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(54) COOLING SYSTEM OF AN INTERNAL COMBUSTION ENGINE

(57) Cooling circuit of an internal combustion engine (ICE) comprising a pump (P) to circulate cooling coolant, a radiator (R) suitable to disperse heat produced by the internal combustion engine in the ambient, at least a first pipe (P1) to convey coolant from the internal combustion engine towards the radiator and at least another pipes (P2) connecting the radiator with the pump, the circuit further comprising a cylinder (C)/piston (P) assembly (CPA) defining a chamber (CH) suitable to be hydraulically connected with said second pipe (P2), an actuator (a) connected to said piston in order to control its displacement in said cylinder, by varying said chamber volume, a pressure sensor (PR) in hydraulic communication with said chamber and an electronic control unit (ECU) coupled with said pressure sensor and with said actuator and configured to control said actuator in order to maintain a pressure measured by said pressure sensor above a predetermined threshold.

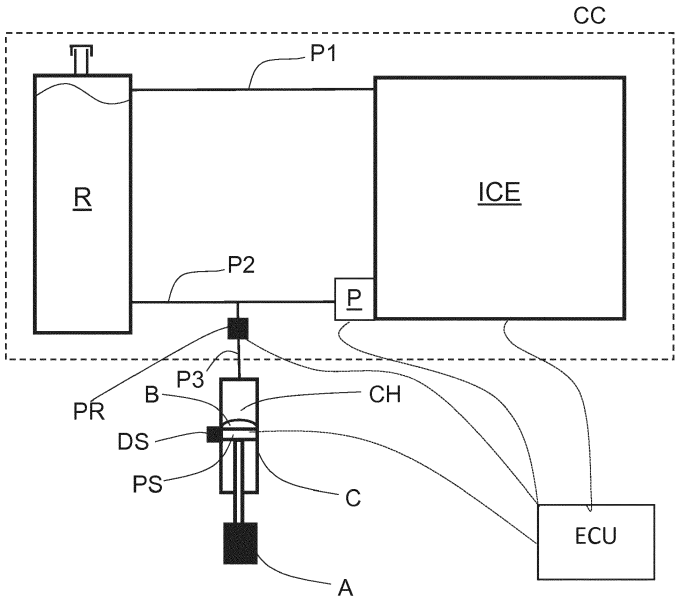

Fig. 1

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Description

Field of the invention

[0001] The present invention relates to cooling system of the internal combustion engines.

Description of the prior art

[0002] Conventionally pressurizing systems has the focus of the pressurizing on the air side of the expansion tank. It is an indirectly pressurization. The pressure level of the coolant will increased with the passive pressure increasing at the expansion air tank, depending on the temperature of the coolant and on the recirculation of the coolant induced by the coolant pump.

[0003] The indirect pressurization is slow and not controllable. It would be helpful if the pressurizing would be faster and controllable, than with the indirect (conventional) pressurization.

Summary of the invention

[0004] Therefore, it is the main object of the present invention to provide for a cooling circuit, which overcomes the above problems/drawbacks through a direct pressurization of the cooling circuit.

[0005] The benefits of the direct pressurizing is that, it is independent from the activation of the coolant circulation pump and the heat produced by the internal combustion engine, thus a good pressurization can be achieved also at cool engine starting.

[0006] The main idea of the present invention is to replace the expansion tank with an auxiliary pressurization assembly comprising a cylinder/piston, where the cylinder communicates with the cooling circuit. Thus, the motion of the piston in its cylinder permits to obtain a direct pressurization of the circuit reached not through the air contribution.

[0007] An actuator is coupled with the piston in order to control its displacement. In addition, an electronic control unit is configured to control such actuator. Preferably, such electronic control unit coincides with the one deputy to control the internal control unit.

[0008] According to preferred embodiment of the invention, the pressure in the cooling circuit is controlled by the cylinder/assembly, therefore the piston displacement is controlled to produce a target pressure in the cylinder chamber and thus in the cooling circuit; to reduce the pressure both in the cylinder chamber and in the cooling circuit; to suck coolant from a tank to refill the cooling circuit both to compensate coolant lost and to vary the amount of coolant in the cooling circuit according to its operating conditions.

[0009] According to a preferred embodiment of the invention, the piston is provided of an elastic buffer to minimize pressure peaks in the cooling circuit.

[0010] According to another preferred embodiment of the invention, the auxiliary pressurization assembly comprises a coolant tank connected to the cooling circuit and to the above cylinder/piston through a three-way valve, where a first port of the three-way valve is directly connected to the cooling circuit, preferably on the sucking pipe, a second port is directly connected with the cylinder/piston assembly and a third port in directly connected with said coolant tank. Preferably, said electronic control unit is configured to control also said three-way valve to develop several procerus to control the status of the cooling circuit and of the auxiliary system.

