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(71) Applicant: **PIERBURG PUMP TECHNOLOGY GMBH** [DE/DE]; Alfred-Pierburg-Straße 1, 41460 Neuss (DE).

(72) Inventors: **CELATA, Bernardo**; Via Montelungo 7, 57128 LIVORNO (IT). **GUGLIELMO, Fabio**; Via Pi-

gafetta 31, 56038 Ponsacco (IT). **MALOTTI, Andrea**; A. Volta 29, 57023 Cecina (IT). **ROSSI, Giuseppe**; Via Gioberti. 96, 55049 Viareggio (IT).

(74) Agent: **PATENTANWÄLTE TER SMITTEN EBERLEIN-VAN HOOF RÜTTEN PARTNERSCHAFTSGESELLSCHAFT MBB**; Burgunderstr. 29, 40549 Düsseldorf (DE).

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(54) Title: A VARIABLE DISPLACEMENT LIQUID PUMP

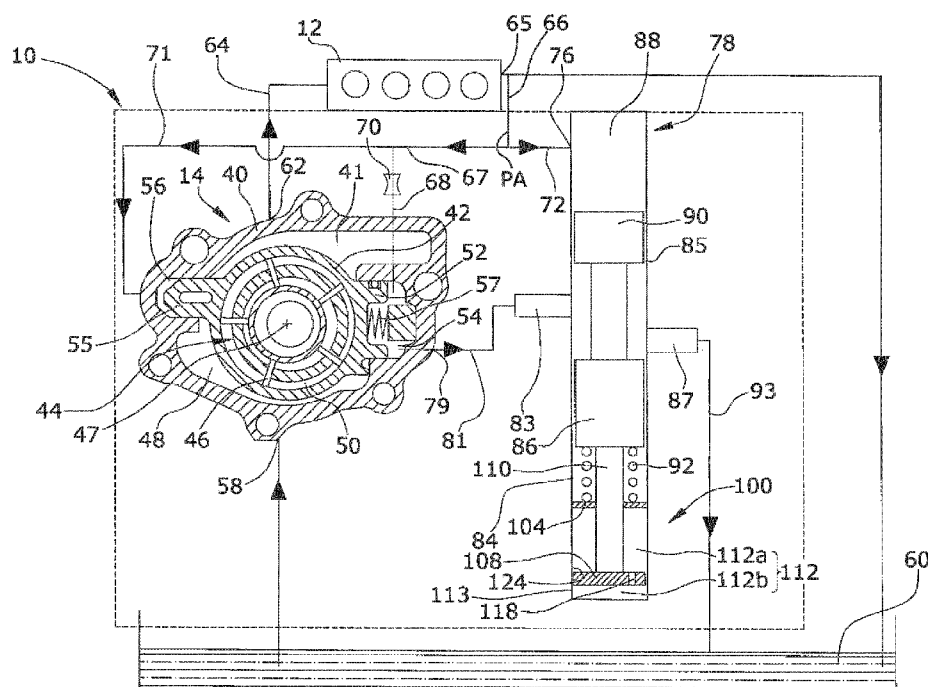


Fig.1

(57) Abstract: The disclosure refers to a variable displacement liquid pump (10) for pumping pressurized liquid, comprising a pump rotor (44) with radially slidable vanes (46) rotating in a shiftable control ring (42), a pressure control system for controlling the discharge pressure of the pressurized liquid. The control system comprises a pressure control chamber (54) for pushing the control ring (42) into high pumping volume direction, and a pressure control valve (78) controlling the pressure in the pressure control chamber (54). The pressure control valve (78) comprises a control plunger (86), which is movable between a first position and a second position, an input pressure plunger (90) being charged with an actual pressure (PA) in an input pressure chamber (88), wherein the input pressure plunger (90) is mechanically connected with the control plunger (86), and a control valve spring (92) preloading the control plunger (86) into the second position against the pressure in the input pressure chamber (88). The control system further comprises a separate damping unit

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(100), comprising a piston (108), which is moving in a separate damping chamber (112) and which is separating the damping chamber (112) in two chamber parts (112a, 112b), which are fluidically connected to each other by a damping channel (118; 120), wherein the piston (108) is stiffly connected to the control plunger (86).

A variable displacement liquid pump

The present invention refers to a variable displacement liquid pump for
5 pumping pressurized liquid.

The variable displacement liquid pump is mechanically driven by the engine and comprises a pump rotor with radially slidable vanes rotating in a shiftable control ring, whereby the control ring is pushed by a pressure control chamber into high pumping volume direction. The pump is
10 provided with a pressure control system for controlling the discharge pressure of the pressurized liquid at the pump outlet port. The pump is provided with a pressure control valve controlling the pressure in the pressure control chamber. The pressure control valve comprises a plunger which is preloaded by a control valve spring.

