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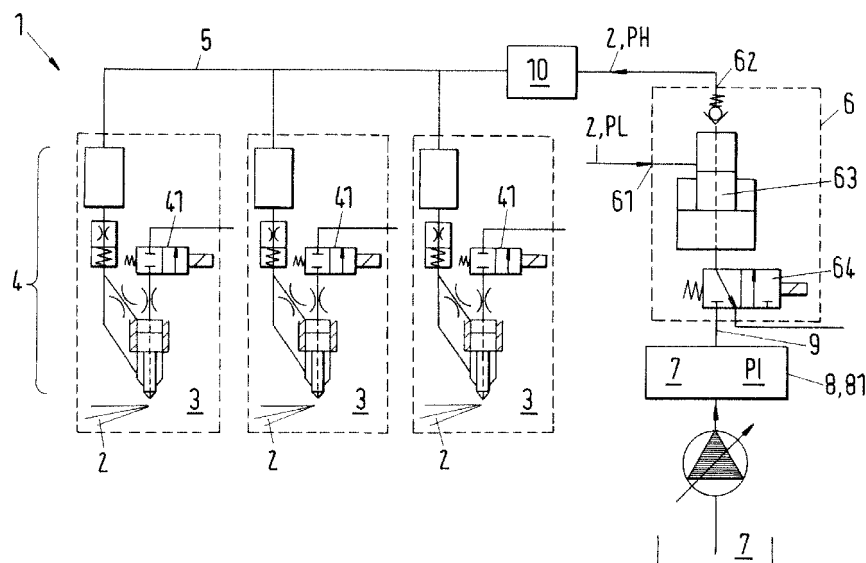
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(54) **Fuel injection system for an internal combustion engine, method for injecting fuel, as well as an internal combustion engine**

(57) The invention relates to a fuel injection system (1) for injecting a fuel (2) into a cylinder (3) of a reciprocating internal combustion engine, in particular two-stroke large diesel engine. Said fuel injection system (1) includes a fuel injector (4) comprising an injector control means (41) for controlling the injection of the fuel (2) into the cylinder (3). The fuel injector (4) is fluidly connected by means of a high pressure pipe (5) to an outlet (62) of a pressure amplifier (6), and the pressure amplifier (6) has an inlet (61) for receiving the fuel (2) being provided under a low inlet pressure (PL) and transforming the low

inlet pressure (PL) of the fuel (2) to a high outlet pressure (PH) being provided at the outlet (62) of the pressure amplifier (6). According to the invention, the pressure amplifier (6) is connected to and driven by a hydraulic servo oil (7) being provided under an intermediate pressure (PI) being higher than the low inlet pressure (PL) and lower than the high outlet pressure (PH). Furthermore, the invention relates to a method for injecting a fuel (2) into a cylinder (3) of a reciprocating internal combustion engine as well as a reciprocating internal combustion engine, in particular two-stroke large diesel engine.

**Fig.2a**

Description

[0001] The invention relates to a fuel injection system for injecting a fuel into a cylinder of a reciprocating combustion engine, a method for injecting a fuel, as well as an internal combustion engine, in particular two-stroke large diesel engine in accordance with the pre-characterising part of the respective independent claims.

[0002] Large diesel engines are often used as power units for ships or also in stationary operation, for example for driving large generators for the production of electrical power. Here as a rule the engines are in constant operation over a considerable period of time which makes high demands on the operating reliability and availability. For this reason, for the operators, long intervals between services, low degrees of wear and, in particular, an economical use of fuel and operating materials are central criteria for the operation of the machines. Among other things, improving the running properties of the engine as such, the reduction of emissions as well as the reduction of the fuel consumption is always a challenging topic.

[0003] Regarding the operating state of an internal combustion engine, for example a two-stroke large diesel engine, the fuel is injected only in a narrow range of crank angle degrees of the whole working cycle. Of course, the same is true for other types of internal combustion engines, for examples for four-stroke combustion engines. The fuel injection has to be accurately controlled to have the correct start of injection and the correct duration in order to properly control for example the power, the maximum cylinder pressure, and in particular the emission of noxious substances. More strict emission requirements are increasing the need to have more flexible fuel injection systems with more accurate control.

[0004] Common rail fuel injection systems are typically used on diesel engines today. Regarding such a well known fuel injection system 1' as exemplarily shown by Fig. 1a and Fig. 1b, there is a directly engine driven high pressure fuel oil pump 6' delivering fuel 2' to a fuel common rail volume 10', the so called common rail 10'. The fuel delivery to the rail 10' is typically controlled by throttling the fuel inlet to the pump 6' based on the feedback from a pressure sensor in the common rail 10'.

[0005] Please note that in the present description reference numbers carrying an inverted comma are always related to examples known from the prior art, as shown in Fig. 1a, Fig. 1b, and Fig. 1c. Wherein reference numbers referencing features of embodiments according to the invention, as exemplarily shown by Fig. 2a and Fig. 2b, respectively, do not carry an inverted comma.

[0006] The fuel oil pump 6' typically works with several oscillating plungers pumping fuel 2' to the fuel oil rail 10'. The pump 6' has a roller 600' following a cam 601', giving the plunger an oscillating movement. The pump 6' has a filling stroke, the downwards stroke when new fuel 2' from the low pressure fuel system is filled into the fuel pump chamber and it has a delivery stroke, the upwards stroke, when the fuel 2' is pressed out into the high pressure

common rail 10'. A non return valve 602' prevents fuel 2' to flow back from the high pressure system to the low pressure system during the return stroke, that is during the filling stroke of the plunger.

