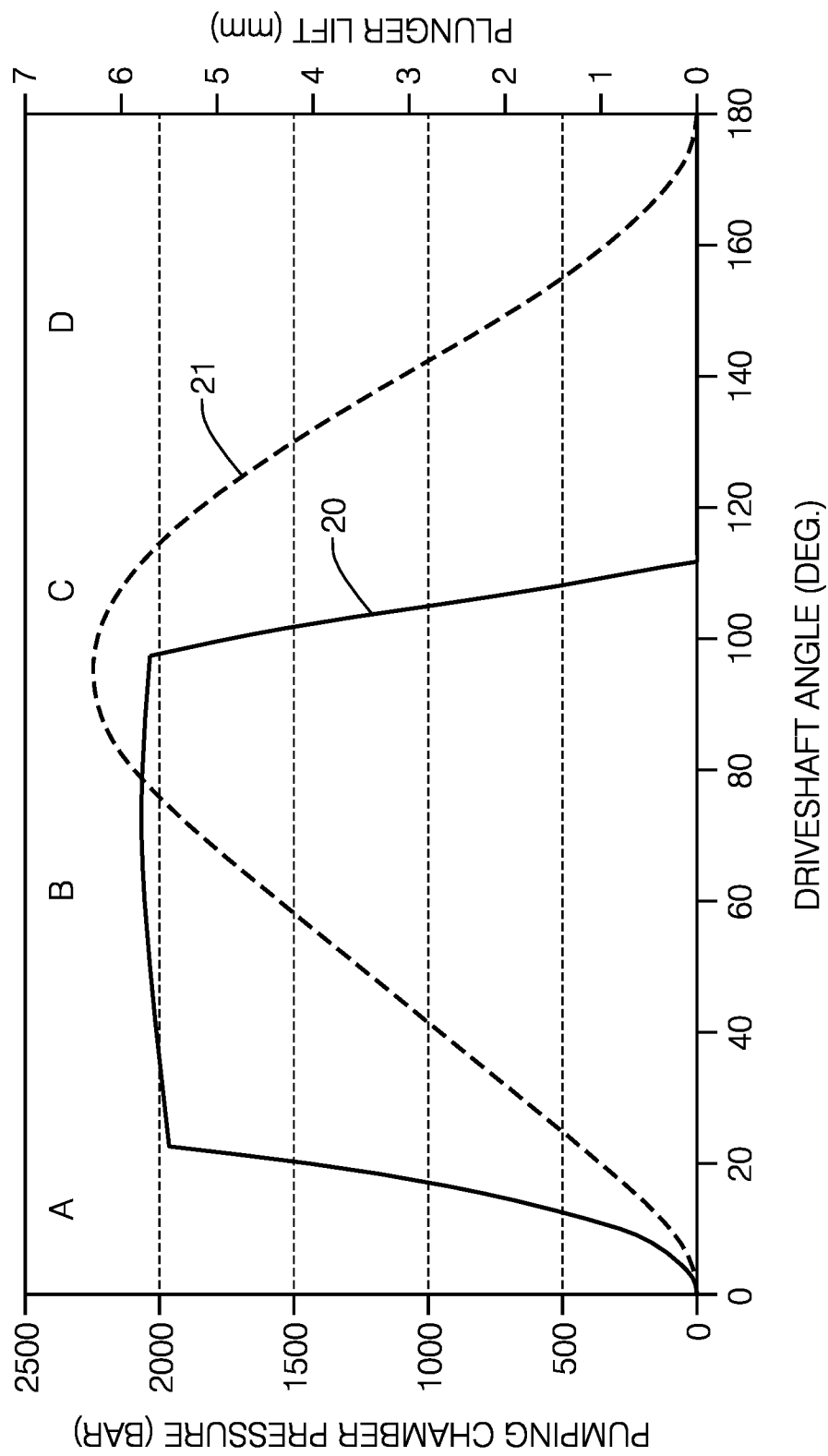


FIG. 2

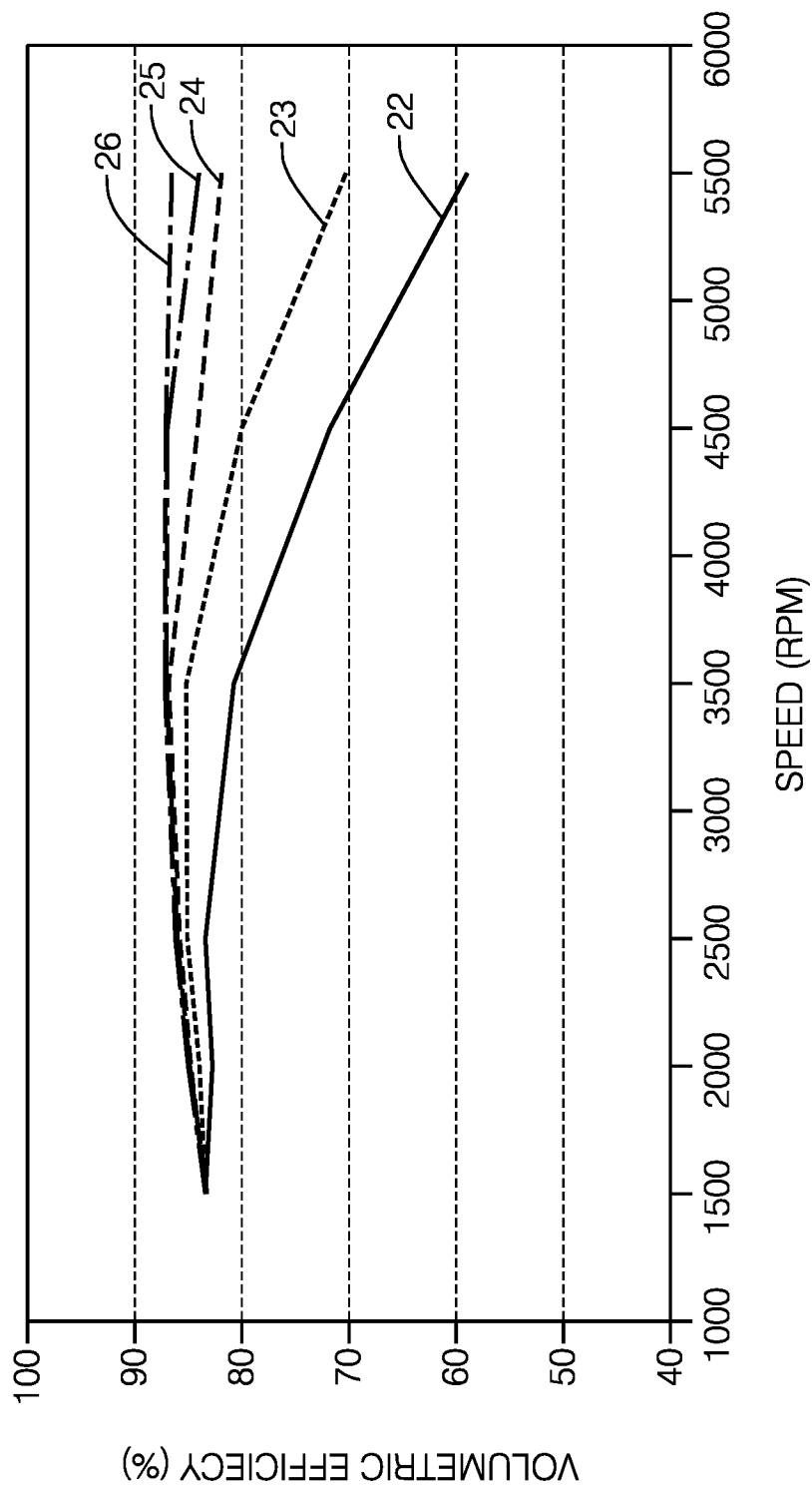


FIG. 3

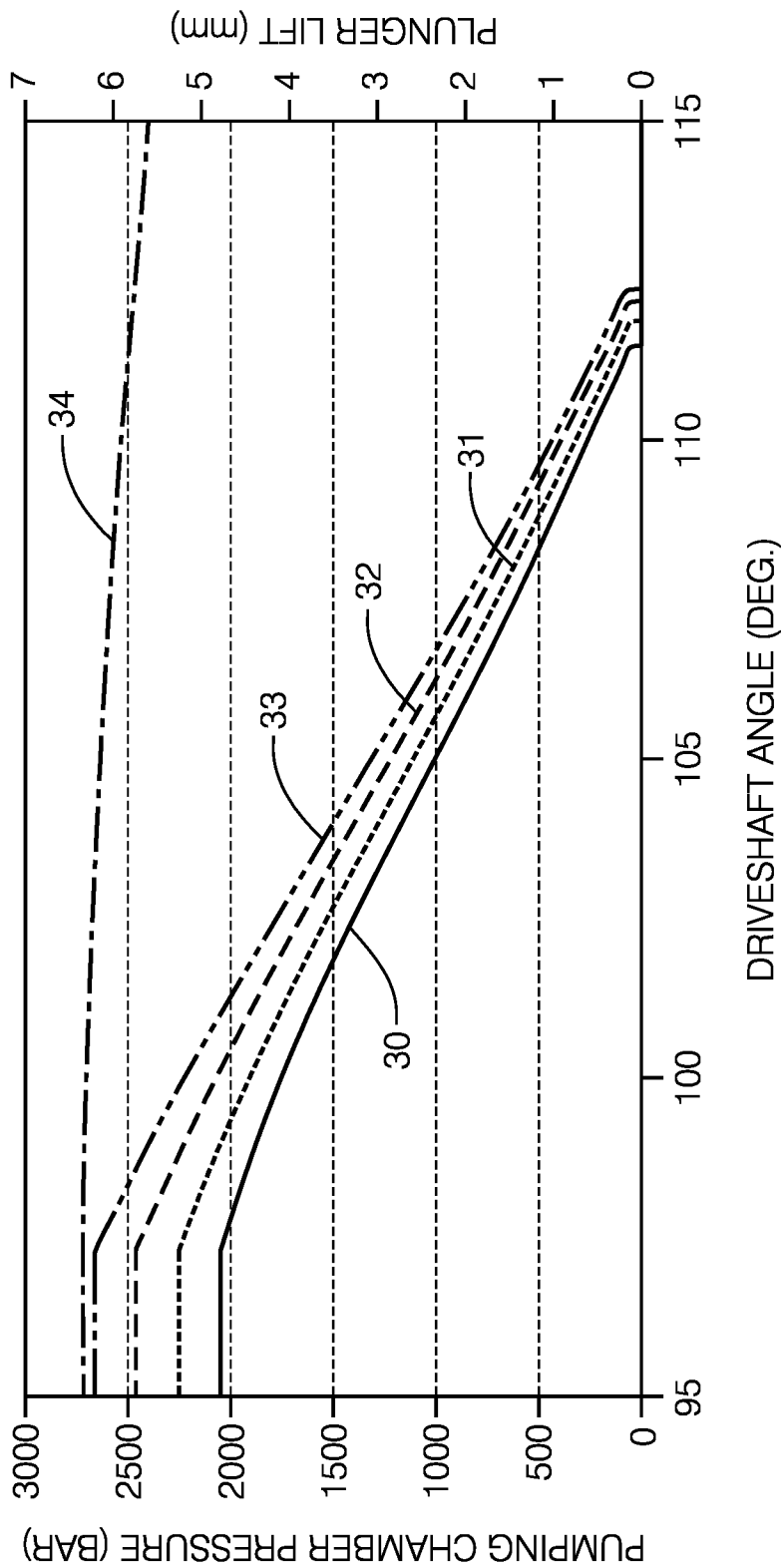


FIG. 4

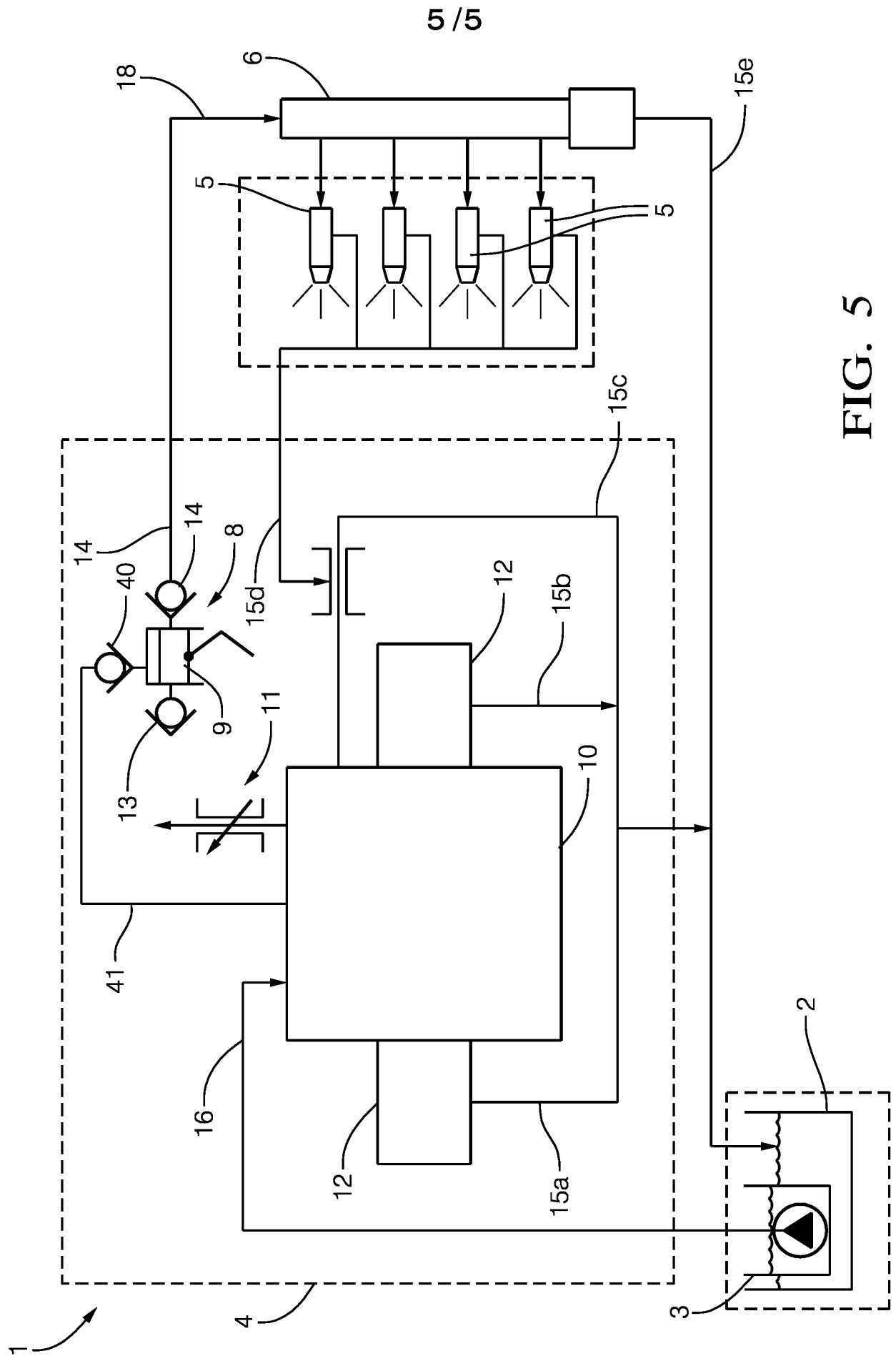


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/057792

A. CLASSIFICATION OF SUBJECT MATTER

INV. F02M59/46 F02M63/02 F02D41/38
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02M F02D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015/285166 A1 (SURNILLA GOPICHANDRA [US] ET AL) 8 October 2015 (2015-10-08) paragraph [0073] paragraph [0074] paragraph [0075] paragraph [0052] paragraph [0065] paragraph [0076] abstract; figure 5 paragraph [0055] paragraph [0053]	1-6,8,9
X	JP 2000 008997 A (HITACHI LTD) 11 January 2000 (2000-01-11) paragraph [0065] - paragraph [0085] abstract; figures 4,5 ----- -/-	1-4,6-9



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

20 June 2018

Date of mailing of the international search report

03/07/2018

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Barunovic, Robert

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/057792

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 241 349 A2 (HITACHI LTD [JP]) 18 September 2002 (2002-09-18) paragraph [0040] - paragraph [0041] abstract; figures 4,5 -----	1-4,6-9
X	GB 2 095 768 A (BOSCH GMBH ROBERT) 6 October 1982 (1982-10-06) page 3, line 101 - line 117 abstract; figures 1,2,3 page 3, line 30 - line 45 claim 1 -----	1-4,9
X	JP H05 71439 A (NIPPON DENSO CO) 23 March 1993 (1993-03-23) paragraph [0017] paragraph [0007] - paragraph [0008] abstract; figures 2,4 paragraph [0009] - paragraph [0012] -----	1-9

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2018/057792

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2015285166	A1	08-10-2015	NONE
JP 20000008997	A	11-01-2000	JP 3428443 B2 22-07-2003 JP 20000008997 A 11-01-2000
EP 1241349	A2	18-09-2002	DE 60120632 T2 12-07-2007 EP 1241349 A2 18-09-2002 EP 1683954 A1 26-07-2006 JP 4123729 B2 23-07-2008 JP 2002276506 A 25-09-2002 US 2002129793 A1 19-09-2002
GB 2095768	A	06-10-1982	AU 8163982 A 07-10-1982 BR 8201744 A 22-02-1983 DE 3112381 A1 11-11-1982 GB 2095768 A 06-10-1982 JP H0411738 B2 02-03-1992 JP S57173554 A 25-10-1982 US 4459963 A 17-07-1984
JP H0571439	A	23-03-1993	NONE