15 According to the present invention the term "radially slidable vanes" also comprises radially slidable pendulums vanes, wherein the orientation of the vanes has not to be understood as to be precisely radial but can have a constant or variable component in a radial direction.

WO 2014/187503 A1 describes a variable lubricant pump, which
20 comprises a pump rotor with radially slidable vanes, wherein the pump rotor is rotating in a shiftable control ring. The control ring is shiftable between a high pumping volume position and a low pumping volume position. The pump comprises a pressure control system comprising a pressure control chamber for pushing the control ring to a high pumping
25 volume position. The control system further comprises a pressure control valve controlling the pressure in the pressure control chamber. A control piston is slidably provided in the control valve to open or close a discharge port of the pressure control chamber to thereby control the

pressure in the pressure control chamber. The control piston is preloaded by a spring at one axial end.

Advantageously, the lubricant pressure at the engine lubricant outlet is used as the control variable to be controlled by the pressure control
5 circuit. This concept guarantees a sufficient lubricant pressure within the engine. However, as the actual lubricant pressure is picked up at the engine lubricant outlet, considerable time makes the control loop more susceptible to pressure oscillations.

The variable displacement fluid pump according to the state of the art
10 shows oscillations of the lubricant outlet pressure in the range of 5 to 50 Hz. The oscillations of the outlet pressure are around an average pressure value which is at high rotational speed below the adjusted pressure value. As a consequence the average pressure value is lower than expected at high rotational speed.

15 The object of the present invention is to provide a variable displacement liquid pump with an improved pressure stability.

This object is solved with a variable displacement liquid pump with the features of claim 1.

According to the present invention the variable displacement liquid pump
20 is provided with a separate damping unit. Accordingly, the damping unit is not integrated in the pressure control valve but is provided as a separate unit of the pressure control system. The damping unit comprises a piston, which is moving in a separate damping chamber and which is separating the damping chamber in two chamber parts, which are
25 fluidically connected to each other by a damping channel. A pressure difference between both chamber parts is balanced via the damping channel. The temporal behavior of balancing the pressure difference between the chamber parts depends on the geometry and the design of

the damping channel and on the damping fluid. As a consequence the temporal behaviour can be influenced by the geometry and the design of the damping channel and the nature and viscosity of the damping fluid. High frequency movements of the piston in the damping chamber
5 therefore are damped. The piston of the damping unit is stiffly connected to the control plunger so that also the movement of the control plunger is damped. High frequency oscillations of the control plunger, resulting in an oscillating outlet pressure, therefore are damped and reduced. As a consequence the variable displacement liquid pump has a higher pressure
10 stability at high rotational speed of the pump.

According to a preferred embodiment of the present invention the liquid pump is a lubricant pump.

Preferably the control valve spring is provided within the pressure control valve. With this arrangement, the damping unit can be easily added to an
15 existing pressure control valve.

In an alternative embodiment the control valve spring is provided in the damping chamber. The control valve spring thereby is provided in one chamber part, preferably the chamber part located at a free axial end of the damping chamber. As a consequence an easy access to the control
20 valve spring from the free axial end is possible. The control valve spring therefore can be easily exchanged in order to e.g. adapt the spring constant.

In a preferred embodiment of the present invention a damping fluid in the damping chamber is the pumping liquid. Accordingly, no separate
25 damping fluid is required.

According to a further preferred embodiment, a damping fluid in the damping chamber is oil. In contrast to gas, oil is not compressible so that no further spring effect is provided by using oil as a damping fluid.

Further, oil has a high boiling temperature so that oil has a broad working range.

According to an alternative embodiment a damping fluid in the damping chamber is air. The viscosity of air slightly increases with increasing
5 temperature so that, in contrast to liquids, the damping effect does not decrease with increasing temperature.

In a further alternative embodiment a damping fluid in the damping chamber is grease. Grease is a fluid having a high viscosity so that a high damping effect can be achieved.

10 Preferably, the piston and the control plunger are mechanically connected to each other by a stiff rod. A rod is a simple structural element for stiffly connecting the control plunger and the piston.

According to a preferred embodiment of the invention, the damping channel is provided as an axial bore in the piston. The piston can be
15 easily provided with a bore so that manufacturing is easy. Further, the bore can be adapted to different viscosities of the damping fluid by providing an adapted geometry of the bore.

In a further preferred embodiment of the present invention the damping channel is provided as radial clearance between the piston and a damping
20 chamber wall. The radial clearance can be provided by choosing an outer radius for the piston, which is significantly smaller than an inner radius of the damping chamber so that a gap between the damping chamber wall and the piston is defined. A sealing provided at the outer circumferential surface of the piston is not necessary. Further, no friction appears.

