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(71) Applicant *(for all designated States except US)*: **WÄRTSILÄ SWITZERLAND LTD.** [CH/CH]; Zürcherstrasse 12, CH-8401 Winterthur (CH).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **HÄUSSLER, Axel** [CH/CH]; Farmerstr. 6, CH-8404 Winterthur (CH). **ERNST, Maximilian** [CH/CH]; Rütlistr. 17, CH-8400 Winterthur (CH).

(74) Agent: **TBK**; Bavariaring 4-6, 80336 München (DE).

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(54) **Title**: METHOD FOR CONTROLLING A DEFECTIVE INJECTOR

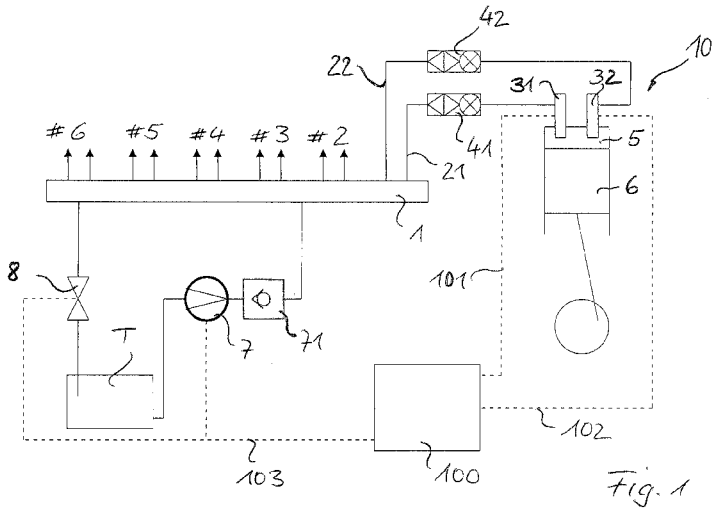

Fig. 1

(57) **Abstract**: There is described a control method, in particular for use with an engine, for shutting down a fluid ejection valve having a leakage malfunction. The valve is connected in series after a flow fuse adapted to fall into a shut-down-state when a fluid flow through said flow fuse exceeds a predetermined flow value. A step of detecting the leakage malfunction of the valve is followed by a step of controlling the valve for ejecting a fluid flow exceeding the predetermined flow value to thereby trigger the flow fuse to cut off the valve from fluid supply. The predetermined flow value may be a value representing characteristic of the flow including cumulated fluid amounts measured by volume or mass. When the valve is a fuel injector of an internal combustion engine, the detection step evaluates at least one operating state parameter of the engine.

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METHOD FOR CONTROLLING A DEFECTIVE INJECTOR

Description

The invention relates to a control method for a fluid ejection valve. Fluid ejection valves are commonly used in, for example combustion engines, wherein these valves are used for ejecting fuel, lubricant, water or other fluids which may be liquid or gaseous.

The term ejection valve shall embrace all types of valves which are suitable to control ejection or spraying of a fluid out of the ejection valve. The ejected fluids may be gaseous or liquid and are in particular a fuel, a lubricant such as oil, aqueous emulsions or solutions, or water. In the particular case, where the ejector valve is used to eject fuel or other liquid or even gas into the cylinder of a combustion engine, the ejector is called injector.

The ejection valves to which the control according to the present invention relates, are valves which are connected to a line in which the fluid to be ejected is present in a pressurized state. Typical example for this are fuel injectors of an engine having a common rail system. Of course, the ejector valves can be ejector valves for spraying a lubricant onto sliding surfaces, or for spaying an additive, like a urea containing solution, or water into the cylinder and/or the piping (intake piping and/or exhaust piping) around the engine.

In view of the hazard of fluids under high pressure, especially if they are dangerous for the environment, flow fuses are built into the pipes or lines with which the respective ejection valves are connected to a source of pressurized fluid. The flow fuses are designed to be triggered when a fluid flow with a flow value exceeding a design flow value passes through the flow fuse, and to cut the fluid supply to the respective ejection valve or valves. In case of a pipe burst, the actual mass flow and/or the flow speed may form a criterion for triggering the flow fuse. But not only an actual mass flow or flow speed can be the parameter defining the decisive flow value; other characteristics of a fluid flow e.g. pressure

loss, temperature change or the like may be used as the parameter representing the flow value. The flow fuses are also known as flow limiting valves.

