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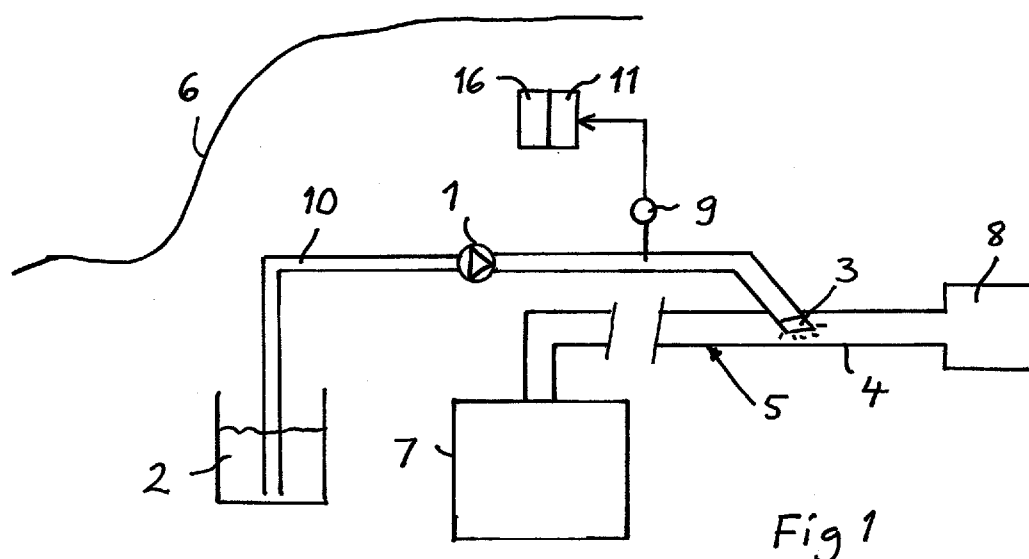
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(54) Title: A METHOD AND A DEVICE FOR ESTIMATING A LEAKAGE OF A PUMP



(57) Abstract: In a method for providing an estimated value of a possible leakage on a suction side of a piston displacement pump (1) pumping a liquid the maximum attainable outlet pressure of the pump is measured while driving the pump. The ratio of air volume to pressure chamber volume of the pump at the bottom dead point of the piston is then calculated by using the pressure value measured in the general gas law while assuming that the gas temperature is constant and by utilizing the knowledge of the geometric compression ratio of the pump. The value calculated is compared with the characteristic value of the air volume ratio of the pump without leakage to determine an estimated value of a possible leakage.

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A METHOD AND A DEVICE FOR ESTIMATING A LEAKAGE OF A PUMP

TECHNICAL FIELD OF THE INVENTION

5 The present invention relates to a method for providing an estimated value of a possible leakage on a suction side of a piston displacement pump pumping a liquid, in which the method comprises the step of driving the pump and measuring the outlet pressure of the pump, as well as a device according to the
10 preamble of the appended independent device claim.

The invention relates to such a method for any conceivable use of such a piston displacement pump, but for illuminating the invention and the problems to be addressed thereby the use of such a piston
15 displacement pump in a motor vehicle for feeding liquid, such as Ad blue or fuel, will hereinafter be discussed without restricting the present invention to that application.

It is of course of interest to be able to detect leakages on the
20 suction side of such a pump, for instance to become aware of why something downstreams the pump is not as it should be, for example the pressure of the liquid pumped, so that measures may be taken to stop the leakage.

25 BACKGROUND ART

Several methods are known for detecting leakages on the suction side of a piston displacement pump. However, most of them are intrusive and often involve having a sensor located in the suction
30 part of the liquid feeding system to which the pump belongs. Such

methods could for example involve closing the end of the suction line and generating a pressure or vacuum in the line that is then measured over a period of time or fitting a sight-glass or similar in the suction line and check if there is bubble formation in the liquid.

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SE 1350438 discloses a method of the type defined in the introduction in which the pressure in a position downstreams the pump is measured and the pump is then switched off and the pressure decrease in said position is measured and compared with values of such a pressure decrease stored so as to determine whether a leakage is located in the line upstreams or downstreams the pump. However, this method may not be carried out during normal operation of the pump and it is not suited for estimating a value of a possible leakage on the suction side of the pump but only to determine whether a leakage is located on the suction side or the exhaust side of the pump.