25 In a preferred embodiment of the present invention the thermal expansion coefficient of the piston and of the housing of the damping chamber differ from each other so that the radial clearance varies with varying temperature. As the viscosity of the damping fluid like e.g. oil

decreases with increasing temperature it is possible to decrease the radial clearance so as to adapt the radial clearance to the viscosity of the damping oil. As a consequence, a substantially stable damping effect over a wide temperature range is realized.

5 Preferably, the discharge port is directly connected to a liquid tank.

The control ring is preferably pretensioned by a spring into the high pumping volume direction. The spring is an antagonist of a pilot chamber and is co-acting with the control chamber.

Preferably, the actual pressure is the engines lubricant outlet pressure at
10 the engine lubricant outlet. The controlled pressure is not the pump outlet pressure but the lubricant's engine outlet pressure. It is thereby avoided that the lubricant pressure in the engine falls under a certain value. By using the lubricant pressure at the engine lubricant outlet as the actual pressure a certain dead time in the control circuit is generated.
15 As a consequence the control loop usually is more susceptible to lubricant pressure oscillations. With the present invention these oscillations of the lubricant pressure in the engine are reduced.

Further advantages will become evident by the following detailed description of the embodiments of the present invention in combination
20 with the drawings, which show:

Figure 1 shows a first embodiment of the variable displacement fluid pump in an open state of the pressure control valve,

Figure 2 shows the embodiment according to Figure 1 in a closed state of the pressure control valve,

25 Figure 3 shows a second embodiment of the variable displacement fluid pump in an open state of the pressure control valve, and

Figure 4 shows an enlarged view of the damping unit according to a third embodiment of the variable displacement fluid pump.

Figure 1 shows a schematic representation of a variable fluid pump 10. The variable fluid pump 10 is a displacement lubricant pump 10 for supplying an internal combustion engine 12 with pressurized lubricant. The pump 10 comprises a pumping unit 14, which is mechanically driven by the engine 12. The pumping unit 14 comprises a housing 40 having a cavity 41 in which a control ring 42 translates, which encircles a pump rotor 44. The pump rotor 44 is provided with numerous radially slidable vanes 46, whereby the vanes 46 are rotating inside the control ring 42. The control ring 42 is radially shiftable so that the eccentricity of the control ring 42 with respect to a rotation axis 47 of the pump rotor 44 can be set to thereby shift the control ring 42 between a low pumping volume position at low eccentricity position and a high pumping volume position at high eccentricity position.

The housing 40 is closed by two side walls 48 of which one is not shown in the drawings. The side walls 48, the vanes 46, the pump rotor 44 and the control ring 42 define five rotating pump chambers 50.

The control ring 42 is provided with a first control ring plunger 52 housed in a pressure control chamber 54 and is provided with a second control ring plunger 55 housed in a pilot chamber 56. The pilot chamber 56 is provided opposite to the pressure control chamber 54. The control ring 42 and the plungers 52, 55 are one single integral part.

A pretensioned control chamber spring 57 inside the pressure control chamber 54 exerts a pushing force to the first control ring plunger 52. The pressure control chamber 54 is defined by the housing 40. The housing 40 also comprises an inlet port 58 for sucking the lubricant from a lubricant tank 60 and an outlet port 62 for feeding lubricant with a discharge pressure to the engine 12. An engine supply conduit 64

extends from the outlet port 62 to the engine 12 to supply the engine 12 with pressurized lubricant.

An actual pressure PA at an engine lubricant outlet 65 is transmitted to the pressure control chamber 54 via a conduit 66, 67, 68 and through a
5 pressure throttle valve 70 in which a calibrated pressure drop occurs as the lubricant flows through. The actual pressure PA is also transmitted to the pilot chamber 56 via a pilot chamber conduit 71.

The actual pressure PA is also transmitted via a conduit 66, 72 to an input pressure port 76 of a pressure control valve 78. The pressure
10 control valve 78 keeps the actual pressure PA at the engine lubricant outlet 65 at a constant nominal pressure value independently of the rotational speed of the engine 12 by regulating the radial position of the control ring 42. The radial position of the control ring 42 is controlled by controlling the pressure in the pressure control chamber 54.

15 The pressure in the pressure control chamber 54 is regulated by controlling a lubricant discharge of an outlet port 79 of the pressure control chamber 54 via a conduit 81 to a control port 83 provided in a cylinder wall 84 of a pressure control valve housing 85.