Furthermore, flow fuses may, for example, be designed such that they have a fluid reservoir, so that they allow a peak ejection volume for a restricted time period, which is followed by a closing period of the ejection valve, so that the flow fuse is triggered if an average flow amount, or an absolute flow amount, which may be calculated for a period including peak ejection and closing period for reservoir refill, is exceeded. Such a flow fuse may react properly on a failure that an ejection valve stays fully open.

Of course, flow fuses must be designed such that they always allow the maximum ejection flow/average flow amount that is to be ejected from the respective ejector valve at any allowable operating state of the machine in which the ejection valve is used. Therefore, the tolerance for triggering the fuse should be set on the save side with regard to allowing the ejection valve to eject the fluid.

Because flow fuses are mechanical systems operating in difficult environment, the required sturdiness of these constructions (strong springs solid parts, large flows, high pressure) usually reduces the sensitivity of the flow fuse to the triggering parameter, which makes it necessary to allow for even larger tolerances to avoid unintended triggering.

In view of the above, there is the possibility that a small leakage from the ejection valve, which may occur permanently or intermittently is not detected by the flow fuse, i.e. the flow fuse will not be triggered.

With regard to small leakage in the above sense, there is the possibility to provide the piping with an additional cut-off valve which may be manually closed by manual operation or by a power drive if there is a small leakage, so as to interrupt or cut the fluid supply to the ejection valve. However, the provision of an additional cut-off valve is expensive and increases the number of sealed

portions in the piping due to the necessary integration of a cut-off valve into a piping.

It is therefore the object of the invention to suggest a method for shutting down a fluid ejection valve having a leakage malfunction.

This object is solved with a method according to claim 1; advantageous modifications are depicted in the dependent claims.

According to the invention, the control method for shutting down a fluid ejection valve having a leakage malfunction is used in an arrangement in which the valve is connected in series after a flow fuse adapted to fall into a shut-down-state when a fluid flow through said flow fuse exceeds a predetermined flow value. The method of the invention comprises a step of detecting the leakage malfunction of the valve and a step of controlling the valve for ejecting a fluid flow exceeding said predetermined flow value to thereby trigger the flow fuse to fall into the shut-down-state and to cut-off the valve from fluid supply.

The term flow value is understood to express a value which relates to one or more parameters of a fluid flow. By setting predetermined flow value (a threshold value) the predetermined flow value can be set as a value representing a flow speed, a volume flow rate, a mass flow rate, a total fluid volume within a predetermined period, a total fluid mass within a predetermined period, or a cumulated fluid amount measured by volume or mass, or it may relate to combinations of these parameters.

As has been explained above, the method of the invention uses a detection step of detecting a leakage malfunction which is separate from the detection of a triggering flow value by the flow fuse.

Preferably, when the fluid ejection valve is a fuel injector adapted to inject fuel under pressure into a cylinder of an internal combustion engine, the leakage malfunction of the injector can be detected on the basis of an abnormality of at least one operating state parameter of the engine. Preferably, the operating

state parameter is at least one of an exhaust gas temperature, a cylinder pressure, a fuel consumption, a crankshaft speed, and a crankshaft torque. Also, combinations of these parameters may be monitored and evaluated for detecting the leakage malfunction.

Preferably, for triggering the flow fuse, when said operating parameter is monitored by an engine control unit (ECU) and when the engine control unit causes the injector to inject fuel during an engine stroke in an amount which exceeds a full load fuel injection amount, said full load fuel injection amount corresponding to the injected fuel amount injected by the injector in an engine stroke when the engine is operated at full load. Accordingly, in this situation, an injected fuel amount is set such that it is higher than the fuel amount which would be injected into the cylinders, when the engine is running at maximum load. In this way, the design triggering value of the flow fuse is exceeded and the fuse is triggered.

