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(54) **INTERNAL COMBUSTION ENGINE PROVIDED WITH A LIQUID COOLING SYSTEM**

(57) An internal combustion engine comprising a cooling circuit of the internal combustion engine including at least one first radiator, a circulation pump to cause a refrigerant to circulate through a plurality of users and a valve assembly arranged to adjust a fraction of refrigerant circulated through the radiator. The valve assembly con-

sists of a first valve and a second valve arranged in series relative to the first valve, wherein the second valve is arranged to define an operating temperature of the refrigerant and the first valve is arranged to selectively adjust flow rates of the refrigerant circulating through the plurality of users.

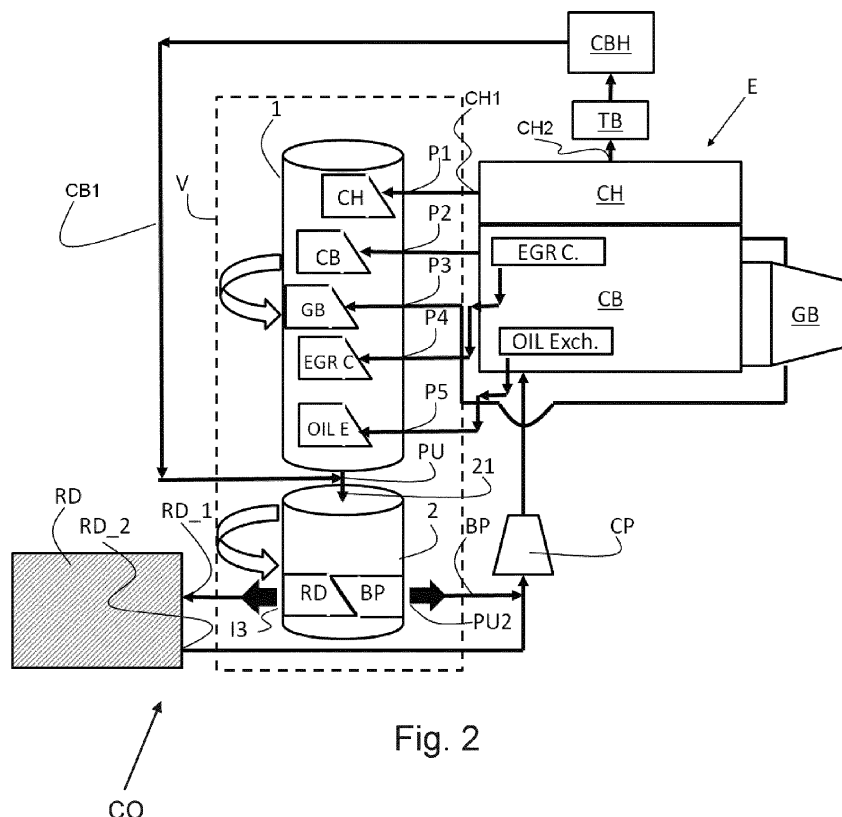


Fig. 2

Description

Cross-reference to related applications

[0001] This patent application claims priority from Italian patent application no. 102019000017663 filed on 01/10/2019.

Technical field of the invention

[0002] The invention relates to a cooling system of an internal combustion engine.

State of the art

[0003] In the field of internal combustion engine cooling, in some cases, the cylinder head and the engine block are cooled in a parallel manner, whereas, more often, the cooling water flows into the engine block and then entirely circulates through the cylinder head in order to be then collected in a suitable outlet manifold.

[0004] A radiator is connected to the cooling circuit in order to cool the water circulated in the internal combustion engine, thus releasing heat into the atmosphere.

[0005] A thermostatic valve generally steps in, bypassing the radiator as long as the water does not reach a predetermined temperature.

[0006] According to a known improving solution, a valve with a motor-driven rotating shutter is used, which allows for an adjustment of the flow rate of the cooling water, hereinafter referred to as "refrigerant", which flows through the internal combustion engine and other auxiliary elements. Among the auxiliary elements there are, for example, the exchanger for the oil of the engine or for the oil of the gearbox and the heater of the vehicle cabin housing the internal combustion engine.

[0007] Said valve comprises a port for each user, for example the cylinder head and the engine block, as well as two mixing ports, a first port being connected to the radiator and a second port being connected to the circulation pump, so as to bypass the radiator.