Dependent on the axial position of a control plunger 86 in the pressure
20 control valve housing 85, a discharge port 87 is opened or closed. The position of the control plunger 86 is dependent on a pressure in an input pressure chamber 88, which pressure thereby is charged to an input pressure plunger 90 and on a preload applied to the control plunger 86 by a control valve spring 92. The control valve spring 92 acts against the
25 pressure in the input pressure chamber 88. The input pressure plunger 90 is mechanically directly connected with the control plunger 86 so that a high pressure in the input pressure chamber 88 forces the control plunger 86 in an opened position with respect to the discharge port 87. Figure 1 shows a position of the control plunger 86 in which the discharge

port 87 is open so that the lubricant is discharged via a discharge conduit 93 to the lubricant tank 60.

In order to damp small pressure variations of the variable displacement lubricant pump 10 the discharge pressure of the pressurized lubricant is further controlled by a damping unit 100, which is arranged on one axial end of the control valve 78. The control valve 78 is fluidically separated from the damping unit 100 by a static separation wall 104. The damping unit 100 comprises a piston 108, which is stiffly connected to the control plunger 86 via a rod 110 and which is moving in a separate damping chamber 112 formed by a housing 113 of the damping unit 100. The damping piston 108 separates the damping chamber 112 filled with lubricant liquid as a damping fluid in two chamber parts 112a, 112b. Both chamber parts 112a, 112b are fluidically connected to each other by a damping channel 118 provided as a bore in the piston 108. When the pressure in the input pressure chamber 88 changes the damping piston 108 is forced in the direction of one of the two chamber parts 112a, 112b, so that the damping fluid is flowing from one chamber part 112a to the other chamber part 112b. As the damping fluid slowly flows through the damping channel 118 from one chamber part 112a to the other chamber part 112b the movement of the piston 108 and therewith of the control plunger 86 is damped. Accordingly, small high frequency pressure variations do not have a strong impact on the movement of the control plunger 86. As a consequence a smoother outlet pressure of the pump is realized, even at high rotational speed of the pump rotor 44.

Figure 2 shows the variable displacement lubricant pump 10 according to Figure 1 in a closed state of the pressure control valve 78. In this state the control valve spring 92 has moved the control plunger 86 in the direction of the input pressure chamber 88. The control plunger 86 thereby closes the discharge port 87 so that no lubricant is discharged from the control chamber 54 to the lubricant tank 60.

Figure 3 shows a second embodiment of the variable displacement lubricant pump 10 in an open state of the pressure control valve 78. The control valve spring 92 is provided in the distal chamber part 112b of the damping unit 100, so that the control valve spring 92 preloads the
5 damping piston 108 in a direction to the input pressure chamber 88.

Figure 4 shows an enlarged view of the damping unit 100 according to a third embodiment of the variable displacement lubricant pump 10. The damping channel 120 is provided as a radial clearance between the piston 108 and a chamber wall 124 of the damping chamber 112.

10 It should be clear that the invention is not limited to the described embodiment. In particular there are various structural changes and modifications possible falling under the scope of the present invention. For example the actual pressure also can be measured directly at the outlet port of the pump.

Reference signs

10	variable displacement lubricant pump
12	combustion engine
14	pumping unit
5 40	housing
41	cavity
42	control ring
44	pump rotor
46	vanes
10 47	rotation axis
48	side wall
50	pump chambers
52	first control ring plunger
54	pressure control chamber
15 55	second control ring plunger
56	pilot chamber
57	control chamber spring
58	inlet port
60	lubricant tank
20 62	outlet port
64	engine supply conduit
65	engine lubricant outlet
66	conduit
67	conduit
25 68	conduit
70	pressure throttle valve
71	pilot chamber conduit
72	conduit
76	input pressure port
30 78	pressure control valve
79	outlet port

	81	conduit
	83	control port
	84	cylinder wall
	85	pressure control valve housing
5	86	control plunger
	87	discharge port
	88	input pressure chamber
	90	input pressure plunger
	92	control valve spring
10	100	damping unit
	104	separation wall
	108	piston
	110	rod
	112	damping chamber
15	112a	chamber part
	112b	chamber part
	113	housing
	118	damping channel
	120	damping channel
20	124	chamber wall
	PA	actual pressure

CLAIMS

- 5 1. A variable displacement liquid pump (10) mechanically driven by an internal combustion engine (12) for pumping pressurized liquid comprising:
- a pump rotor (44) with radially slidable vanes (46) rotating in a shiftable control ring (42) being radially shiftable or pivotable
 - 10 with respect to the rotor axis (47) between a high pumping volume position and a low pumping volume position, and
 - a pressure control system for controlling the discharge pressure of the pressurized liquid, the control system comprising:
 - a pressure control chamber (54) for pushing the control ring
 - 15 (42) into high pumping volume direction, and
 - a pressure control valve (78) controlling the pressure in the pressure control chamber (54), the pressure control valve (78) comprising:
 - a control plunger (86), which is movable between a
 - 20 first position, where a control port (83) in a cylinder wall (84) of the pressure control valve (78) is connected to a discharge port (87) in the cylinder wall (84) and a second position where the discharge port (87) is closed, whereby the control port (83) is
 - 25 connected with an outlet port (79) of the pressure control chamber (54),
 - an input pressure plunger (90) being charged with an actual pressure (PA) in an input pressure chamber (88), wherein the input pressure plunger (90) is
 - 30 mechanically connected with the control plunger (86), and