[0011] Further object of the invention are the method to actuate the pressurizing system in order to venting, refill and pressurize the cooling circuit according to the second embodiment disclosed in the following detailed description. These and further objects are achieved by means of the attached claims, which describe preferred embodiments of the invention, forming an integral part of the present description.

Brief description of the drawings

[0012] The invention will become fully clear from the following detailed description, given by way of a mere exemplifying and non-limiting example, to be read with reference to the attached drawing figures, wherein:

Fig. 1 shows schematically a first embodiment of the cooling system according to the present invention;
Fig. 2 shows schematically a second embodiment of the cooling system according to the present invention;
Figure 3 shows schematically with greater detail a portion of figure 2 and relating control means.

[0013] The same reference numerals and letters in the figures designate the same or functionally equivalent parts.

[0014] According to the present invention, the term "second element" does not imply the presence of a "first element", first, second, etc.. are used only for improving the clarity of the description and they should not be interpreted in a limiting way.

Detailed description of the preferred embodiments

[0015] A cooling circuit of an internal combustion engine ICE usually comprises a pump P driven by the crankshaft of the combustion engine or by an electric drive, a radiator R suitable to disperse the heat in the ambient and eventually a fan (not shown) suitable to increase the convection effects of such heat dispersion.

[0016] At least a pipe P1 conveys the hot coolant from the internal combustion engine towards a higher part of the radiator R and at least another pipes, named second pipe P2, connects a lower part of the radiator with the pump P. Usually, the pump is directly arranged on the combustion engine block, therefore, no further pipes are

disclosed, however, another pipe/passage connects the pump with the internal combustion engine.

[0017] Figure 1 discloses an example of implementation of the present invention.

[0018] The second pipe P2 is in hydraulic communication with a cylinder/piston assembly CPA through the pipe P3 in a T configuration with the second pipe P2.

[0019] The piston PS is displaceably coupled with its cylinder C. The chamber CH formed between the piston and the cylinder is in hydraulic communication with the cooling circuit CC through the second pipe P3. In the following such cylinder chamber is also called coolant chamber.

[0020] An actuator A commands the displacement of the piston in the cylinder, therefore, when the cooling circuit is sealed, the displacement of the piston varies the pressure inside the cooling circuit itself.

[0021] The actuator can be an electric drive or pneumatic actuator. The opposite face of the piston PS facing the coolant chamber CH can be subjected to a pneumatic action in order to command its displacement in its cylinder.

[0022] According to a preferred embodiment of the invention, a surface of the chamber facing the piston, is provided with a baffle B to avoid pressure peaks.

[0023] According to a preferred embodiment of the invention, a pressure sensor PS, such as a piezoelectric sensor, is also associated with the cooling circuit for example, it can be coupled with the coolant chamber CH of the cylinder or along the third pipe P3 connecting the assembly CPA with the pipe 2.

[0024] According to the invention, the pressure inside the circuit is continuously monitored when the ignition is ON and the actuator A is controlled accordingly, in order to maintain the pressure over a predetermined threshold and preferably within a predefined range of pressures.

[0025] When the piston reaches a second position corresponding to the smaller volume of the coolant chamber CH and the pressure is still below said predefined range, then a warning is sent to the instrument panel of the vehicle in order to signal to the driver that the circuit lacks of refrigerant/coolant.

[0026] A contact sensor or any other suitable displacement sensor DS to detect the position of the piston can be implemented by the skilled person in the art. It could coupled with the piston rod or can be a Hall per se known.

[0027] According to a preferred embodiment of the invention, when the ignition switches from ON to OFF, the piston is moved in a second position, corresponding to the largest volume of the chamber CH.

[0028] This operation, assure no injuries to an operator opening the cooling circuit and permit a correct refueling of the circuit.

[0029] Figure 1 discloses as electronic control unit ECU monitoring the pressure and controlling the actuator A coinciding with the Engine Control Unit, namely the electronic control unit controlling the internal combustion engine ICE. However, an independent electronic control unit can be implemented. For example, according to the present invention a kit to adjourn conventional cooling circuits can be conceived, so as it is sufficient to hydraulically connect the cylinder C with the cooling circuit and the control unit to the vehicle battery and to the electric wire energized when the ignition is ON.

[0030] Figure 2 discloses a second embodiment of the present invention.

[0031] As for the previous embodiment, ICE represents an internal combustion engine and R a radiator to dissipate heat in the environment produced by said internal combustion engine.

[0032] The first pipe P1 connects a high portion of the radiator to the ICE.

[0033] The second pipe P2, instead, connects a lower portion of the radiator with a pump P sucking coolant from the radiator to cool the ICE.