[0008] An opening rotation of the shutter determines an opening in sequence of the apertures of the relative users and the gradual switching between the first port and the second port.

[0009] Therefore, the ratio between the flow rate of the refrigerant flowing through the users and the temperature of the mixed water is fixed and depends on the angular position of the rotating shutter.

[0010] The basic difference from a traditional thermostatic valve lies in that the operating temperatures of the single users can be handled in a more accurate manner, so that they can operate at higher mean temperatures, in order to reduce frictions inside of the internal combustion engine.

[0011] Figure 1 of the prior art shows the interaction of the rotating shutter valve of the prior art with the users, the circulation pump, the radiator and the bypass of the

radiator.

[0012] If not specifically excluded by the detailed description below, the information contained in this part should be considered as an integral part of the detailed description itself.

[0013] Said prior art can be improved so as to obtain further benefits.

Summary of the invention

[0014] The aim of the invention is to improve the thermal control of an internal combustion engine and of a vehicle including said internal combustion engine.

[0015] The idea on which the invention is based is that of using a first valve, preferably with a rotating shutter, to adjust the flow rates of the refrigerant flowing through two or more users and a second valve, separate and distinct from said first valve and preferably with a rotating shutter, to adjust an operating temperature of the refrigerant.

[0016] An adjustment of the fluid flow rates evidently affects the temperatures of the cooled component, but, thanks to the invention, an operating temperature of the refrigerant is established independently of the fluid flow rates circuited in the different components cooled by the cooling circuit.

[0017] In other words, the temperature of the refrigerant is defined by the second valve, whereas the refrigerant flow rate in each cooled component is defined by the first valve.

[0018] Hereinafter, the term "user" indicates a component cooled by the cooling circuit.

[0019] Thanks to the invention, the flow rate of the refrigerant circulated through the single users is independent of the temperature of the refrigerant sent to the users themselves.

[0020] The first valve and the second valve are controlled by means of respective electric motors, which are independent of one another.

[0021] In other words, while the sole rotating shutter valve of the prior art adjusts, at the same time, the refrigerant flow rates and the refrigerant temperature according to predetermined fixed ratios, in this invention these functions are divided between the first and the second valve, thus potentially leading to infinite combinations between flow rates and operating temperature of the refrigerant fluid circulated through the users. Furthermore, the possibility of adjusting the temperature of the recirculated fluid independently of the recirculated flow rates allows for ideal engine pressurization levels; indeed, keeping the temperature of the fluid high, in order to reach predetermined temperatures within the single cooled components it is possible to circulate greater refrigerant flow rates with a consequent ideal pressurization of the cooled component. The valve assembly comprises the first valve and the second valve and is connected between the outlet of the users and the inlet of the circulation pump, upstream or downstream of said at least one radiator.

[0022] Thanks to the invention, the possible cavitation of refrigerant in the ducts inside the users is completely avoided.

[0023] The first valve preferably controls, in a sequential manner, at least the flow rates of the refrigerant flowing through at least two different portions of the internal combustion engine, such as for example the cylinder head and the engine block.

[0024] Therefore, the portions of the internal combustion engine are inserted in a first circuit including the first valve, the second valve, the radiator, which, depending on the position of the second valve, is at least partially included or completely bypassed, and a circulation pump. According to another preferred variant of the invention, the cooling circuit comprises two distinct and separate radiators, which are arranged in series relative to one another, and the second valve is connected in parallel to the series of the first and second radiator; this parallel configuration, which is obtained by so doing, is connected immediately downstream of the first valve.

[0025] A duct connects the connection point between the outlet of the first radiator and the inlet of the second radiator to a port of the second valve.

[0026] The outlet of the second valve is connected to the inlet of the recirculation pump.

[0027] Unlike the first variant, this variant allows the water coming from the first valve to be mixed with the valve coming from the first radiator or from the series of the first and second radiator. This allows for a quick cooling of the refrigerant under maximum thermal load conditions. Indeed, the series of the first and second radiator corresponds to the nominal exchange surface needed for a predetermined application. The fact that the radiator is divided into two portions allows for a greater efficiency of the first one, namely the one directly connected to the first valve, in the exchange of heat with the atmosphere, whereas the second radiator, which is less efficient for it has a lower temperature, is used only occasionally and to face greater loads, thus offering further advantages. According to a preferred variant of the invention, the second radiator can be steadily used in an independent circuit to cool the air compressed by the supercharging compressor of the internal combustion engine and, when needed, it is introduced in the cooling circuit of the internal combustion engine to face possible load and heat peaks.