Preferably, the injected fuel amount is at least 101%, preferably at least 120%, and most preferably in the range including 130% and 170% of the full load fuel injection amount. Preferably, the injected fuel amount is set such that a related flow value (based on one or more parameters of the flow) is larger than the predetermined flow value.

As mentioned above, the control method according to the invention may also be applied to various types of machines other than combustion engines or it may be applied to various types of fluid ejecting devices other than fuel injection, in combustion engines and other types of machines.

Preferably, the fluid ejection valve is an ejector for ejecting a lubricant toward contact surfaces in an internal combustion engine, in particular toward the piston/cylinder contact surfaces (cylinder lining), and the leakage malfunction is detected on the basis of an abnormality of at least one operating state parameter of the engine.

Preferably, the operating state parameter is at least one of a lubricant supply pressure, a lubricant consumption, an exhaust gas temperature and a cylinder pressure.

Also preferably and similarly, the fluid ejection valve may be an ejector for ejecting water, or other aqueous solution like urea containing solutions into the cylinders, the inlet piping or the exhaust piping, wherein the leakage malfunction may be detected on the basis of an operating state parameter of the related system or of the engine (e.g. exhaust gas composition, temperature etc). Preferably, the fluid ejection valve is a valve injecting water into a cylinder of the engine. Such water injectors have a risk of lime-scale formation, so that a switch-off may be required if the water injector stays open.

Preferably, when the engine is provided with a fuel flow fuse and the fluid ejection valve is a fuel injector, and the engine is further provided with a lubricant flow fuse and the fluid ejection valve is a lubricant ejector, the detection of a leakage malfunction of a fluid ejection valve includes a differentiation of the operation parameter having an abnormality according to the fluid ejection valve type. Preferably, the operation parameters used for the differentiation include fuel consumption and lubricant pressure.

Preferably, when the flow fuse is arranged upstream of a plurality of fluid ejection valves, the plurality of fluid ejection valves is simultaneously operated for ejecting a fluid flow exceeding the predetermined flow value of the flow fuse to thereby trigger the flow fuse to fall into the shut-down-state and to cut off the plurality of fluid ejection valves from fluid supply.

In a preferable application of the invention as is described above, the engine is a direct injection engine and the fuel supply system of the engine comprises a common rail in which fuel is stored in pressurized state, and the flow fuse is arranged in a fuel pipe between the common rail and the fuel injector or fuel injectors. That engine may comprise a plurality of cylinders and a flow fuse is provided in each fuel supply pipe for the injector or the injectors of each cylinder.

In preferred form, the control method further comprises a step of displaying an optical alarm and/or an acoustic alarm in case of detection of a malfunction, and/or a step of triggering the flow fuse to fall into the shut-down-state, if malfunction is detected. Preferably, the control method is executed without stopping the engine.

Further preferably, the control method may be applied to hydraulic systems in which hydraulic oil is used in piston/cylinder arrangements, for example in pressure amplifiers which are used to amplify fuel injection pressure for injection from a fuel injector. In this case, flow fuses may be used before the pressure amplifiers and a flow of hydraulic oil which triggers the flow fuse of the hydraulic circuit is caused by controlling the fuel injector to inject a fuel flow exceeding a predetermined flow value.

Preferably, as an example, an application of the invention in a ship engine allows continued operation of the engine, despite an injector or ejector having a problem. In case of a permanent leakage of an injector, fuel is permanently injected into the cylinder, causing fuel enrichment which may cause explosions in the exhaust, the exhaust turbocharger or severe defects of the engine. On the other hand, stopping and re-starting of such large engines is cumbersome and time consuming. Especially if the ship is sailing in rough weather conditions, the time for stopping and re-starting the engine may not be available or may endanger the safe sailing of the ship. In this case, the continuous operation of the engine with reduced number of cylinders is a safety option. This is one beneficial aspect of the invention, and there is further advantages obtained by it, as will become apparent from the following description of an application example of the invention.

Fig. 1 shows a schematic of a fuel injection system for a 6-cylinder engine with a common rail and flow fuses associated with each individual injector.