[0034] The third pipe P3 is connected, in one end, with the second pipe P2 in a T connection, and in a second end, with a first port of a three-way valve V1.

[0035] A second port of the three-way valve is connected, through the fourth pipe 4, to the coolant chamber CH of a pressure piston PS and a third port of the three-way valve is connected to a lower portion of a coolant tank T through the fifth pipe P5.

[0036] According to the condition a) of the three-way valve, the fourth P4 and fifth pipes P5 communicate between each other, while according to the condition b) of the three-way valve, the third P3 and fourth P4 pipes communicates between each other.

[0037] Preferably, a first check valve FVV bypasses the three-way valve V1 connecting the pipes P4 and P5. If the engine is off, the piston can suck fresh coolant from the tank without switching the valve V1 into said a) condition. This means that instead of a three-way valve it is possible to implement a simple two-way valve on the pipe P4, installing a check valve on the pipe P5 and inserting a T connection instead of the three-way valve.

[0038] Furthermore, a sixth pipe P6 connects a higher portion of the ICE with a higher portion of the tank in order to permit the de-aeration of the ICE and a seventh pipe P7 connects a higher portion of the radiator R with said higher portion of the tank T in order to permit a de-aeration of the radiator.

[0039] A second valve V2 is preferably arranged on said sixth pipe P6 and a third valve V3 is preferably arranged on said seventh pipe P7.

[0040] Preferably, relief valve SPRV bypasses said third valve V3 permitting the radiator to discharge medium in the tank T in case of overpressure in the radiator.

[0041] As for the previous embodiment, when the piston is in the minimum displacement, the coolant chamber CH has the main size and vice versa, when the piston is in the maximum displacement, the coolant chamber CH has the minimum size.

[0042] According to this second embodiment, the ECU is programmed to develop at least one of the following operations:

When the engine is on the three-way valve is switched into said b) condition and the piston regulates the pressure into said cooling circuit over the above threshold or within the above range. Then the three-way valve is switched in said a) condition as long as said detected pressure is over said threshold or within said range of pressures.

[0043] When the ignition switches from ON to OFF, the three-way valve is switched in said b) condition and the piston is released towards said minimum displacement in order to depressurize the cooling circuit till the ambient pressure for the reasons depicted above.

[0044] When the ignition switches from off to on, an air detection procedure is carried out: the valve V1 assumes said b) condition and the piston moves towards the maximum position. The pressure sensor PR detects the pressure in the cooling circuit CC. The ECU compares the pressure variation with the force impressed by the piston to the cooling circuit and evaluates the amount of air in the cooling circuit, being the air compressible.

[0045] When the amount of air exceeds a predetermined threshold, a venting/de-aeration procedure is carried out.

[0046] The venting procedure depends mainly on the presence of one or both the branches P6 and P7.

[0047] According to the venting procedure, the valve V1 assumes the a) condition, thus the piston moves towards its minimum displacement. This implies that it sucks coolant from the tank T. Then, V1 switches into b) condition and the valve V2 and/or V3 is/are opened, while the piston moves towards its maximum displacement, thus air pushed from the engine and/or the radiator to the tank. Then the valves V2 and V3 are closed and maintained closed.

[0048] After the venting procedure, that can be executed for one or both branches, in parallel or in succession, the air detection procedure is carried out again and eventually the venting procedure is repeated for one or both the branches. In case the air detection procedure does not detect air in the cooling circuit, at least at the start of the engine, the piston is controlled according to a closed loop control to maintain a target pressure in the cooling circuit as long as the engine is on. After stabilization of the pressure in the cooling circuit, the valve 1 could be switched in said a) condition, disconnecting the piston form the cooling circuit.

[0049] When the ignition switch turned to position "ON" and the engine is not running, the ECU carries out a piston reset: ECU detects the position of the piston and in case it is outside a predetermined range of positions, preferably centrally arranged with respect to the whole piston displacement, the valve V1 is switched in the a) condition and the piston is moved to reach said predetermined range.

[0050] This procedure permits to maintain the piston in an intermediate position along its whole displacement, so as it is controlled to compensate positively or negatively the pressures variations detected in the cooling circuit CC.

[0051] In order to avoid the opposite situation where the piston is close to its minimum displacement condition, the displacement towards the minimum displacement condition during coolant sucking from the tank can be suitably limited.

[0052] Anyway, the "centering" operation of the piston in the above range of positions can be obtained by opening one or both the above valves V2/V3 as disclosed in the above venting procedure and moving the piston toward said intermediate position.