[0007] The delivery for the different plungers is typically not phased with the injection events but the high pressure common rail volume 10' is sized large enough to prevent high pressure fluctuations to a certain, but not to a sufficient extent. The pump 6' is thus controlled purely based on rail pressure feedback and not based on feedback when the injection events into the different cylinders 3' of the combustion engine are happening. The injection into the cylinders itself is controlled by an electronic control unit CU' either with an injection control unit CU' at directly the fuel oil rail 10' or in the injector 4' itself.

[0008] As can be seen from Fig. 1a or Fig. 1b, respectively, the fuel injectors 4' are typically connected to the common rail 10' by means of a high pressure pipe 5'. The start and the end of the fuel injection are typically controlled by a solenoid included with the injector 4'. The fuel 2' is stored in the rail volume 10' under a given high pressure PH', wherein the fuel rail volume 10' is designed to have a relatively large volume of fuel in order to not to have too high pressure drops during the injection events. The control of the fuel pumps 6' raising the pressure of the fuel 2' from a low pressure PL' to the high pressure PH' and delivering the fuel 2' to the common rail 10' under the high pressure PH', is typically based on the feedback from the rail pressure signal in order to keep the average high pressure PH' within a correct pressure range.

[0009] The injection of the fuel 2' into the cylinders 3' is thereby controlled by an injector control unit CU', wherein the known injection system 1' according to Fig. 1b includes in addition to that presented by Fig. 1a a volumetric injection control VIC' allowing a more accurate timing and dosage of the fuel injection compared to the more simple injection system 1' according to Fig. 1a.

[0010] However, as can be seen by Fig. 1c showing the common rail pressure variations PH' given in bar in dependence from the crank angle α' given in degrees as measured in a known fuel injection system 1' according to Fig. 1a or Fig. 1b, respectively, there are significant pressure drops in the common rail storage 10' during the injection of fuel 2' into the cylinders 3' since the control of the pump 6' cannot cope with the very high frequency pressure variations due to the injection events.

[0011] The object of the invention is thus to suggest an improved fuel injection system in which the variations of the high pressure are significantly reduced compared with the known prior art systems, and wherein at the same time, the fuel injection can be controlled more accurate resulting in a reduced fuel consumption and in significantly reduced emissions of noxious substances.

[0012] The subject-matter of the invention which satisfies these objects are characterised by the features of the respective independent claims.

[0013] The respective dependent claims relate to particularly advantageous embodiments of the invention.

[0014] The invention thus relates to a fuel injection system for injecting a fuel into a cylinder of a reciprocating internal combustion engine, in particular two-stroke large diesel engine. Said fuel injection system includes a fuel injector comprising an injector control means for controlling the injection of the fuel into the cylinder. The fuel injector is fluidly connected by means of a high pressure pipe to an outlet of a pressure amplifier, and the pressure amplifier has an inlet for receiving the fuel being provided under a low inlet pressure and transforming the low inlet pressure of the fuel to a high outlet pressure being provided at the outlet of the pressure amplifier. According to the invention, the pressure amplifier is connected to and driven by a hydraulic servo oil being provided under an intermediate pressure which intermediate pressure is higher than the low inlet pressure and lower than the high outlet pressure.

[0015] That means, the common rail system according to the present invention has a smart control pressure amplifier driven by an hydraulic servo oil. The pressure amplifier is preferably electronically controlled in such a way that it is only pumping fuel to the injectors during the injection events. The pressure amplifier and the respective injector can be activated for example at the same time, leading to a small pressure drop at the beginning of the injection. Regarding another embodiment, the pressure amplifier can be activated just before the start of the injection in order to avoid pressure drops at the beginning of the injection. The advantage with this design and the intelligent control of the pressure amplifier is that it is possible to reduce the fuel oil rail after the pressure amplifier to a minimum. It gives as well possibility to control the injection pressure during the injection event depending on when the pressure amplifier is activated in relation to the start of the injection event.

[0016] What is more, the fuel injection system according to the present invention does not compulsory require a large high pressure common rail storage as known from the prior art and as exemplarily displayed by Fig. 1a or Fig. 1b, respectively. This is because of the fact that according to the invention the high pressure fuel is provided just and only during a relatively small time range in which the injection occurs. In principle, no storage of a relatively large reservoir of high pressure fuel is required, resulting in an injection system which is of very simple construction, which is less expensive, and which needs less maintenance and being more reliable in operation.

[0017] But of course, it is understood that in a special embodiment a common rail storage for high pressure fuel may be present in an injection system according to the invention in order to further reduce the pressure drops in the high pressure fuel line to an absolute minimum.

[0018] As will be below explained in greater detail, there can also be more than one pressure amplifier feeding the system as for example shown in Fig. 2b. In this case, the pressure amplifiers can be made smaller and, thus, less expensive. At low engine loads, for example, when less fuel is needed it is possible to operate only

with one pressure amplifier, and at increased engine load more pressure amplifiers can additionally be switched on to deliver more fuel. The overall efficiency of the system will be increased by this since only the amount of fuel needed to deliver to the system is compressed. The activation of the different pressure amplifiers can be done either at the same time for all amplifiers or at different time for different amplifiers to get a different pressure increase rate during the injection. The different pressure amplifiers can either be identical or they may have a different design either different size or slightly different pressure amplifying ratio. This gives more freedom for different injection rate shapes.