Fig. 1 shows an arrangement of a fuel supply system of a two-stroke engine 10 having a common rail 1 in which fuel is stored under elevated pressure. Only the connection of the common rail 1 to injectors 31, 32 of one cylinder 5 of the

engine 10 is shown in detail in Fig. 1, the further connections to the other cylinders are indicated by #2, #3, #4, #5, and #6, and shall have the same structure. The fuel is fed to the common rail 1 by means of fuel pump 7, which may be driven by the engine 10. The fuel is stored in tank T. A check valve 71 avoids back flow of fuel from the common rail 1 to the pump 7. A pressure control device including a pressure relief valve 8 is designed to co-operate with an engine control unit ECU 100 to maintain the fuel pressure in the common rail 1 on the desired level. ECU 100 controls the pump 7 and/or the pressure control valve 8 in order to supply enough fuel under high pressure, but to avoid surplus pressurizing of the fuel to save energy. Alternatively mechanical pressure relief valve(s) may be used instead of an active pressure control valve 8 for pressure control. The control of the pump 7 and pressure control valve 8 are connected to the ECU 100 via wiring 103 for transmission of signals and/or electric drive power.

Fuel injectors 31 and 32 are connected to the common rail 1 by way of pipes 21, 22, respectively. In the pipe 21, there is arranged a flow fuse 41 which, after being triggered, interrupts fuel supply via pipe 21 to fuel injector 31. The fuel supply stays interrupted until the flow fuse is manually reset e.g. after the injector problem has been solved. Similarly, in the pipe 22, there is arranged a flow fuse 42 which, after being triggered, interrupts fuel supply via pipe 22 to fuel injector 32. Also here, the fuel supply stays interrupted until the flow fuse is manually reset e.g. after the injector problem has been solved.

Fig. 1 further shows a cylinder 5 and a piston 6 of the engine 10 in a schematic drawing style. Furthermore, control lines 101, 102 connecting the injectors 31 and 32, respectively to the ECU 100 are shown. By way of these control lines the injectors are controlled by the ECU 100 to open or close, so as to inject fuel into the cylinder 5 in a desired amount and at a desired timing. The ECU 100 and the injectors 31, 32 are tuned such that the ECU 100 can send an opening signal to the respective injector 31, 32 and the respective injector 31, 32 stays open as long as the opening signal is received. The injectors are self-closing so that, when the opening signal is off, the respective injector 31, 32 closes and interrupts the injection of fuel into the cylinder 5.

The flow fuses 41, 42 are designed to be triggered, when a flow value of the flow of fuel through the flow fuse exceeds a predetermined flow value. The predetermined flow value may be a value associated to a parameter of the fluid flow. For example, the flow value may be a pressure loss over the flow fuse, a dynamic pressure of the flow acting on a triggering surface of the flow fuse, or even a difference of static and/or dynamic pressures in the flow path through the flow fuse. Of course, other parameters of the fluid flow may be selected for setting the flow value and the related threshold value.

For explanation purpose, hereafter the accumulated flow amount through the flow fuse within a predetermined period will be used as the flow value, the explanation for other flow values applies mutatis mutandis.

During operation of the engine 10, assume that one of the injectors 31, 32 has a leakage malfunction. The leakage malfunction is a case in which the injector fails to fully close, i.e. the injector does not close tightly. This can have various reasons, including debris in the fuel, wear of the tightening surfaces, cracks in surfaces or the like. In this case, the malfunctioning injector 31, 32 will permanently inject a small amount of fuel into the cylinder 5 when it is supposed to close, while driving the injector 31, 32 to inject fuel may work normal, i.e. the injector 31, 32 injects the desired fuel amount when it is controlled to be open.

Because the predetermined flow value for triggering the flow fuse is based on an average fluid amount per unit of time, there may be the case that the flow through the malfunctioning injector is too small to trigger the flow fuse.

The ECU 100 is connected to various sensors (not shown) which are capable of measuring/detecting operating parameters of the engine 10 and its peripheral devices (sub-systems). The surplus amount of fuel which is permanently injected into the cylinder 5 from the malfunctioning injector causes changes in the monitored operating parameter(s) and from the changes it can be concluded that there is a malfunction in one injector 31, 32.