Fitting extra sensors and/or having to perform intrusive tests on a system to detect leakages is mostly undesirable. It would be a great advantage if the leakages could be detected using the hardware already available in the system, possibly even under normal operation.

SUMMARY OF THE INVENTION

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The object of the present invention is to provide a method and a device of the type defined in the introduction being improved in at least some aspect with respect to such methods and devices already known.

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This object is with respect to the method obtained by providing such a method with the features listed in the characterizing part of appended patent claim 1.

- 5 The invention is based on the understanding that the geometric compression ratio known for a piston displacement pump may be used in combination with the value of the maximum attainable outlet pressure of the pump measured for providing an estimated value of a possible leakage on a suction side of the pump. This
10 may be achieved by assuming that the gas temperature is constant allowing the general gas law to be used for calculating the ratio of air volume to pressure chamber volume of the pump at the bottom dead point of the piston. The value of the air volume ratio so calculated is then compared with a characteristic value thereof for
15 the pump without leakage on the suction side thereof enabling determining of an estimated value of a possible leakage on the suction side of the pump through the result of this comparison.

- A sensor measuring the outlet pressure of the pump is in most
20 systems including such a pump already there, and the steps b)-d) of the method may be carried out by an electronic control unit already present, such as for the control of components in a vehicle. This means that in such a case the hardware already available in the system may be used for detecting and estimating a value of a
25 possible leakage on the suction side of a piston displacement pump under normal operation of the pump. The maximum attainable outlet pressure may either be actively achieved by driving the pump at a maximum in the case this pressure is higher than the normal operation pressure of the system or under normal
30 operation of the pump in case the maximum attainable pressure in

fact is lower than the normal operation pressure and the pump works at a maximum for trying to reach the normal operation pressure.

- 5 According to an embodiment of the invention a knowledge of the flow rate of the pump is utilized in the determining step d) to determine said estimated value of a possible leakage as an air leakage flow rate. This determination may form the basis for a decision whether any measure is to be taken for stopping the
10 leakage.

According to another embodiment of the invention the method is carried out for a pump in a low pressure part of a system for feeding liquid in a motor vehicle. "Low pressure" does here
15 normally mean a pressure in the region of 5-30 bars, and a piston displacement pump is suitable to be used in such a low pressure part of a system for feeding liquid in a motor vehicle and it will be crucial for the operation of the vehicle to detect and provide an estimated value of a possible leakage on the suction side of such
20 a pump.

According to another embodiment of the invention the method is carried out for a piston displacement pump connected between a tank of Ad blue to pump Ad blue to be downstreams of the pump
25 sprayed into the exhaust gas system of the vehicle upstreams the catalytic converter thereof. In such an application of a piston displacement pump there is already a pressure sensor arranged downstreams the pump for measuring the pressure of Ad blue to be sprayed into the exhaust gas system, so that no extra sensor

is needed for carrying out the method according to the present invention.

According to another embodiment of the invention the method is
5 carried out for a piston displacement pump connected to a fuel
tank of the vehicle to pump fuel towards a high pressure part of a
system for injection of fuel into an internal combustion engine of
the vehicle. This constitutes another application of a piston
displacement pump where it is important to be able to provide an
10 estimated value of a possible leakage on the suction side of the
pump.

The object of the present invention is with respect to the device
obtained by providing a device with the features listed in the
15 appended independent device claim. The advantages of such a
device and the embodiments thereof defined in the dependent
device claims appear clearly from the above discussion of the
method according to the invention.

20 The invention also relates to a computer program, a computer-
readable medium, an electronic control unit and a motor vehicle
according to the appended claims directed thereto.

Further advantages as well as advantageous features of the
25 invention will appear from the description following below.

BRIEF DESCRIPTION OF THE DRAWINGS

With reference to the appended drawings, below follows a specific
30 description of an embodiment of the invention cited as an example.

In the drawings:

5 Fig. 1 is a schematic simplified view showing a possible use of a device according to the invention,

Fig. 2 is a simplified view of a piston displacement pump used for explaining the method according to the present invention,

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Fig. 3 is a graph of the maximum attainable outlet pressure P of a piston displacement pump versus ratio of air volume to pressure chamber volume of the pump at the bottom dead point of the piston of the pump,

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Fig. 4 is a flow chart illustrating the steps carried out in a method according to an embodiment of the invention, and

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Fig. 5 is a schematic view illustrating an electronic control unit for implementing a method according to the invention.