[0019] Summarizing the advantages of the fuel injection system according to the invention, the correct start and end of the fuel injection into the cylinder of the combustion engine and also the correct duration can be most accurately controlled so that a proper control for example of the power, the control of a maximum cylinder pressure, and in particular the control and reduction of the emission of noxious substances is firstly properly ensured by the present invention.

[0020] Regarding a special embodiment of a fuel injection system in accordance with the present invention, the hydraulic servo oil is provided under the intermediate pressure in a hydraulic supply volume being fluidly connected to the pressure amplifier by a hydraulic driving pipe.

[0021] Preferably, the pressure amplifier includes a pressure amplifier piston for transforming the low inlet pressure to the high outlet pressure, wherein the pressure amplifier in practice may include a hydraulic control means for actuating and controlling the pressure amplifier piston.

[0022] In order to achieve a maximum of flexibility, a plurality of pressure amplifiers may be provided, wherein the hydraulic supply volume is preferably a hydraulic common rail volume, most preferably being connected to all pressure amplifiers being present in the fuel injection system and providing the hydraulic servo oil to all pressure amplifiers being present in the fuel injection system.

[0023] Regarding a very special embodiment of the present invention, a fuel common rail volume may be provided between the fuel injector and the outlet of the pressure amplifier in order to reduce pressure drops in the high pressure pipe to an absolute minimum.

[0024] It is understood, that most preferably the injector control means and / or the pressure amplifier is electronically controllable, in particular independently electronically controllable in order to ensure a maximum of flexibility regarding the injection of the fuel into the cylinder of the combustion engine.

[0025] The present invention relates furthermore to a method for injecting a fuel into a cylinder of a reciprocating internal combustion engine, in particular two-stroke large diesel engine. The fuel is injected into the cylinder by means of a fuel injection system including a fuel in-

jector comprising an injector control means for controlling the injection of the fuel into the cylinder. Thereby, the fuel injector is fluidly connected by means of a high pressure pipe to an outlet of a pressure amplifier, the pressure amplifier having an inlet for receiving the fuel being provided under a low inlet pressure and transforming the low inlet pressure of the fuel to a high outlet pressure and providing the high outlet pressure at the outlet of the pressure amplifier. According to the invention, the pressure amplifier is connected to and driven by a hydraulic servo oil being provided under an intermediate pressure wherein the intermediate pressure is chosen higher than the low inlet pressure and lower than the high outlet pressure.

[0026] Regarding a special embodiment of a method according to the invention, the low inlet pressure is transformed to the high outlet pressure by means of a pressure amplifier piston, wherein the pressure amplifier piston is preferably actuated and controlled by a hydraulic control means.

[0027] Preferably, a plurality of pressure amplifiers is provided, wherein in particular a hydraulic supply volume is provided and designed as a hydraulic common rail volume, being connected to and providing the hydraulic servo oil to all pressure amplifiers being present in the fuel injection system used for working the method of the invention.

[0028] Regarding another special embodiment of a method in accordance with the invention which is very important in practise, the injector control means and / or the pressure amplifier is electronically controlled, preferably independently electronically controlled, wherein the pressure amplifier and the fuel injector are activated at the same time and / or wherein the pressure amplifier is activated before the fuel injector is started.

[0029] In case that a plurality of pressure amplifiers is present in the fuel injection system, in a low load operation state of the combustion engine at least one pressure amplifier of the fuel injection system may be deactivated in order to reduce the fuel consumption. By increasing the load and / or the engine speed, the number of pressure amplifiers being in operation may be increased successively, respectively.

[0030] In addition, the invention is related to an internal combustion engine, in particular to a two-stroke large diesel engine comprising a fuel injection system as described and / or being operated using a method in accordance with the present invention.

[0031] The invention will be described more closely with the help of the schematic drawings which show:

- Fig. 1 a a first example of a known fuel injection system from the prior art;
- Fig. 1 b a second example according to Fig. 1 a having a volumetric injection control;
- Fig. 1 c common rail pressure variations measured in a known fuel injection system according to

Fig. 1 a or Fig. 1 b;

Fig. 2a a first embodiment of a fuel injection system according to the invention;

Fig. 2b A second embodiment according to Fig. 2a having a plurality of pressure amplifiers.

[0032] Fig. 1a, Fig1b, and Fig. 1c, respectively, show examples known from the prior art which have been discussed above in great detail, already, and thus, do not need any further consideration.

[0033] Regarding Fig. 2a and Fig. 2b, two special embodiments of fuel injection systems 1 for an internal combustion engine are displayed, wherein the fuel injection system 1 according to Fig. 2 has a plurality of pressure amplifiers 6 of which, for reasons of clarity, two pressure amplifiers 6 are shown, only.

[0034] The fuel injection system 1 for injecting a fuel 2 into a cylinder 3 of a reciprocating internal combustion engine, which is in the present examples of Fig. 2a and Fig. 2b a two-stroke large diesel engine for a vessel, includes a fuel injector 4 comprising an injector control means 41 for controlling the injection of the fuel 2 into the cylinder 3. The fuel injector 4 is fluidly connected by means of a high pressure pipe 5 to an outlet 62 of a pressure amplifier 6. The pressure amplifier 6 has an inlet 61 for receiving the fuel 2 being provided under a low inlet pressure PL and increases the low inlet pressure PL of the fuel 2 to a high outlet pressure PH being provided at the outlet 62 of the pressure amplifier 6. Thereby, the pressure amplifier 6 is connected to and driven by a hydraulic servo oil 7 being provided under an intermediate pressure PI being higher than the low inlet pressure PL and lower than the high outlet pressure PH.