Parameters to monitor can include an exhaust gas temperature, a cylinder pressure, a fuel consumption, a crankshaft speed, and a crankshaft torque. Power consumption or discharge flow (switch-on/switch-off periods) of the fuel pump 8 may also be used as an indicator for a leakage malfunction in combination with other parameters.

Once the cylinder having the malfunction is detected, the ECU 100 sets an alarm signal which gives acoustic and/or visible alarm. Additionally the alarm may be sent out via telecommunication to a responsible person informing about the malfunction. Then, a decision is made to switch-off at least one of the injectors 31, 32. That decision may be found by a person or automatically by executing programs in the ECU. If the malfunctioning injector of the two injectors 31, 32 is switched-off, the cylinder may still be operated at low performance with a single injector which operates normally. Further, if both injectors 31, 32 are switched off, the individual cylinder 5 of the engine 10 is switched-off, but the engine 10 is kept running by operating the remaining cylinders (not shown).

When the injector 31, 32 to be switched off is identified, and the signal for switching-off the injector is generated (either manually by personnel, or automatically by engine control unit ECU) the ECU 100 outputs a opening control signal to the injector 31, 32 which signal is –preferably significantly- longer than the opening control signal which the ECU 100 outputs when the engine 10 is operating normally and at maximum load. Due to this long opening signal from the ECU 100, the injector 31, 32 releases so much fuel into the cylinder 5, that the flow value of that fuel flow exceeds the predetermined flow value of the flow fuse. Thus, the flow fuse 41, 42 is triggered and interrupts the fuel supply to the related injector 31, 32. Although there is made surplus injection of fuel into the cylinder, it was found that this surplus injection in the single stroke of the engine does not cause any problems in engine operation. In this way, the hazardous permanent leakage flow into the engine is stopped. The flow fuse may be designed such that it requires a manual reset after the problem of the injector has been solved. The flow fuse may be also designed such that it automatically resets when the pressure in the fuel pipes is relieved after engine stop and the required maintenance.

In Fig. 1, an engine layout has been described which provides each injector with its own flow fuse. It is possible that two or more injectors of one cylinder are connected to a common flow fuse. For triggering such a flow fuse, the flow value shall be set larger than the flow value of a total fuel flow of all the injectors of the one cylinder at maximum load operation of the engine.

If each injector is provided with its own flow fuse, then the switch-off procedure may be set such that only one injector in a stroke of the piston is controlled to inject the excess fuel amount. In this way, overload of the cylinder due to combustion of an extremely rich mixture in the cylinder is avoided.

In the foregoing, an example has been described which relates to fuel injectors injecting fuel into engine cylinders. The same layout may be adopted when the injectors are replaced by ejection valves ejecting a lubricant on sliding surfaces in an engine or a machine different from an engine, or ejection valves ejecting water or additives or mixtures thereof into the cylinder, intake, exhaust, or other parts of the engine or other applications. In these adaptations, the common rail is replaced by any pressurized fluid accumulator, and, of course, the flow fuse or flow fuses are designed for the expected or allowable maximum flow. The operation of the control for the ejection valve(s) is similar to the above description, i.e. to cause a flow fuse to trip or to be triggered by way of controlling the ejection valve to eject an excessive flow.

In the foregoing example, the flow fuses are shown and described as separate elements, the flow fuses may be integrated into the injectors.

Claims

1. A control method, in particular for use with an engine, for shutting down a fluid ejection valve having a leakage malfunction, wherein the valve is connected in series after a flow fuse adapted to fall into a shut-down-state when a fluid flow through said flow fuse exceeds a predetermined flow value, said method comprising a step of detecting the leakage malfunction of the valve and a step of controlling the valve for ejecting a fluid flow exceeding said predetermined flow value to thereby trigger the flow fuse to fall into the shut-down-state and to cut off the valve from fluid supply.

2. A control method according to claim 1, wherein the predetermined flow value is a value representing a flow speed, a volume flow rate, a mass flow rate, a total fluid volume within a predetermined period, a total fluid mass within a predetermined period, or a cumulated fluid amount measured by volume or mass.