25 DETAILED DESCRIPTION OF AN EMBODIMENT OF THE INVENTION

A method and a device according to an embodiment of the invention will now be described while making reference to Figs. 1-3. It is very simplifiably shown in Fig. 1 how a piston displacement

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pump 1 is arranged to feed Ad blue from a tank 2 of Ad blue to a nozzle 3 spraying Ad blue into a pipe 4 of the exhaust gas system 5 of a vehicle 6 at the location between an internal combustion engine 7 and a catalytic converter 8 of the exhaust gas system.

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A member 9 configured to measure the outlet pressure of the pump in operation thereof in the form of a pressure sensor is arranged in the line 10 from the tank 2 to the nozzle 3 downstreams the pump 1. This pressure measuring member 9 is there for checking that the liquid pressure at the nozzle 3 is as desired. The pressure sensor sends during normal operation of the pump 1 pressure values so measured to a first unit 11 configured to calculate the ratio of air volume to pressure chamber volume of the pump at the bottom dead point of the piston. How this will be done will now be explained while making reference to Figs. 2 and 3.

The bottom dead point of the piston 12 is indicated at 13 in Fig. 2 defining the maximum pressure chamber volume $V_{\max}$ of the pump, whereas 14 indicates the upper dead point of the piston defining the minimum pressure chamber volume $V_{\min}$ of the pump. The geometric compression ratio r_{geo} of the pump is $V_{\max}/V_{\min}$ and is known by the unit 11. Assuming that both the pump chamber and the liquid 15 inside it are incompressible, as soon as the pump chamber volume decreases below the liquid volume, liquid will be expelled from the pump. If an elastic element, for example a gas, is present in the pump chamber, that elastic element will have to be compressed enough to generate sufficient pressure to overcome the back pressure at the outlet of the pump before any liquid can be expelled. If we assume that the only (significant) elasticity is caused by an ideal gas inside the pump chamber, the

ideal or general gas law can be used along with a known geometric compression ratio to determine the amount of gas in the chamber at maximum chamber volume if the maximum attainable outlet pressure of the pump is known. It is then assumed that the gas temperature is constant. Said maximum attainable pressure at the outlet of the pump is for a pump with a given geometric compression ratio a function of the ratio of gas, here air, volume to the total chamber volume $V_{\max}$ and this is for a certain pump shown by the graph in Fig. 3. It is there shown how a maximum attainable pressure of about 3.5 bars results in a calculated ratio of air volume to chamber volume of 0.5, whereas this ratio is 0.42 for a pressure of 9 bars normally obtainable without any leakage. A second unit 16 of the device according to the invention is configured to compare the value of the air volume ratio calculated by the first unit and shown in Fig. 3 with a characteristic value thereof for the pump without leakage on the suction side thereof and to determine an estimated value of a possible leakage on the suction side of the pump through the result of this comparison.

Accordingly, no extra hardware, such as sensors, or invasive measure, such as by blocking/disconnecting components, is required for providing an estimated value of a possible leakage on the suction side of the pump. The method simply relies on getting the opportunity to measure the maximum obtainable pressure on the outlet side of the pump, where pressure might already be measured for control purposes.

Fig. 4 illustrates a flow chart of a method according to an embodiment of the present invention carried out for a liquid feeding system of the type shown in Fig. 1. The method is started

with the step S_1 of continuing to drive the pump. While driving the pump the maximum attainable pump outlet pressure is measured in a step S_2 , whereupon in a step S_3 the general gas law and a knowledge of geometric compression ratio of the pump is utilized to calculate the ratio of air volume to pressure chamber volume. Then the value calculated is in a step S_4 compared with a characteristic value for the pump without leakage, and finally an estimated value of a possible leakage on the pump suction side is in a step S_5 determined based on the comparison.