[0035] The hydraulic servo oil 7 is provided under the intermediate pressure PI in a hydraulic supply volume 8, 81 which is fluidly connected to the pressure amplifier 6 by a hydraulic driving pipe 9.

[0036] The pressure amplifier 6 as such includes a pressure amplifier piston 63 for transforming the low inlet pressure PL to the high outlet pressure PH in a per se known manner. In addition, the pressure amplifier 6 includes a hydraulic control means 64 for actuating and controlling the pressure amplifier piston 63, wherein the control means 64 is connected to and supplied from the hydraulic supply volume 8, 81 with the hydraulic servo oil 7.

[0037] Regarding the special embodiment of Fig. 2b, a plurality of pressure amplifiers 6 is provided of which for reasons of clarity of the drawing two pressure amplifiers 6 are shown, only. The hydraulic supply volume 8, 81 according to Fig. 2a and Fig. 2b, respectively, is a hydraulic common rail volume 81, which is in the embodiment according to Fig. 2b connected to all pressure amplifiers 6 being present in the fuel injection system 1 and, thus, providing the hydraulic servo oil 7 to all pressure amplifiers 6 being present in the fuel injection system 1

at the same time.

[0038] In the special embodiments according to Fig. 2a and Fig. 2b, a fuel common rail volume 10 is provided between the fuel injector 4 and the outlet 62 of the pressure amplifier 6, which is not necessarily compulsory.

[0039] It is understood, that the injector control means 41 as well as the pressure amplifier 4 is electronically controllable, preferably independently electronically controllable by an electronic control means not explicitly shown in Fig. 2a or Fig. 2b.

Claims

1. Fuel injection system for injecting a fuel (2) into a cylinder (3) of a reciprocating internal combustion engine, in particular two-stroke large diesel engine, said fuel injection system including a fuel injector (4) comprising an injector control means (41) for controlling the injection of the fuel (2) into the cylinder (3), wherein the fuel injector (4) is fluidly connected by means of a high pressure pipe (5) to an outlet (62) of a pressure amplifier (6), the pressure amplifier (6) having an inlet (61) for receiving the fuel (2) being provided under a low inlet pressure (PL) and transforming the low inlet pressure (PL) of the fuel (2) to a high outlet pressure (PH) being provided at the outlet (62) of the pressure amplifier (6), **characterized in that** the pressure amplifier (6) is connected to and driven by a hydraulic servo oil (7) being provided under an intermediate pressure (PI) being higher than the low inlet pressure (PL) and lower than the high outlet pressure (PH).
2. Fuel injection system in accordance with claim 1, wherein the hydraulic servo oil (7) is provided under the intermediate pressure (PI) in a hydraulic supply volume (8, 81) being fluidly connected to the pressure amplifier (6) by a hydraulic driving pipe (9).
3. Fuel injection system in accordance with anyone of claims 1 or 2, wherein the pressure amplifier (6) includes a pressure amplifier piston (63) for transforming the low inlet pressure (PL) to the high outlet pressure (PH).
4. Fuel injection system in accordance with claim 3, wherein the pressure amplifier (6) includes a hydraulic control means (64) for actuating and controlling the pressure amplifier piston (63).
5. Fuel injection system in accordance with anyone of the preceding claims, wherein a plurality of pressure amplifiers (6) is provided.
6. Fuel injection system in accordance with claim 5, wherein the hydraulic supply volume (8, 81) is a hydraulic common rail volume (81), preferably being connected to all pressure amplifiers (6) being present in the fuel injection system and providing the hydraulic servo oil (7) to all pressure amplifiers (6) being present in the fuel injection system.
7. Fuel injection system in accordance with anyone of the preceding claims, wherein a fuel common rail volume (10) is provided between the fuel injector (4) and the outlet (62) of the pressure amplifier (6).
8. Fuel injection system in accordance with anyone of the preceding claims, wherein the injector control means (41) and / or the pressure amplifier (4) is electronically controllable, preferably independently electronically controllable.
9. Method for injecting a fuel (2) into a cylinder (3) of a reciprocating internal combustion engine, in particular two-stroke large diesel engine, wherein the fuel (2) is injected into the cylinder (3) by means of a fuel injection system (1) including a fuel injector (4) comprising an injector control means (41) for controlling the injection of the fuel (2) into the cylinder (3), and wherein the fuel injector (4) is fluidly connected by means of a high pressure pipe (5) to an outlet (62) of a pressure amplifier (6), the pressure amplifier (6) having an inlet (61) for receiving the fuel (2) being provided under a low inlet pressure (PL) and transforming the low inlet pressure (PL) of the fuel (2) to a high outlet pressure (PH) and providing the high outlet pressure (PH) at the outlet (62) of the pressure amplifier (6), **characterized in that** the pressure amplifier (6) is connected to and driven by a hydraulic servo oil (7) being provided under an intermediate pressure (PI) wherein the intermediate pressure (PI) is chosen higher than the low inlet pressure (PL) and lower than the high outlet pressure (PH).
10. Method in accordance with claim 9, wherein the low inlet pressure (PL) is transformed to the high outlet pressure (PH) by means of a pressure amplifier piston (63), wherein the pressure amplifier piston (63) is preferably actuated and controlled by a hydraulic control means (64).
11. Method in accordance with anyone of claims 9 or 10, wherein a plurality of pressure amplifiers (6) is provided.
12. Method in accordance with claim 11, wherein a hydraulic supply volume (8, 81) is provided and designed as a hydraulic common rail volume (81), being connected to and providing the hydraulic servo oil (7) to all pressure amplifiers (6) being present in the fuel injection system (1).
13. Method in accordance with anyone of claims 9 to 12, wherein the injector control means (41) and / or the

pressure amplifier (6) is electronically controlled, preferably independently electronically controlled, wherein the pressure amplifier (6) and the fuel injector (4) are activated at the same time and / or wherein the pressure amplifier (6) is activated before the fuel injector (4) is started. 5