3. A control method according to claim 1 and/or 2, wherein the fluid ejection valve is a fuel injector adapted to inject fuel under pressure into a cylinder of an internal combustion engine and the leakage malfunction of the injector is detected on the basis of an abnormality of at least one operating state parameter of the engine.

4. A control method according to claim 3, wherein the operating state parameter is at least one of an exhaust gas temperature, a cylinder pressure, a fuel consumption, a crankshaft speed, and a crankshaft torque.

5. A control method according to claim 3 and/or 4, wherein said operating parameter is monitored by an engine control unit (ECU) and wherein the engine control unit causes the injector to inject fuel during an engine stroke in an amount which exceeds a full load fuel injection amount, said full load fuel injection amount corresponding to the injected fuel amount injected by the injector in an engine stroke when the engine is operated at full load.

6. A control method according to claim 5, wherein the injected fuel amount is at least 101%, preferably at least 120%, and most preferably in the range including 130% and 170% of the full load fuel injection amount.

7. A control method according to claim 1 and/or 2, wherein the fluid ejection valve is an ejector for ejecting a lubricant toward contact surfaces in an internal combustion engine, in particular toward the piston/cylinder contact surfaces, and wherein the leakage malfunction is detected on the basis of an abnormality of at least one operating state parameter of the engine.

8. A control method according to claim 7, wherein the operating state parameter is at least one of a lubricant supply pressure, a lubricant consumption, an exhaust gas temperature and a cylinder pressure.

9. A control method according to any one of claims 1 to 8, wherein the engine is provided with a fuel flow fuse and the fluid ejection valve is a fuel injector, and wherein the engine is further provided with a lubricant flow fuse and wherein the fluid ejection valve is a lubricant ejector, and wherein the detection of a leakage malfunction of a fluid ejection valve includes a differentiation of the operation parameter having an abnormality according to the fluid ejection valve type.

10. A control method according to claim 9, wherein the operation parameters used for the differentiation include fuel consumption and lubricant pressure.

11. A control method according any one of the preceding claims 1 to 10, wherein the flow fuse is arranged upstream of a plurality of fluid ejection valves, and wherein the plurality of fluid ejection valves is simultaneously operated for ejecting a fluid flow exceeding the predetermined flow value of the flow fuse to thereby trigger the flow fuse to fall into the shut-down-state and to cut off the plurality of fluid ejection valves from fluid supply.

12. A control method according to any one of the preceding claims, wherein the engine is a direct injection engine and the fuel supply system of the engine comprises a common rail in which fuel is stored in pressurized state, and wherein

the flow fuse is arranged in a fuel pipe between the common rail and the fuel injector or fuel injectors.

13. A control method according to claim 12, wherein the engine comprises a plurality of cylinders and a flow fuse is provided in each fuel supply pipe for the injector or the injectors of each cylinder.

14. A control method according to any one of the preceding claims, wherein the control method further comprises a step of displaying an optical alarm and/or an acoustic alarm in case of detection of a malfunction, and/or a step of triggering the flow fuse to fall into the shut-down-state, if malfunction is detected.

15. A control method according to any one of the preceding claims, wherein the control method is executed without stopping the engine.

16. A control method according to claim 3, wherein the engine has a hydraulic system including a hydraulic pressure amplifier driven by said hydraulic system to increase the fuel pressure for fuel injection, wherein a flow fuse is provided in the hydraulic system in connection with pressure amplifier, and wherein the flow fuse is triggered to interrupt the supply of hydraulic fluid to the pressure amplifier by injection of an excess flow from the fuel injector.