[0053] Figure 3 shows an example of piston actuated by means of the pneumatic circuit of the vehicle. Heavy vehicle, usually are provided with pneumatic circuit for controlling braking and/or suspensions of the vehicles. Therefore, figure 3 shows a preferred embodiment of the invention that can be combined with the above described according to the embodiment of figure 2.

[0054] The piston disclosed is pneumatically controlled and is of double-action type. In particular, it has a first or coolant chamber CH communicating with the cooling circuit as in the figures 1 or 2 and a left chamber LC and a right chamber RC separated from the left chamber through a central fixed septum.

[0055] Thus, the piston is a double-piston with two movable pistons interconnected by a plunger rod. The left movable piston defines, on the plunger face, said left chamber LC and on the opposite face compresses the coolant in the first chamber CH.

[0056] The left chamber LC communicates operatively with a pressurized air source, such as the above compressed air circuit, through the valve PV. The right chamber communicate also with a pressurized air source through the valve VV.

[0057] In the left chamber a pressure sensor Psens is arranged and operatively associated with the control unit ECU. In the right chamber also a pressure sensor Vsens is arranged and operatively associated with the control unit ECU.

[0058] The ECU is also configured to control the valves PV and VV on the basis of the pressure values measured by the PR sensor alone or also on the basis of Psens and Vsens measurements, first of all to pressurize the cooling circuit CC when the engine is running, or to carry out the above air detection and venting/de-aeration procedures or said piston reset.

[0059] Figure 3 shows also the pressure sensor PR associated to the cooling circuit, however it can be placed in any place of the cooling circuit; and the displacement sensor DS as disclosed above. It can be of any type, for example it can be determine the position of the double-piston along with the whole displacement of the piston or it can detect the piston only in predefined positions, for example an intermediate "centering" position along the whole displacement of the double-piston.

[0060] The valve VV has two positions (configurations) and it is suitable, in a first position (from the top), to con-

nect the right chamber with the Air pressure AS to build the pressure in the right chamber RC with the result to depressurize the left chamber LC and the cylinder or coolant chamber CH or, according to a second (neutral) position, to connect the right chamber with the ambient "am" (venting).

[0061] The valve PV has three positions. The first position (from the top) connects the left chamber LC with the ambient (venting) and the pressure source is sealed; the second (neutral) position interrupts all the ports, thus the left chamber and the pressure source are sealed; the third position communicate the left chamber with pressure source AS to pressurize the left chamber LC and thus the cylinder chamber CH.

[0062] Figure 3 is drafted according to standard convention on the pneumatic drawings, therefore is per se clear to the skilled person in the art.

[0063] According to the present embodiment, when ignition is off, the engine is not running and the three-way valve V1, disclosed in figure 2, assumes said b) condition, thus communicates the coolant chamber CH of the pressure cylinder with the cooling circuit CC and the air pressure valve PV is in neutral (second) position while, the valve VV is also in its neutral (second) position.

[0064] The pressure in the left chamber, also called "pressure-side chamber", can only be relieved via a pressure relief valve PRV1 communicating with the left chamber, instead the pressure from the right chamber RC is blown down to the atmospheric pressure.

[0065] When the hot internal combustion engine ICE is switched off, the temperature can rise up, thus the pressure in the cooling circuit causes the cylinder or coolant chamber CH to increase and the piston PS to move towards its minimum displacement position. The Air Pressure in the left chamber increases, being the septum fixed. If this exceeds the opening pressure of the pressure relief valve PRV1. However, despite the opening of such relief valve the pressure in the cooling circuit CC continues to rise even after reaching the piston minimum displacement, the above disclosed pressure relief valve SPRV opens bypassing said third valve V3 and permitting the radiator to discharge medium in the tank T, thus pressure builds up in coolant tank T.

[0066] The size of the water tank T is preferably designed and filled of coolant so that all excess of expanding coolant of the cooling circuit can flow into the tank T.

[0067] After some time since the engine switching off, the coolant temperature falls down and the coolant contracts.

[0068] The piston PS moves towards its maximum displacement position, therefore vacuum would be produced in the left chamber. In order to avoid such condition, the pressure retaining valve PRV2 communicates the left chamber with the ambient. If, despite of the opening of the pressure retaining valve PRV2 the piston PS reaches its maximum displacement position, this means that the cooling process in the cooling circuit CC has not yet been completed, thus, the check valve FVV disclosed on figure 2 can open possible by sharing the vacuum also with the coolant tank T. Advantageously, the cooling liquid is balanced until the cooling liquid has reached the ambient temperature and the cooling process is finished.

[0069] Instead of a double piston cylinder, it is also possible to use a cylinder with spring load piston in such a way, a spring moves the piston towards its minimum displacement, while one single chamber equivalent to the above left chamber is used to move the piston towards its maximum displacement position. In this case the valve VV is not required.