14. Method in accordance with anyone of claims 9 to 13, wherein in a low load operation state at least one pressure amplifier (6) of the fuel injection system (1) is deactivated. 10

15. Internal combustion engine, in particular two-stroke large diesel engine comprising a fuel injection system (1) in accordance with anyone of claims 1 to 8 and / or being operated using a method in accordance with anyone of claims 9 to 14. 15

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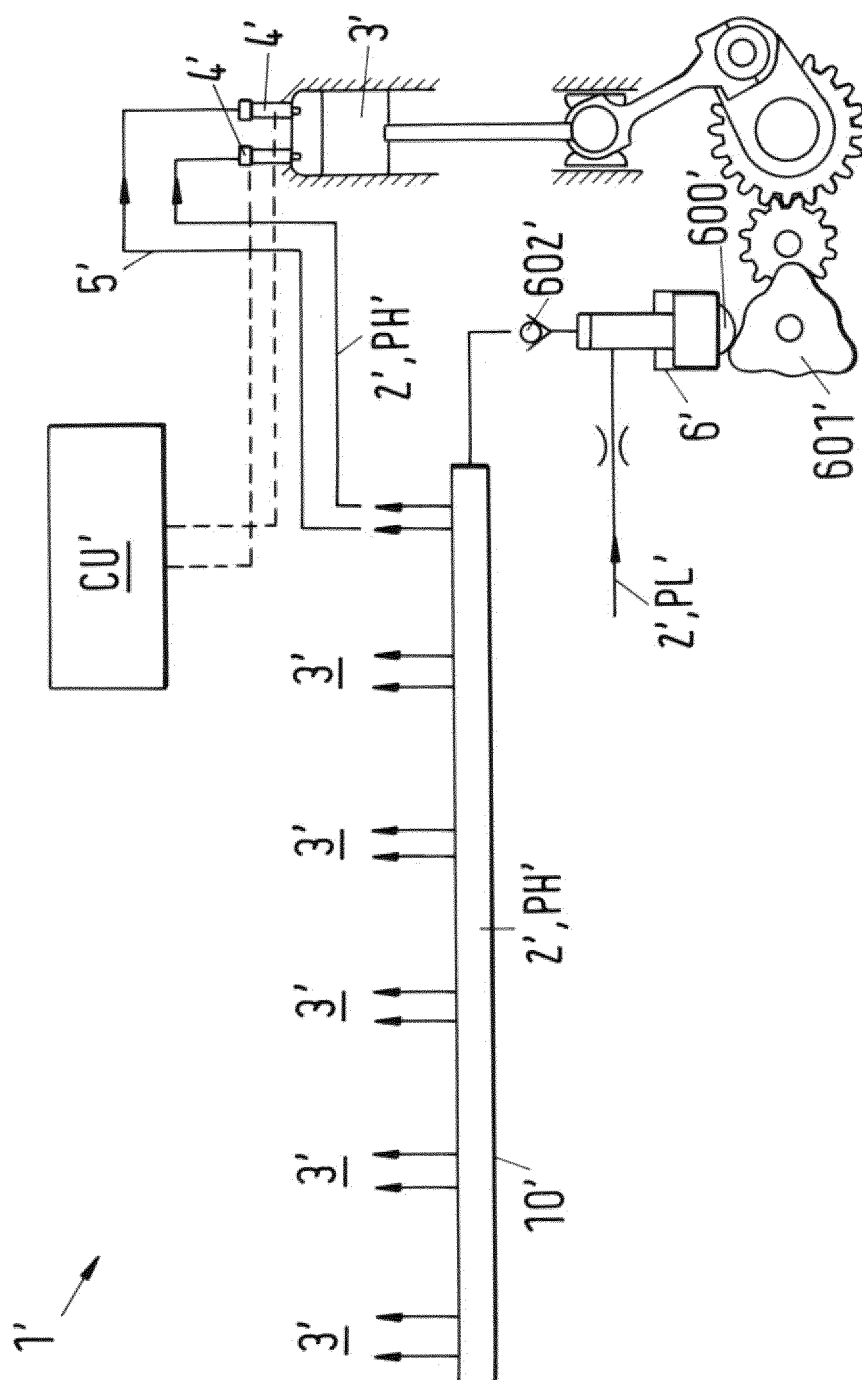