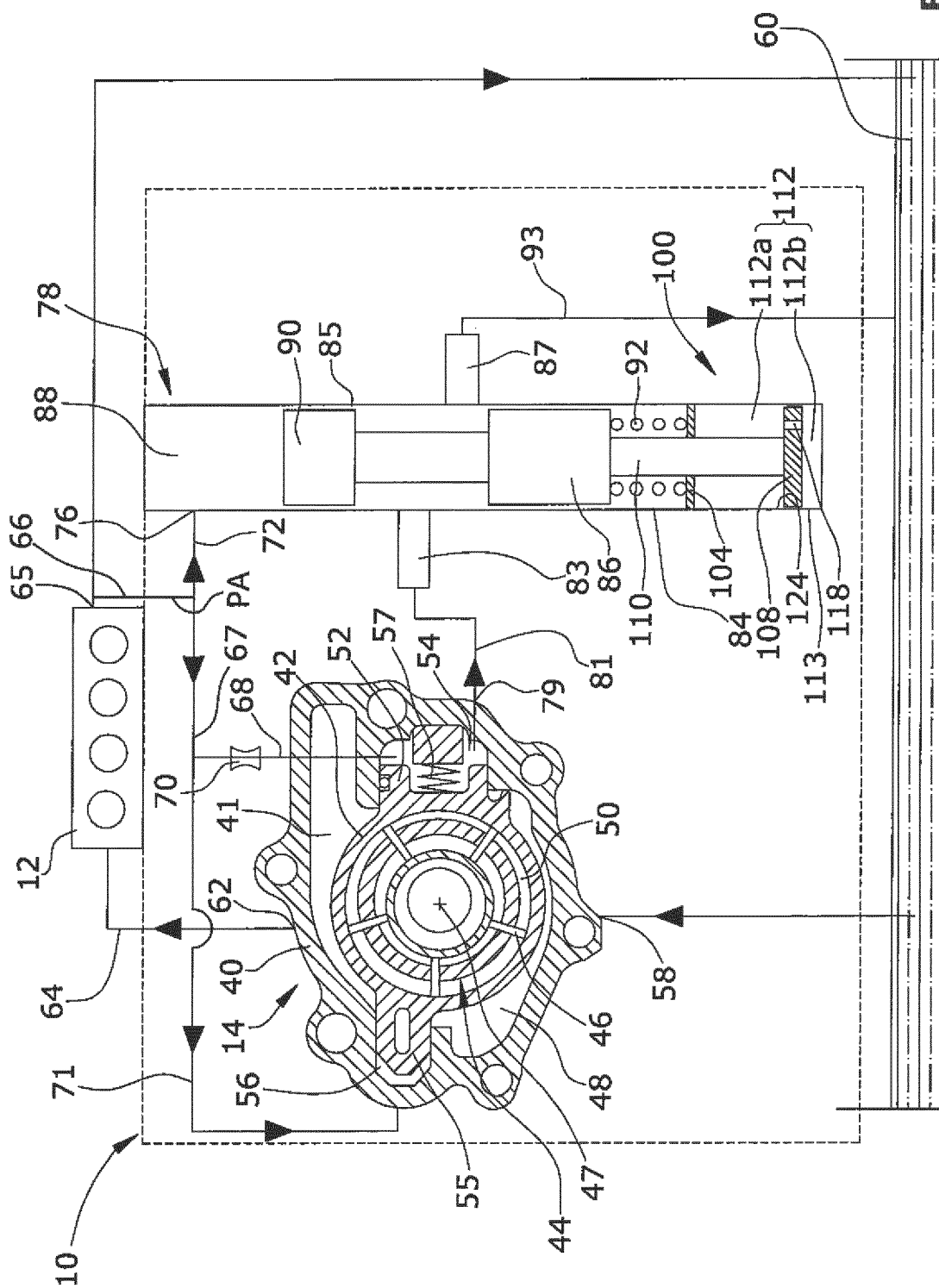
- a control valve spring (92) preloading the control plunger (86) into the second position against the pressure in the input pressure chamber (88); and
- a separate damping unit (100), comprising a piston (108), which is moving in a separate damping chamber (112) and which is separating the damping chamber (112) in two chamber parts (112a, 112b), which are fluidically connected to each other by a damping channel (118; 120), wherein the piston (108) is stiffly connected to the control plunger (86).