[0070] According to the present embodiment, instead to signal a warning to the driver when the ECU detect air in the system or a leak in the cooling system or a level sensor is installed in the tank and when the coolant falls under a predetermined level a warning is given to the driver.

[0071] This invention can be implemented advantageously in a computer program comprising program code means for performing one or more steps of such method, when such program is run on a computer. For this reason, the patent shall also cover such computer program and the computer-readable medium that comprises a recorded message, such computer-readable medium comprising the program code means for performing one or more steps of such method, when such program is run on a computer.

[0072] Many changes, modifications, variations and other uses and applications of the subject invention will become apparent to those skilled in the art after considering the specification and the accompanying drawings which disclose preferred embodiments thereof. All such changes, modifications, variations and other uses and applications which do not depart from the scope of the invention are deemed to be covered by this invention.

[0073] It should be understood that all the single features and/or embodiments can be combined between each other. In addition, the features disclosed in the prior art background are introduced only in order to better understand the invention and not as a declaration about the existence of known prior art. Therefore, also the features described in the prior art background can be considered in combination with those mentioned in each embodiment of the detailed description.

[0074] Further implementation details will not be described, as the man skilled in the art is able to carry out the invention starting from the teaching of the above description.

Claims

1. Cooling system of an internal combustion engine (ICE) comprising a cooling circuit (CC) with

   - a pump (P) to circulate coolant,
   - a radiator (R) suitable to disperse heat produced by the internal combustion engine in the

ambient,
- at least a first pipe (P1) to convey coolant from the internal combustion engine towards the radiator and
- at least a second pipe (P2) connecting the radiator with the pump,

The system further comprising

- a cylinder (C)/piston (P) assembly (CPA) defining a chamber (CH) suitable to be hydraulically connected with said second pipe (P2) though a third pipe (P3) communicating with said second pipe (P2),
- an actuator (A) connected to said piston in order to control its displacement in said cylinder, by varying said chamber volume,
- a pressure sensor (PR) in hydraulic communication with said cooling circuit (CC) and
- an electronic control unit (ECU) coupled with said pressure sensor and with said actuator and configured to control said actuator in order to maintain a pressure measured by said pressure sensor above a predetermined threshold.

2. System according to claim 1, wherein said control unit is configured to maintain said pressure in a predetermined pressure range.

3. System according to claims 1 or 2, wherein the chamber (CH) is provided with a baffle (B) of elastic material.

4. System according to claim 3, wherein said baffle is arranged on an inner surface of the chamber facing said piston.

5. System according to any of the previous claims, further comprising a displacement sensor (DS) to sense a position of the piston in said cylinder and wherein said electronic control unit is coupled also with said displacement sensor (DS) and configured so as when the piston reaches a maximum displacement condition corresponding to the smaller volume of the chamber (CH) and the pressure is still below said predefined threshold, then generate a warning.

6. System according to any of the previous claims, wherein said electronic control unit is configured to sense an ignition status ON/OFF and an internal combustion engine status ON/OFF.

7. System according to any of previous claims from 1 to 6, further comprising a three-way valve (V1), wherein a first port of the three-way valve (V1) communicate with said cooling circuit, wherein said cylinder/piston assembly is connected to a second port of said three-way valve (V1), and wherein the system further comprising a coolant tank (T) connected with a third port of said three-way valve (V1); wherein according to a first condition a) the three-way valve connects the cylinder/piston assembly with said coolant tank, and according to a second condition b) the three-way valve connects the cylinder/piston assembly with the cooling circuit (CC) and wherein said control unit (ECU) is configured to control also said three-way valve so as the three-way valve is in said b) condition when the piston displacement is adjusted to maintain a pressure measured by said pressure sensor above said predetermined threshold.

8. System according to claim 7, wherein said control unit (ECU) is further configure to carry out a cooling circuit filling by switching said three-way valve (V1) into said first condition a) and to move said piston towards its minimum displacement position by sucking coolant from said coolant tank (T).

9. System according to claims 7 or 8 wherein said control unit is further configured to carry out an air detection procedure:

- said three-way valve (V1) is commanded to assume said b) condition and the piston (PS) is commanded to move towards its maximum displacement position, while
- the pressure sensor (PR) detects the pressure in the cooling circuit (CC) and
- the ECU is configured to compare a pressure variation with a force impressed by said piston (PS) to the cooling circuit and evaluate the amount of air in the cooling circuit, provided that the air compressible.