Fig. 1a

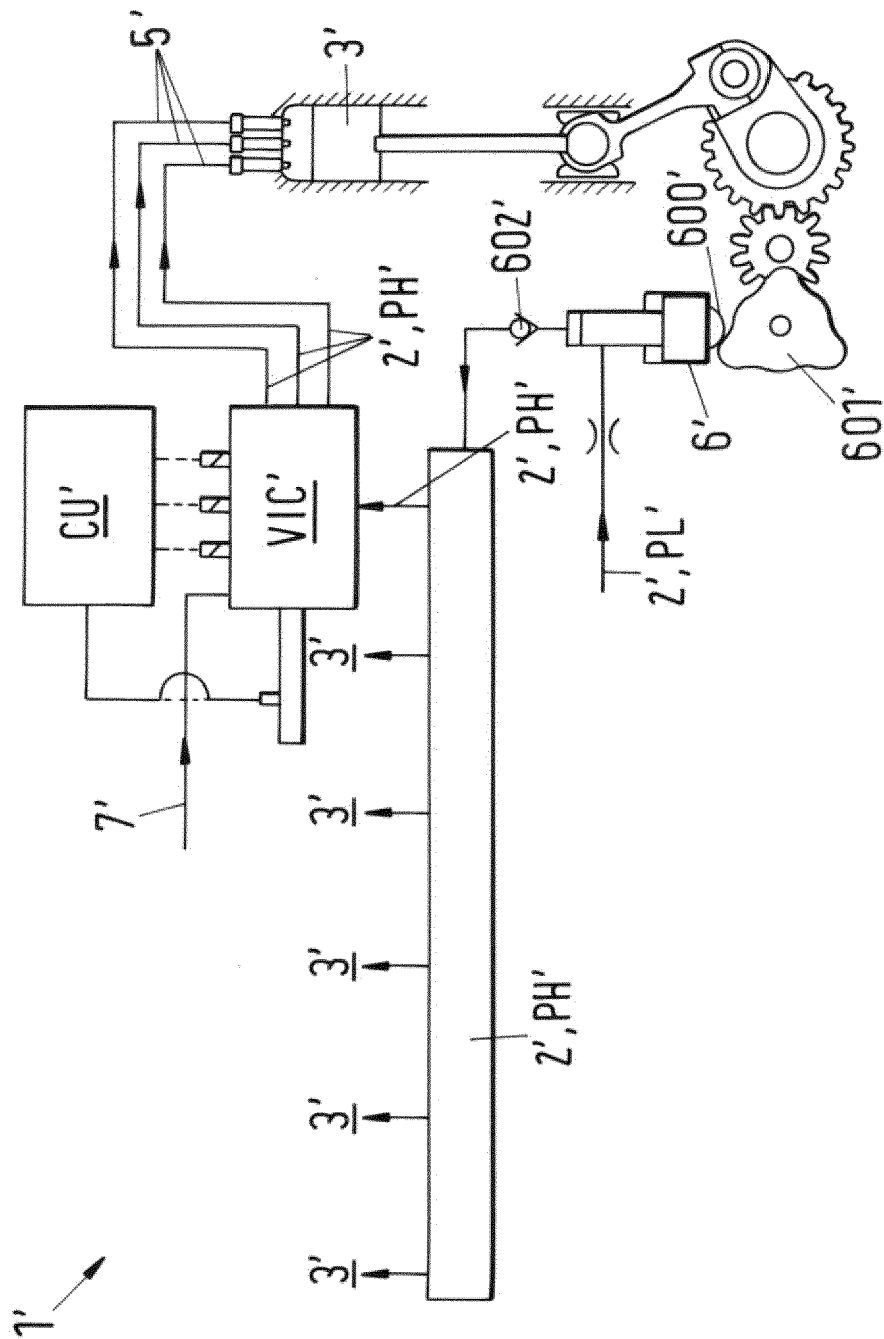


Fig.1b

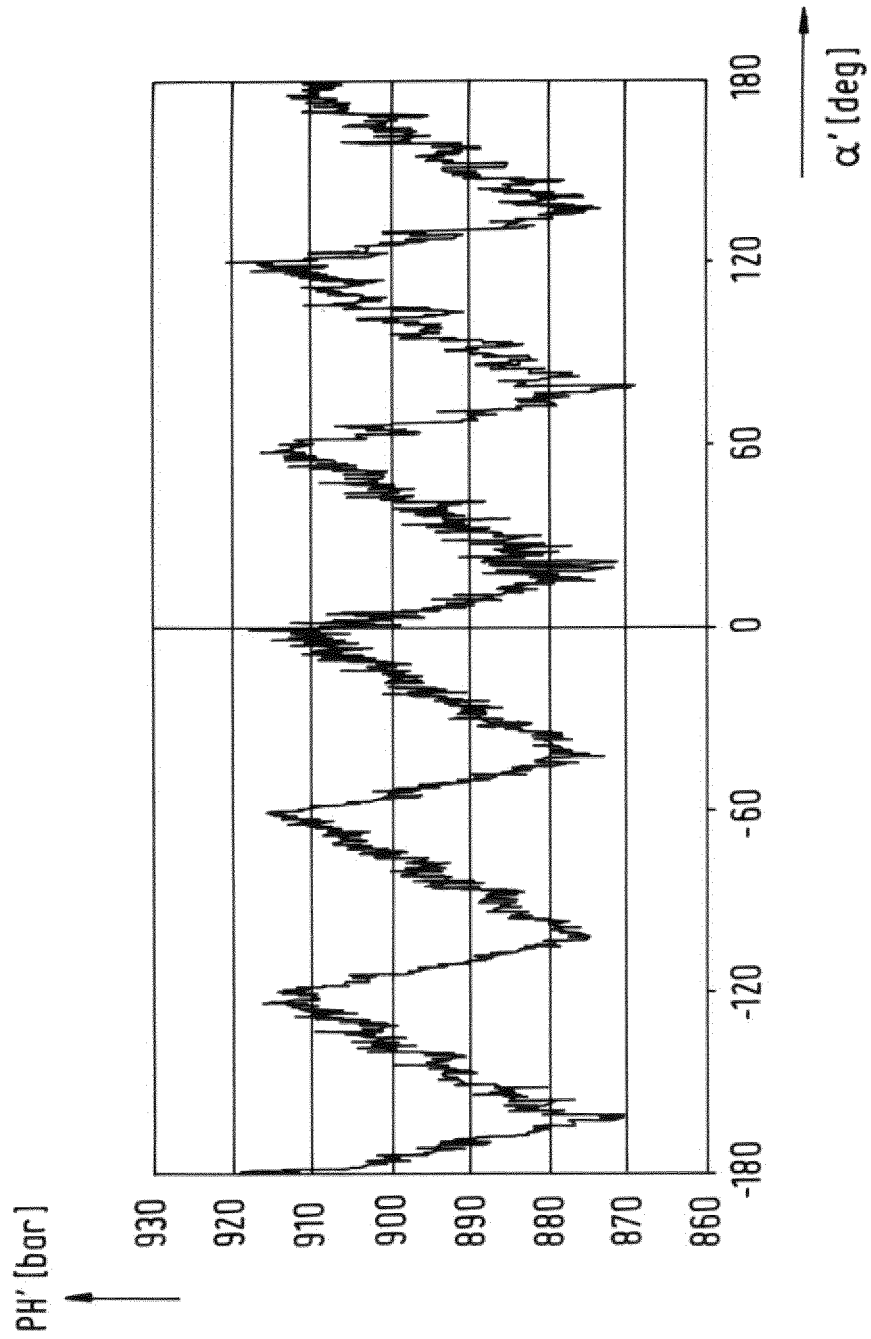


Fig.1c

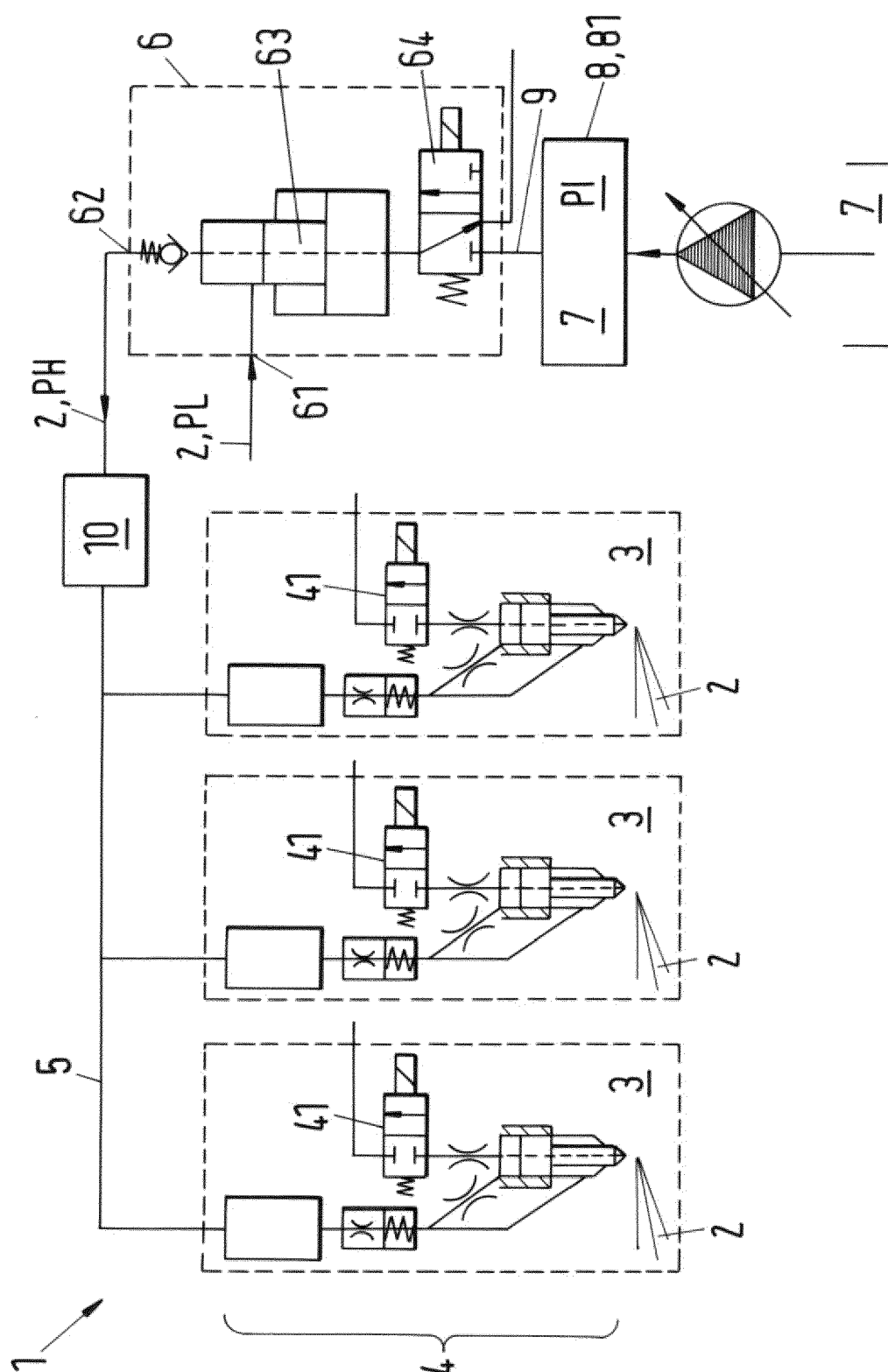


Fig. 2a

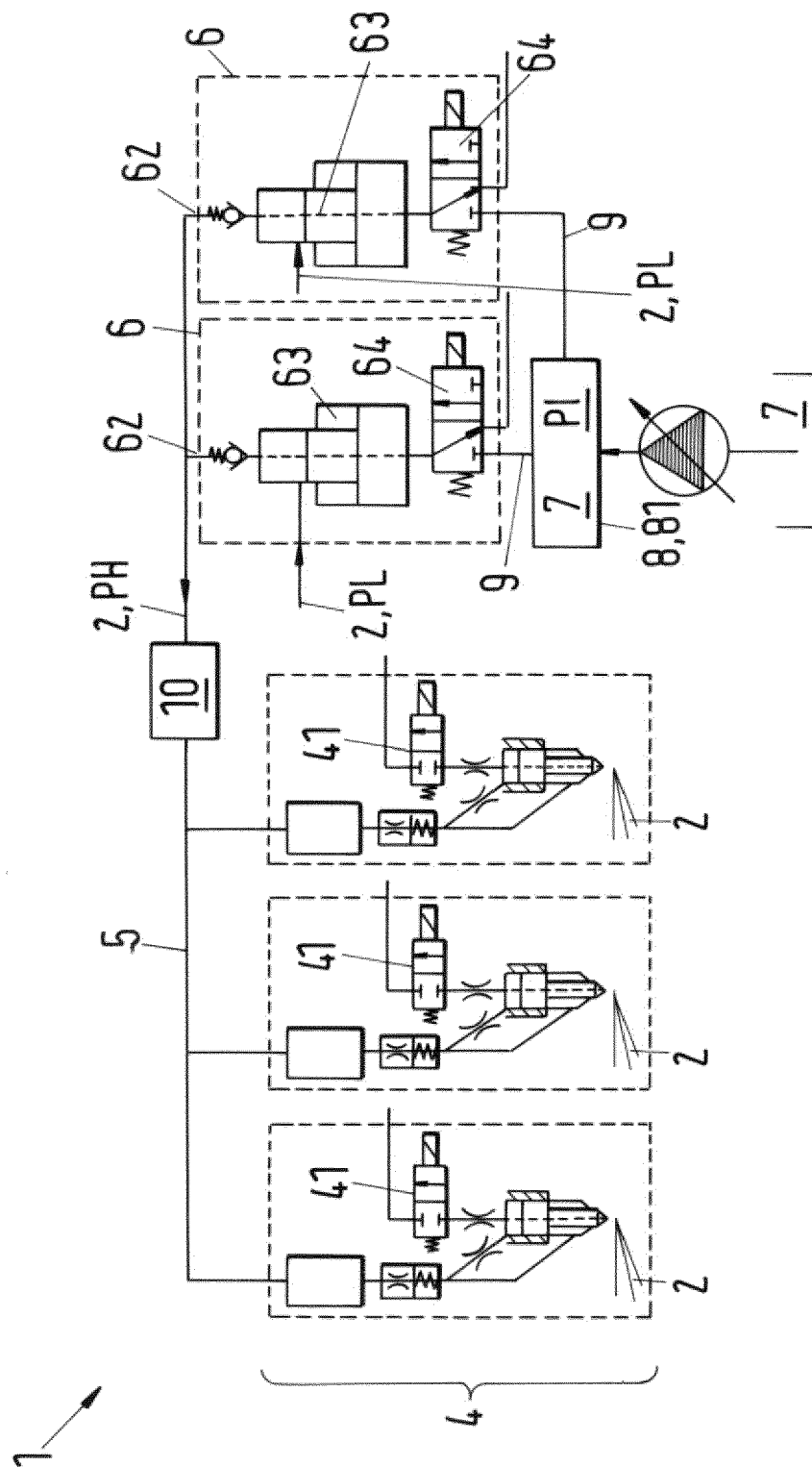


Fig.2b



EUROPEAN SEARCH REPORT

Application Number
EP 12 17 9866

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	DE 199 39 421 A1 (BOSCH GMBH ROBERT [DE]) 1 March 2001 (2001-03-01) * column 5, line 21 - line 28 * * column 6, line 21 - line 39 * -----	1-15	INV. F02M59/10 F02M63/02