[0028] According to a further preferred embodiment of the invention, which can be combined with any one of the previous variants, the second valve is connected not only to the radiator or radiator battery and to the circulation pump, but also to a heat recuperator.

[0029] Heat recuperators are heat exchanger arranged on the exhaust pipe as last component and are used in the first engine cold start phases in order to recover the heat content of the exhaust gases to heat the refrigerant. In this variant of the invention, as well, the second valve has the task of defining the operating temperature of the refrigerant, whereas the first valve adjusts the flow rates.

[0030] Thanks to the invention, the temperature of the users can be controlled independently of the flow rate of the refrigerant flowing through the users themselves, thus ensuring a uniform distribution of the heat, which allows the engine to operate at higher temperatures with a great accuracy.

[0031] The fact of operating at higher temperatures allows for a reduction in the viscosity of the oil and, hence, in the frictions of the mechanical components, thus increasing the efficiency thereof without the risk of thermal shocks of some of the users.

[0032] The claims describe preferred embodiments of the invention, thus forming an integral part of the description.

Brief description of the figures

[0033] Further aims and advantages of the invention will be best understood upon perusal of the following detailed description of an embodiment thereof (and of relative variants) with reference to the accompanying drawings merely showing non-limiting examples, wherein:

figure 1 shows a shutter valve of the prior art;
figure 2 shows a diagram of an example of cooling circuit according to a first variant of the invention;
figure 3 shows a diagram of an example of cooling circuit according to a second variant of the invention;
figure 4 shows a variant of the diagram of figure 3;
figure 5 shows an angular diagram of an example of operating coordination between the first and the second valve of figures 2 and 3;
figure 6 shows a diagram of a vehicle comprising an internal combustion engine, an exhaust gas after-treatment device, a cooling circuit of the internal combustion engine integrated in the conditioning system of the vehicle cabin. In the figures, the same numbers and the same reference letters indicate the same elements or components.

[0034] For the purposes of the invention, the term "second" component does not imply the presence of a "first" component. As a matter of fact, these terms are only used as labels to improve clarity and should not be interpreted in a limiting manner.

[0035] The elements and features contained in the different preferred embodiments, drawings included, can be combined with one another, without for this reason going beyond the scope of protection of this patent application, as described hereinafter.

Detailed description of embodiments

[0036] Figure 2 shows a first preferred variant of the cooling circuit CO of the invention.

[0037] An internal combustion engine E comprises a cylinder head CH, which is coupled to an engine block CB, where at least one cylinder is obtained, in which a

relative piston slides.

[0038] The drive shaft (not shown) is connected to a transmission, which preferably comprises a gearbox GB.

[0039] The invention can also be dedicated to a fixed installation, in which the internal combustion engine E drives an electric generator and, therefore, the gearbox GB could be absent.

[0040] According to the invention, the cooling circuit CO of the internal combustion engine includes at least:

- at least one first radiator RD,
- a circulation pump CP to circulate a refrigerant through a plurality of users, among which said cylinder head and said engine block are included, and
- a valve assembly V arranged to control a fraction of refrigerant circulated through the radiator RD.

[0041] Like the prior art, the valve assembly defines the fraction of refrigerant sent to the users of the cooling circuit without any cooling of the refrigerant and a remaining part circulated through the radiator RD and subsequently sent to the users, thus obtaining a mixing of hot refrigerant flowing out of the users and cold refrigerant flowing out of the radiator RD.

[0042] Unlike the prior art, though, the valve assembly does not include one single valve, but two valves 1, 2:

- a first valve 1 having at least two inlet ports P1, P2, P3, ..., a first inlet port P1 being operatively connected to said cylinder head CH and a second inlet port P2 being connected to said engine block CB, and an outlet port PU,
- a second valve having at least one first inlet port 21, which is operatively connected to the outlet port PU of the first valve 1, and at least two further ports I2, I3 or I2 - I5, a first one I2 being directly connected to the circulation pump CP and a second one I3 or I3, I4 being indirectly connected to the circulation pump CP through the first radiator RD or RD1 or the series of RD1 and RD2, as described below; wherein said second valve is arranged to define an operating temperature of the refrigerant and said first valve is arranged to selectively adjust the flow rates of the refrigerant circulating through said at least two inlet ports P1, P2, P3,....