10. System according to one of the claims 7 - 9, further comprising

- a sixth pipe (P6) connecting a higher portion of the internal combustion engine (ICE) with a higher portion of said coolant tank (T) and a second valve (V2), controllable, normally closed, arranged on said sixth pipe (P6) and/or
- a seventh pipe (P7) connecting a higher portion of the radiator (R) with a higher portion of the coolant tank (T) and a third valve (V3), controllable, normally closed, arranged on said seventh pipe (P7) and

wherein said control unit (ECU) is configured to carry out a de-aeration procedure comprising controlling

- said first three-way valve (V1) to assume said first condition a), thus
- the piston to move towards its minimum displacement position, then,
- said first three-way valve (V1) to switch into

said second condition b) and
- said second and/or third valves (V2, V3) to open, while the piston moves towards its maximum displacement, thus air is pushed from the engine and/or the radiator to the tank, then
- Said second and/or third valves (V2, V3) to close.

11. System according to any of previous claims from 7 to 10, further comprising a pressure source (AS) and wherein said piston/cylinder assembly is pneumatically actuated by means of said pressure source (AS).

12. System according to claim 11, wherein said piston is of double-action type having first and second movable pistons interconnected by a plunger rod, the first movable piston defining, on the plunger face, a first chamber (LC) and on the opposite face said chamber (CH) communicating with the cooling circuit (CC) and said second piston defines a second chamber (RC) wherein the first and second chambers are separated between each another through a central fixed septum, wherein said first chamber (LC) and second chamber (RC) are suitable connected with said pressure source to control a displacement of the piston within the cylinder.

13. System according to claim 11, wherein said first chamber (LC) communicates operatively with said pressurized air source through a first control valve (PV) and wherein, when ignition is off, said three-way valve (V) assumes said second condition b), and said first control valve (PV) is in neutral position while by interrupting all ports thereof.

14. Terrestrial vehicle comprising an internal combustion engine (ICE), a cooling system of the internal combustion engine according to any of the previous claims from 1 to 13.