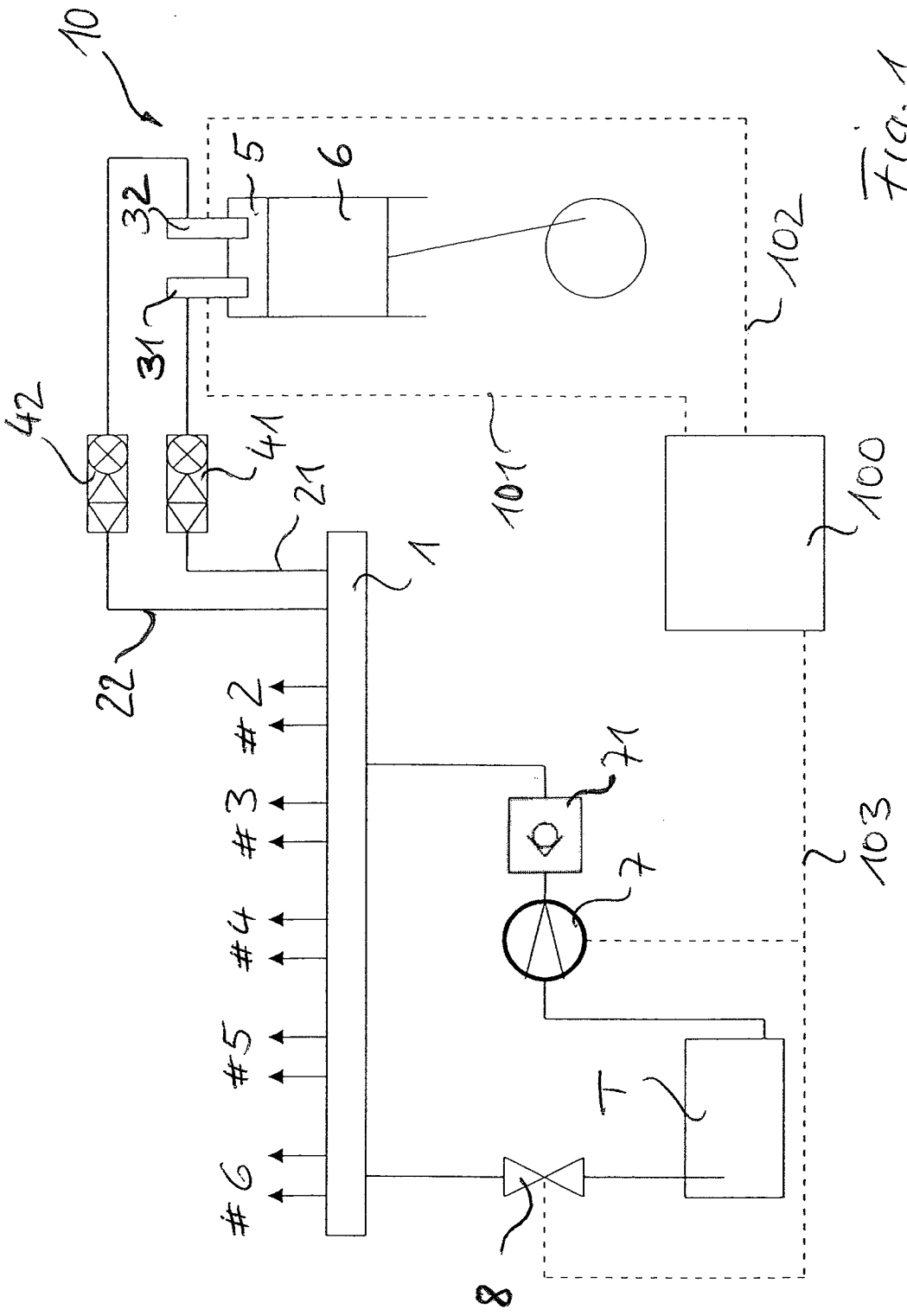

Fig. 1

INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER
INV. F02D41/22 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)
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	DE 196 32 339 A1 (BOSCH GMBH ROBERT [DE]) 12 February 1998 (1998-02-12) column 1, line 42 - line 44 column 1, line 65 - line 68 column 2, line 15 - line 32 column 3, line 67 - column 4, line 4	1-16
X	FR 2 762 358 A1 (PEUGEOT [FR]) 23 October 1998 (1998-10-23) page 2, line 6 - line 22	1-16
A	US 2006/102152 A1 (SHINOGLE RONALD D [US] ET AL) 18 May 2006 (2006-05-18) paragraph [0011] - paragraph [0019]	1-16

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Jackson, Stephen

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INTERNATIONAL SEARCH REPORT

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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