X	WO 02/073024 A1 (BOSCH GMBH ROBERT [DE]; MAHR BERND [DE]; KROPP MARTIN [DE]; MAGEL HANS) 19 September 2002 (2002-09-19) * page 4, line 3 - line 9 * * page 5, line 14 - page 6, line 19 * * page 7, line 10 - line 13 * * page 7, line 19 - line 23 * * figures 1,6 * -----	1-6,8-15	
X	JP 60 162021 A (KAWASAKI HEAVY IND LTD) 23 August 1985 (1985-08-23) * abstract * -----	1-6,8-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			F02M
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 9 January 2013	Examiner Schmitter, Thierry
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503 03/82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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09-01-2013

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 19939421 A1	01-03-2001	AT 281597 T	15-11-2004
		DE 19939421 A1	01-03-2001
		EP 1125049 A1	22-08-2001
		JP 2003507639 A	25-02-2003
		US 6491017 B1	10-12-2002
		WO 0114713 A1	01-03-2001

WO 02073024 A1	19-09-2002	DE 10112154 A1	26-09-2002
		EP 1370762 A1	17-12-2003
		JP 2004518872 A	24-06-2004
		US 2003183198 A1	02-10-2003
		WO 02073024 A1	19-09-2002

JP 60162021 A	23-08-1985	JP 1831471 C	15-03-1994
		JP 5044539 B	06-07-1993
		JP 60162021 A	23-08-1985