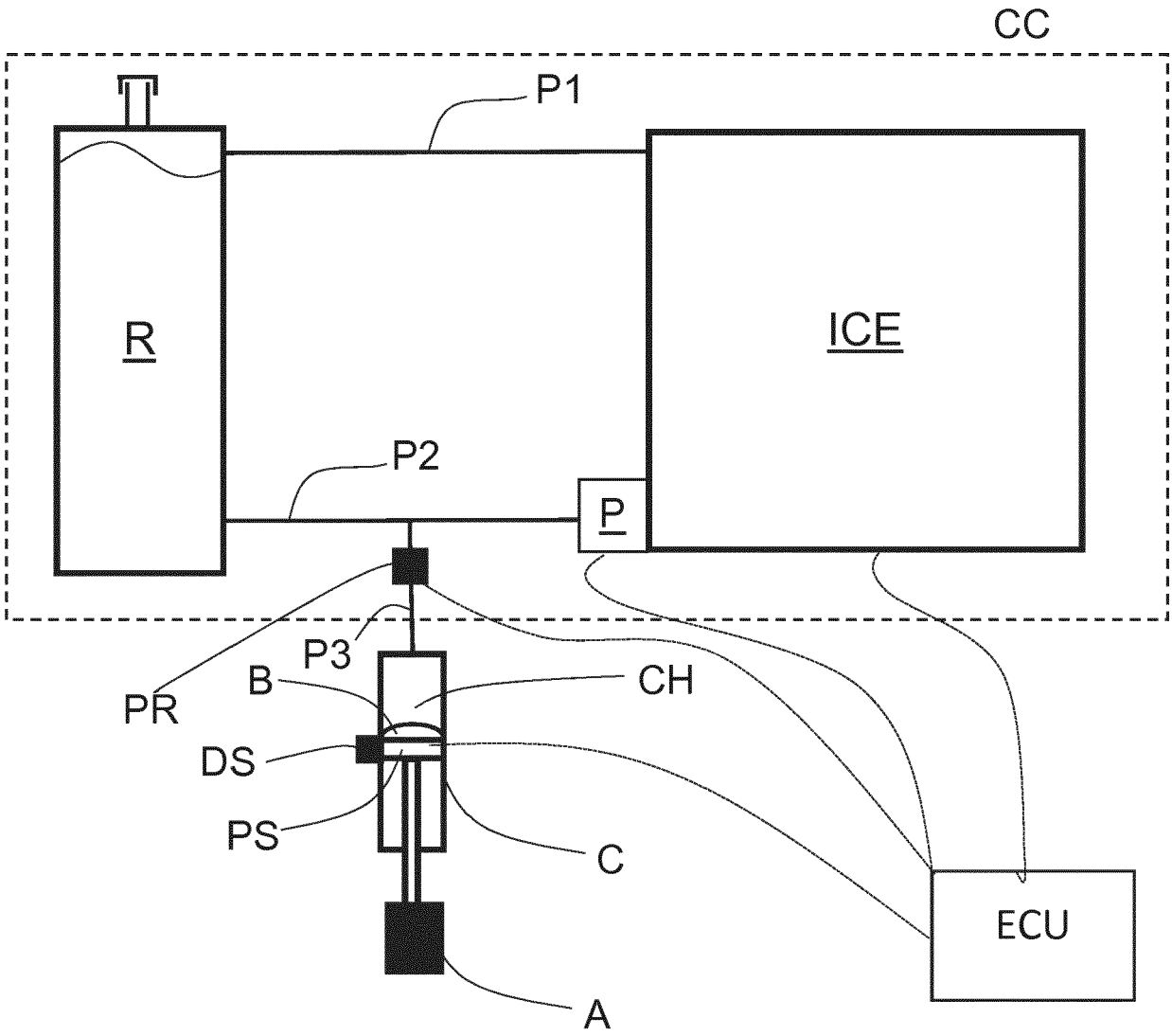

Fig. 1

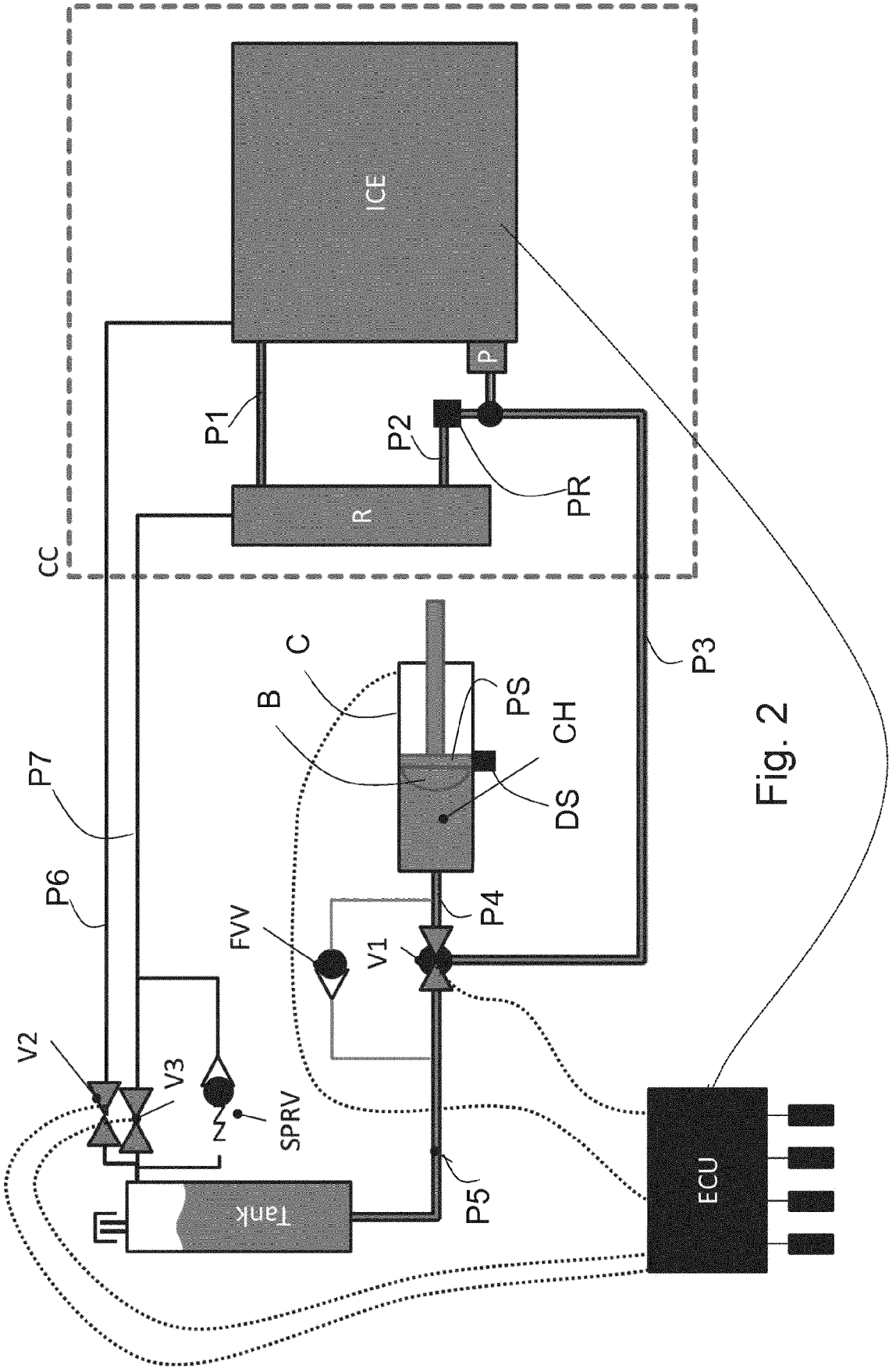
ICE
P
P1
P2
PR
R
CC
P3
C
B
PS
CH
DS
P7
P6
P4
FVV
V1
V2
V3
SPRV
Tank
P5
ECU