2. The variable displacement liquid pump (10) according to claim 1, **characterized in that** the liquid pump (10) is a lubricant pump.
3. The variable displacement liquid pump (10) according to claim 1 or 2, **characterized in that** the control valve spring (92) is provided in the pressure control valve (78).
4. The variable displacement liquid pump (10) according to claim 1 or 2, **characterized in that** the control valve spring (92) is provided in the damping chamber (112).
5. The variable displacement liquid pump (10) of one of the preceding claims, **characterized in that** a damping fluid in the damping chamber (112) is the pumping liquid.
6. The variable displacement liquid pump (10) of one of the preceding claims, **characterized in that** a damping fluid in the damping chamber (112) is oil.

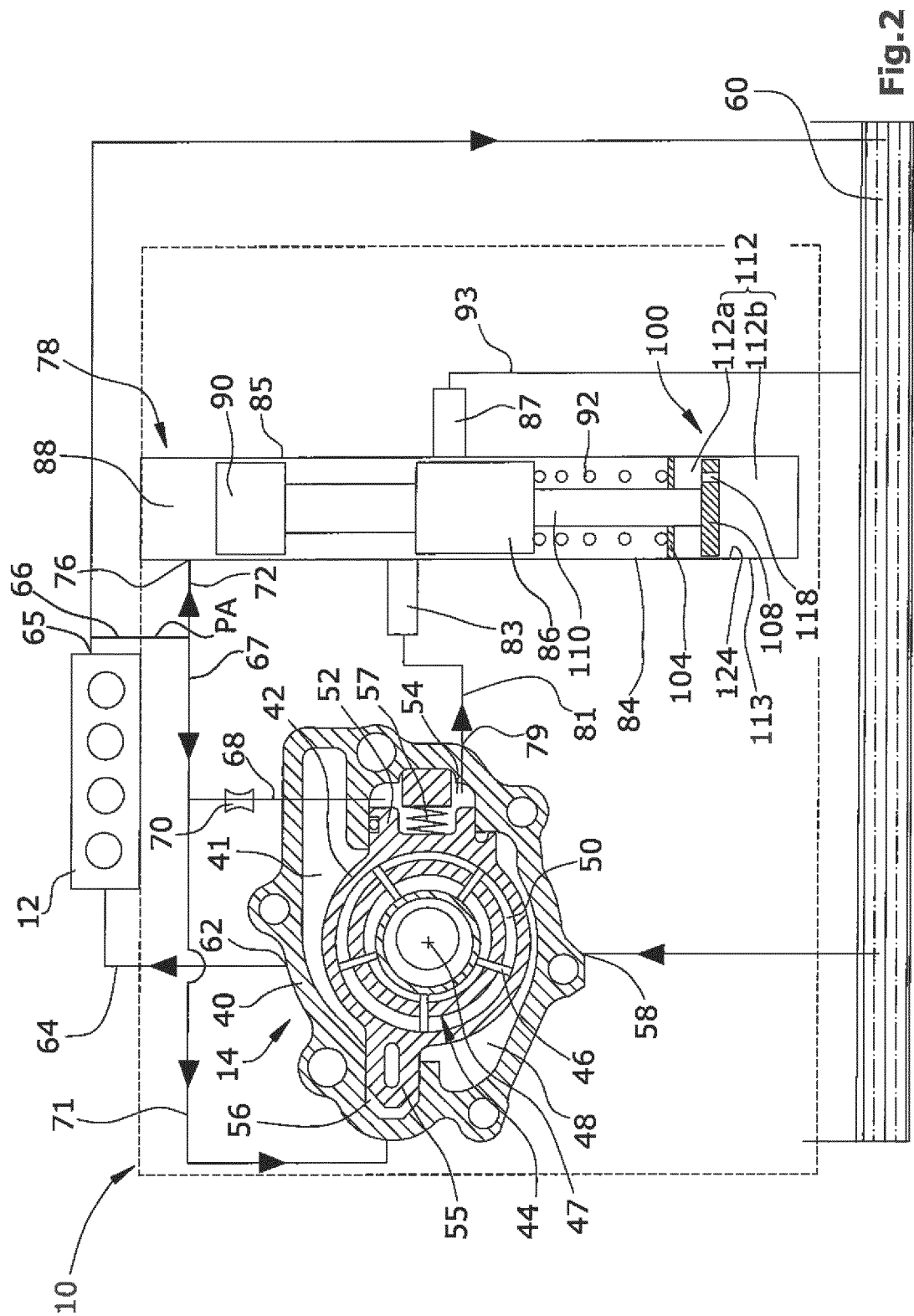
7. The variable displacement liquid pump (10) according to one of claims 1 to 5, **characterized in that** a damping fluid in the damping chamber (112) is air.
8. The variable displacement liquid pump (10) according to one of
5 claims 1 to 5, **characterized in that** a damping fluid in the damping chamber (112) is grease.
9. The variable displacement liquid pump (10) of one of the preceding claims, **characterized in that** the piston (108) and the control plunger (86) are mechanically connected to each other by a rod
10 (110).
10. The variable displacement liquid pump (10) of one of the preceding claims, **characterized in that** the damping channel (118) is provided as a bore in the piston (108).
11. The variable displacement liquid pump (10) according to one of
15 claims 1 to 9, **characterized in that** the damping channel (120) is provided as radial clearance between the piston (108) and a damping chamber wall (124).
12. The variable displacement liquid pump (10) according to claim 11,
20 **characterized in that** the thermal expansion coefficient of the piston (108) and a housing (113) of the damping chamber (112) differ to each other so that the radial clearance (120) varies with varying temperature.
13. The variable displacement liquid pump (10) of one of the preceding claims, **characterized in that** the discharge port (87) is directly
25 connected to a liquid tank (60).