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Computer program code for implementing a method according to the invention is with advantage included in a computer program which can be read into the internal memory of a computer, e.g. the internal memory of an electronic control unit of a motor vehicle. Such a computer program is with advantage provided via a computer program product comprising a data storage medium which can be read by a computer and which has the computer program stored on it. Said data storage medium is for example an optical data storage medium in the form of a CD ROM disc, a DVD disc etc., a magnetic data storage medium in the form of a hard disc, a diskette, a cassette tape etc., or a flash memory or a memory of the ROM, PROM, EPROM or EEPROM type. Fig. 5 illustrates very schematically an electronic control unit comprising an execution means 18, e.g. a central processor unit (CPU), for execution of computer software. The execution means 18 communicates with a memory 19, e.g. of the RAM type, via a data bus 20. The control unit 17 comprises also a non-transitory data storage medium 21, e.g. in the form of a flash memory or a memory of the ROM, PROM, EPROM or EEPROM type. The execution means 18 communicates with the data storage medium

21 via the data bus 20. A computer program comprising computer program code for implementing a method according to the invention, e.g. in accordance with the embodiment illustrated in Fig. 3, is stored on the data storage medium 21.

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The invention is of course in no way restricted to the embodiments described above, since many possibilities for modifications thereof are likely to be obvious to one skilled in the art without having to deviate from the scope of invention defined in the appended

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claims.

The first and second units may of course be combined in one single member, such as the ECU of a vehicle.

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Claims

1. A method for providing an estimated value of a possible leakage on a suction side of a piston displacement pump (1) pumping a liquid, the method comprising the step of
- 5 a) driving the pump and measuring the maximum attainable outlet pressure of the pump,
- characterized** in that it comprises the further steps of
- b) calculating the ratio of air volume (V_{air}) to pressure chamber volume (V_{max}) of the pump at the bottom dead point (13) of the piston (12) by using the pressure value measured in step a) in the general gas law while assuming that the gas temperature is constant and by utilizing the knowledge of the geometric compression ratio (r_{geo}) of the
- 10 pump,
- c) comparing the value of the air volume ratio calculated in step b) with the characteristic value thereof for the pump without leakage on the suction side thereof, and
- d) determining an estimated value of a said possible leakage
- 15 through the result of the comparison carried out in step c).
2. A method according to claim 1, **characterized** in that in step d) a knowledge of the flow rate of the pump (1) is utilised to determine said estimated value of a possible leakage as an
- 20 air leakage flow rate.
3. A method according to claim 1 or 2, **characterized** in that it is carried out for a pump (1) in a low pressure part of a system for feeding liquid in a motor vehicle (6).
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4. A method according to claim 3, **characterized** in that it is carried out for a piston displacement pump (1) connected between a tank (2) of Ad blue to pump Ad blue to be downstreams of the pump sprayed into the exhaust gas system (5) of the vehicle (6) upstreams the catalytic converter (8) thereof.
5. A method according to claim 3, **characterized** in that it is carried out for a piston displacement pump (1) connected to a fuel tank of the vehicle to pump fuel towards a high pressure part of a system for injection of fuel into an internal combustion engine (7) of the vehicle (6).
6. A device for providing an estimated value of a possible leakage on a suction side of a piston displacement pump (1) pumping a liquid, the device comprising a member (9) configured to measure the maximum attainable outlet pressure of the pump in operation thereof,
characterized in that the device further comprises
- a first unit (11) configured to calculate the ratio of air volume (V_{air}) to pressure chamber volume (V_{max}) of the pump at the bottom dead point (13) of the piston (12) by using the pressure value measured by said member (9) in the general gas law while assuming that the gas temperature is constant and by utilising the knowledge of the geometric compression ratio (r_{geo}) of the pump, and
 - a second unit (16) configured to compare the value of the air volume ratio calculated by the first unit (11) with the characteristic value thereof for the pump (1) without leakage on the suction side thereof and to determine an

estimated value of a said possible leakage through the result of this comparison.

- 5 7. A device according to claim 6, **characterized** in that said pressure measuring member (9) is configured to be arranged downstreams a said pump (1) in a low pressure part of a system for pumping liquid in a motor vehicle (6).
- 10 8. A device according to claim 7, **characterized** in that said pressure measuring member (9) is configured to be arranged downstreams a said pump (1) for pumping Ad blue from a tank (2) of Ad blue to be downstreams of the pump sprayed into the exhaust gas system (5) of the vehicle upstreams a catalytic converter (8) thereof.
- 15 9. A device according to claim 7, **characterized** in that said pressure measuring member is configured to be arranged downstreams a said pump connected to a fuel tank of the vehicle in a low pressure part of a system for injection of fuel
20 in an internal combustion engine (7) of the vehicle (6) to pump fuel towards a high pressure part of said system.
- 25 10. A computer program comprising instructions which, when the computer program is executed by a computer, causes the computer to carry out the method according to any of claims 1-5.
- 30 11. A computer-readable medium comprising instructions which, when executed by computer, cause the computer to carry out the method according to any of claims 1-5.