Fig. 2

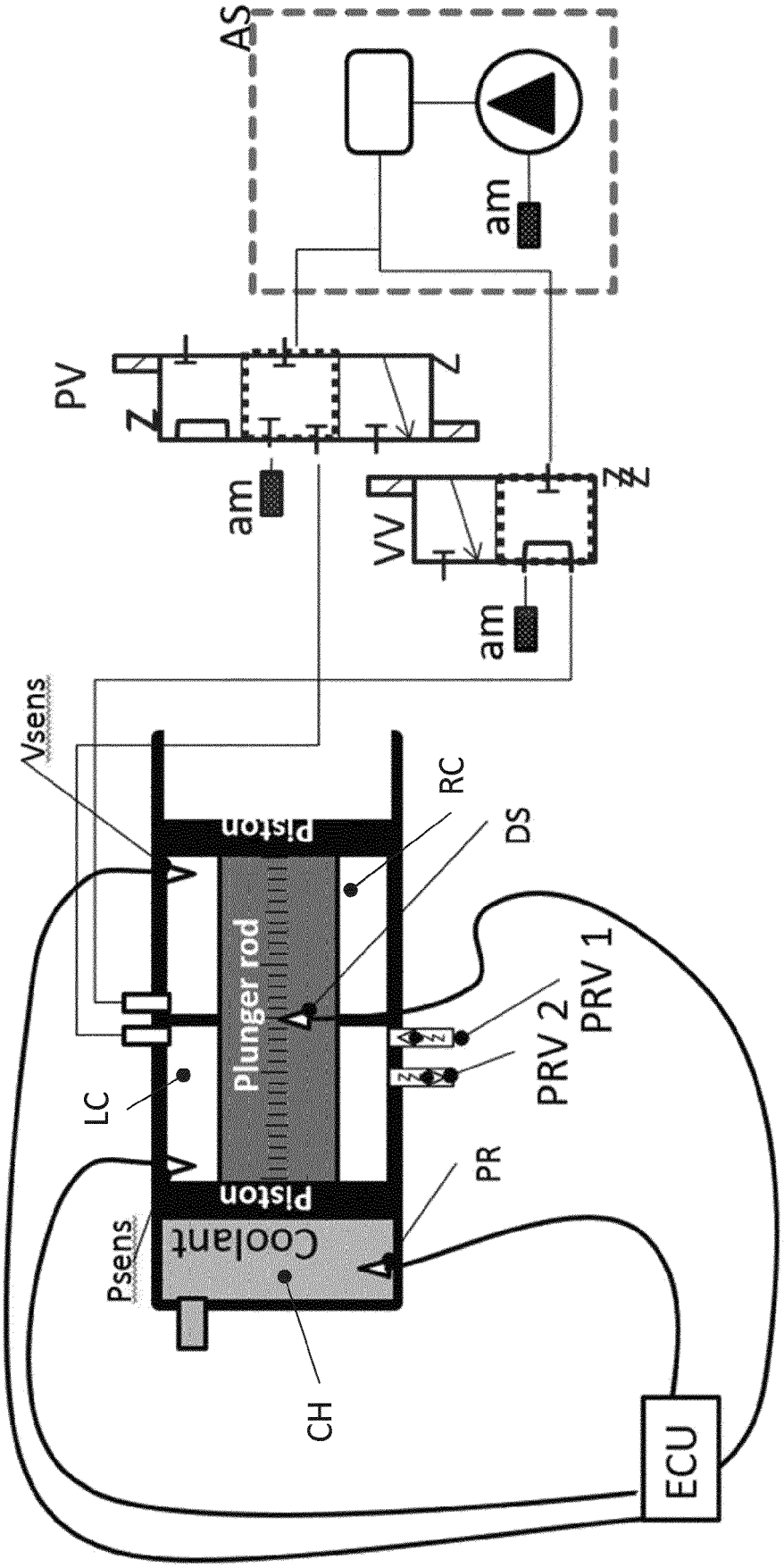
AS
am
PV
am
VV
am
Vsens
RC
DS
Piston
Plunger rod
Piston
Coolant
LC
Psens
PR
PRV 2
PRV 1
CH
ECU

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 17 20 5033

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

F01P

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	29 January 2018	Schwaller, Vincent

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 20 5033

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29-01-2018

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