14. The variable displacement lubricant pump (10) of one of the preceding claims, **characterized in that** the control ring (42) is pretensioned by a spring (57) into the high pumping volume direction.
- s 15. The variable displacement lubricant pump (10) of one of the preceding claims, **characterized in that** the actual pressure (PA) is the engines (12) lubricant outlet pressure.

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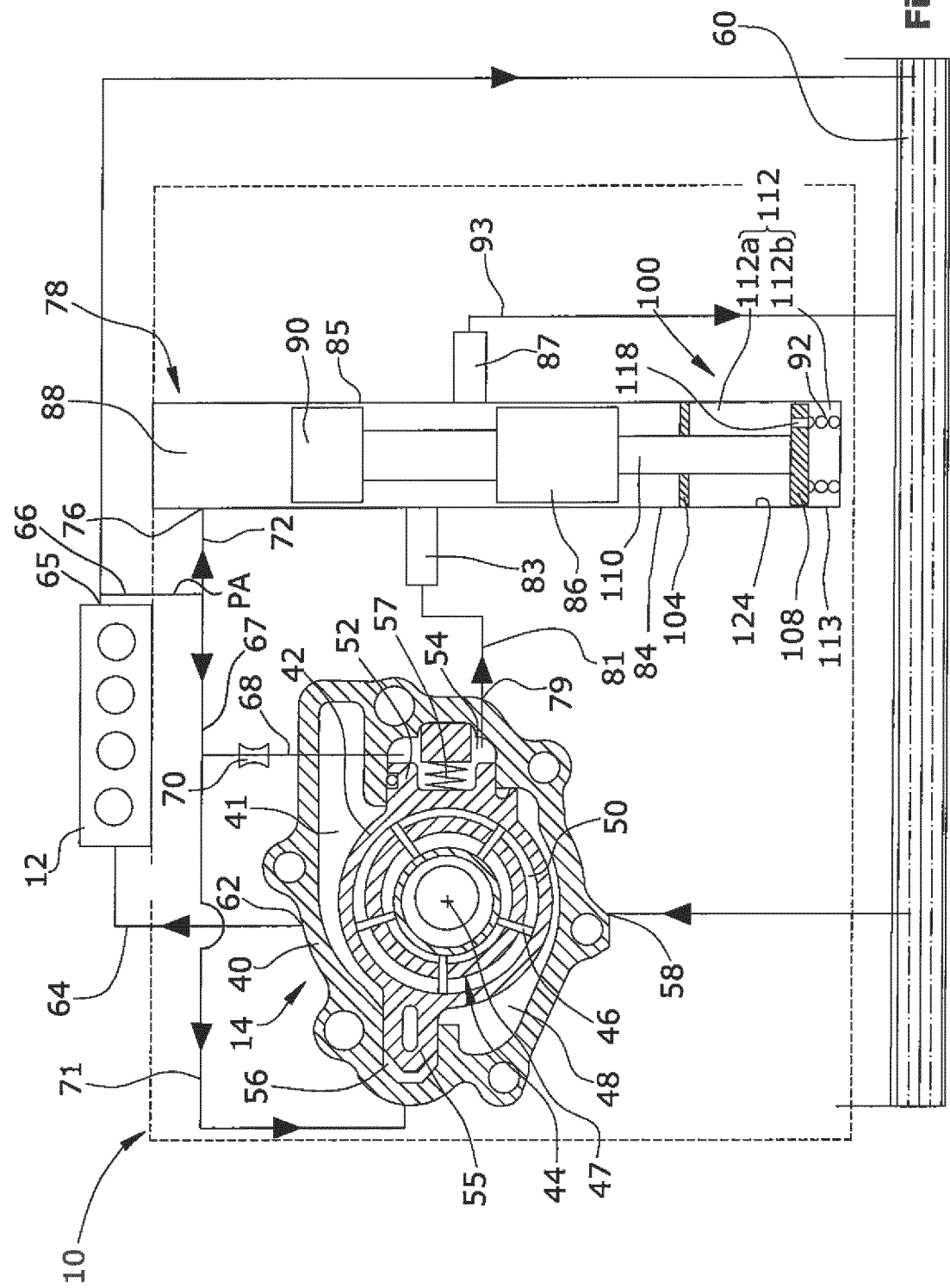