12. An electronic control unit of a motor vehicle (6) comprising an execution means (18), a memory (19) connected to the execution means and a non-transitory data storage medium (21) which is connected to the execution means (18) and on which the computer program code of a computer program according to claim 10 is stored.
13. A motor vehicle, especially a wheeled vehicle, such as a truck or a bus, **characterized** in that it comprises an electronic control unit (17) according to claim 12.

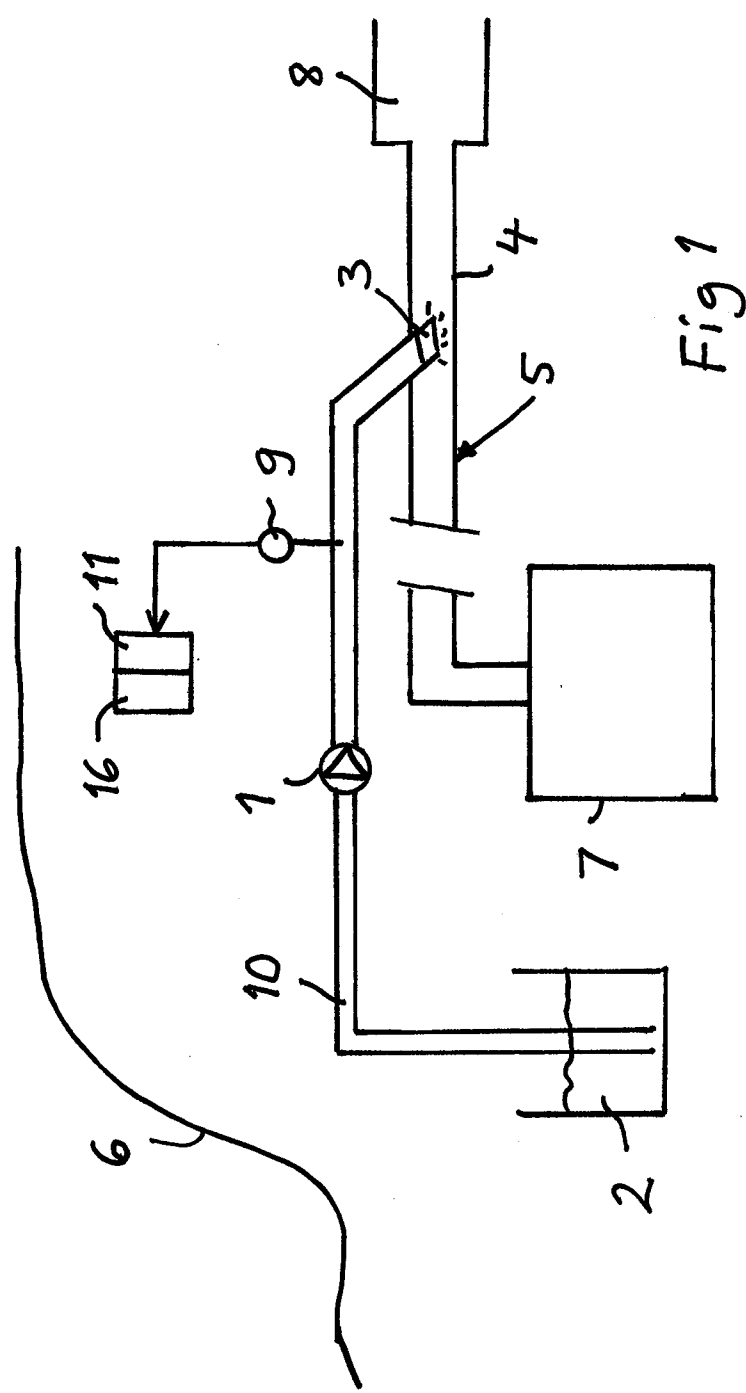


Fig 1

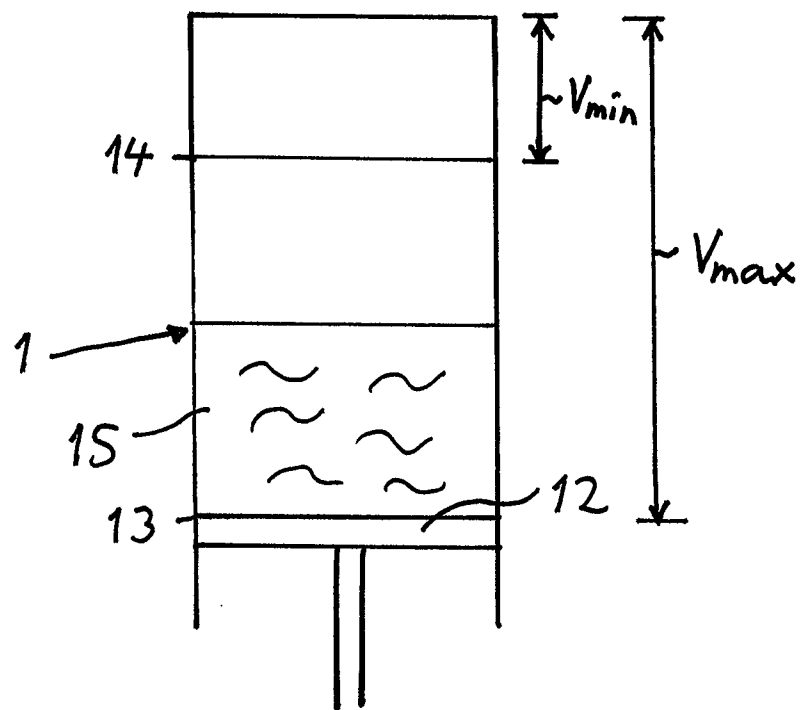


Fig 2

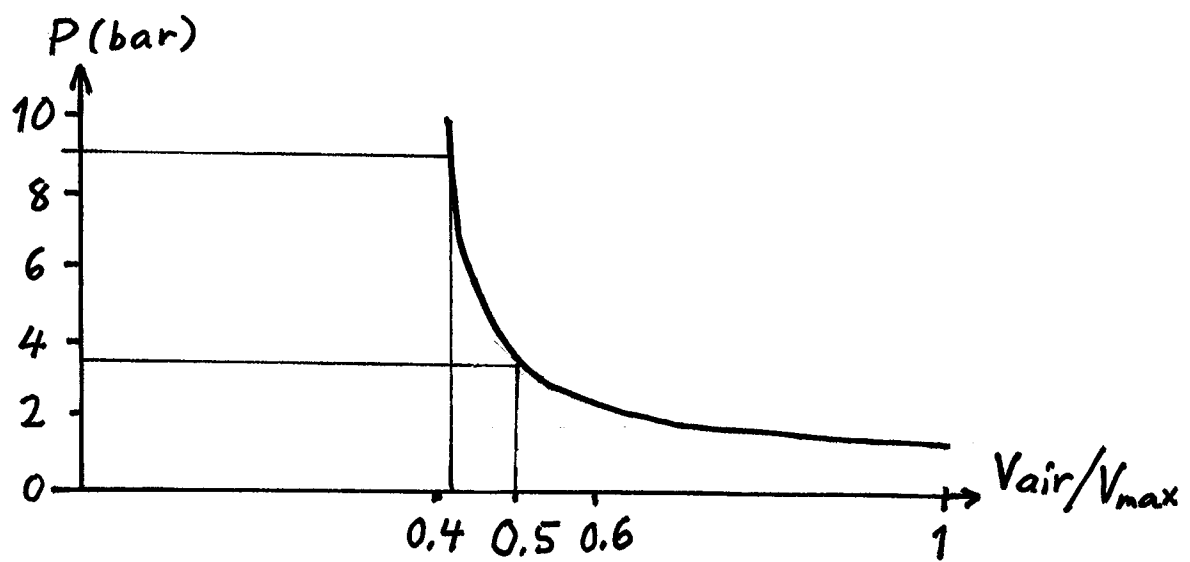


Fig 3

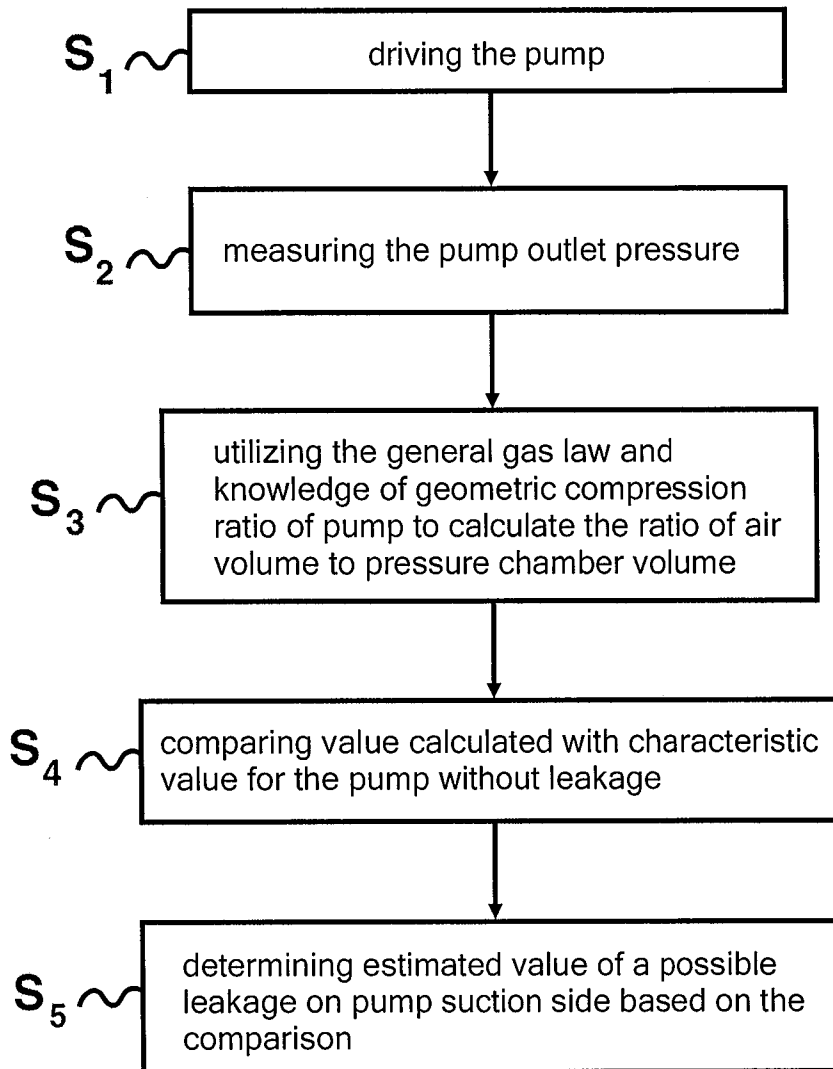


Fig 4