Fig.3

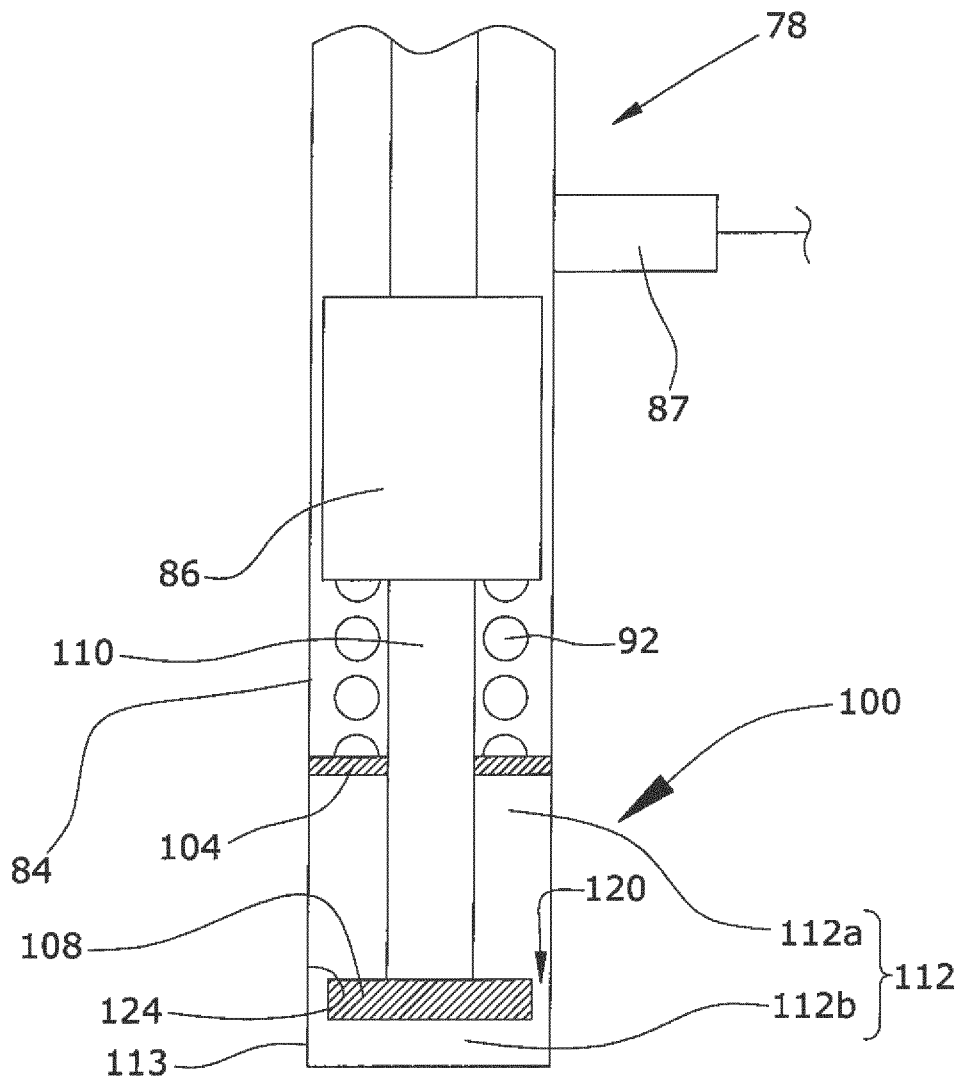


Fig.4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/060163

A. CLASSIFICATION OF SUBJECT MATTER INV. F04C2/344 F04C14/22 F04C14/24 F04C15/00 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) F04C F01C F16K		
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.
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A	DE 10 2015 218615 A1 (YAMADA MFG CO [JP]) 31 March 2016 (2016-03-31) the whole document paragraph [0012] paragraph [0048] ----- -/--	1-15
☒ 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 9 January 2018		Date of mailing of the international search report 19/01/2018
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 Sbresny, Heiko

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Information on patent family members

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