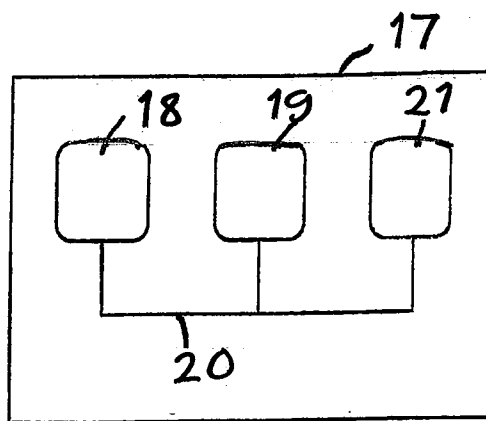


Fig 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2018/050717

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: F02D, F02M, F04B

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2013028542 A2 (ENTEGRIS INC ET AL), 28 February 2013 (2013-02-28); paragraphs [0051]-[0052], [0006]-[0008], [0031]-[0033], [0035]-[0036]; figures 1, 2, 5; claims 1, 7-8, 11, 16-17 --	1-13
A	US 9546652 B2 (YIN DAN), 17 January 2017 (2017-01-17); abstract; column 1, line 35 - line 67; column 4, line 5 - column 5, line 63; figure 6; claim 1 --	1-13
A	WO 2011104545 A2 (ARTEMIS INTELLIGENT POWER LTD ET AL), 1 September 2011 (2011-09-01); abstract; figures 1, 3; claim 7 --	1-13



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	"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
"A" document defining the general state of the art which is not considered to be of particular relevance	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"&" document member of the same patent family
"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	

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INTERNATIONAL SEARCH REPORT

International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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Continuation of: second sheet

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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