[0043] Therefore, the second valve 2 is arranged to adjust a mixing of refrigerant flowing out of the plurality of users with refrigerant flowing out of said at least one radiator RD.

[0044] It is evident that the second valve can completely bypass said at least one radiator, so that the entire recirculated refrigerant is the same as the refrigerant flowing out of the plurality of users.

[0045] In the same way, the users involved in the mixing carried out by the second valve 2 depend on the position of the first valve 1, since the latter could potentially completely stop the circulation of refrigerant through the

plurality of users.

[0046] Figure 2 and figures 3/4 show variants applying the invention.

[0047] According to the diagram of figure 2, there is one single engine cooling radiator RD, which is arranged downstream of the second valve 2, so that the following sequence is obtained:

first valve 1, second valve 2, radiator RD, pump CP, engine E.

[0048] According to the diagram of figures 3 and 4, the first radiator RD1 is operatively interposed between the first valve 1 and the second valve 2, so that the following sequence is obtained:

first valve 1, first radiator RD1, second valve 2, second radiator RD2, pump CP, engine E. This allows the radiators RD1 and RD2 to be arranged in series.

[0049] Figure 4 differs from figure 3 only in that the second radiator is connected to a cooling circuit for the air compressed by the compressor, so that it can be introduced in the cooling circuit of the engine only when it is necessary.

[0050] According to figure 4, the second radiator is connected, independently of the operating conditions of the second valve, to a heat exchanger WCAC designed to work as an intercooler. An electric pump ePump allows the refrigerant to circulate through the circuit including the second radiator RD2, the electric pump ePump and the exchanger WCAC.

[0051] When needed, the second valve allows the second radiator to operate in series with the first radiator, thus evidently worsening the efficiency in the cooling of the air compressed by the supercharging compressor, but causing an immediate benefit for the internal combustion engine E when it needs to face a sudden load or heat peak.

[0052] As far as the sizing is concerned, given a target heat exchange surface, it can be obtained by adding the first and the second radiator.

[0053] This implies that, if the second radiator is generally involved in the circuit of the WCAC, the sizing thereof does not need to depend on the needs of the WCAC, but on the nominal needs of the internal combustion engine, taking into account the exchange surface of the first radiator RD1.

[0054] Anyway, it is evident that the electric pump ePump can be properly controlled taking into account the dimensions of the second radiator RD2. In other words, if the latter is oversized because of the task linked to the WCAC, it means that the flow rate of the refrigerant pumped by the WCAC can proportionally be reduced, taking into account that the risks of cavitation are modest or non-existent in that circuit.

[0055] The cylinder head of the internal combustion engine preferably comprises an opening, which is directly connected to the inlet 21 of the second valve 2. As a matter of fact, the first valve is at least partially bypassed by means of this bypass connection CB1 for the first valve. Said opening allows the cylinder head to always

have a minimum circulation of refrigerant, preventing it from boiling in contact with some inner parts of the cylinder head that can reach high temperatures. For example, when the exhaust manifold is inside the cylinder head, temperatures can reach 500°C very quickly.

[0056] In any case, this arrangement avoids thermal fatigue or cavitation phenomena due to a local boiling on the flame plate or in the bridges between the valves, in particular between the two exhaust valves of an engine provided with 4 valves per cylinder.

[0057] If the internal combustion engine E is also provided with a turbocharger unit TB cooled by means of the same refrigerant, said unit is preferably connected to the bypass connection CB1 for the first valve, so as to have a predetermined and constant circulation of refrigerant. When the internal combustion engine is designed for a vehicle application, downstream of the turbocharger there is the heater CBH of the cabin of the vehicle VHE, which is useful for a relative HVAC, namely a conditioning device for the cabin CAB of the vehicle, HVAC meaning "Heating, Ventilation and Air Conditioning", which is well known to a person skilled in the art.

[0058] The first valve 1 and/or the second valve 2 preferably are valves with a rotating shutter, in which an aperture respectively corresponds to each inlet and outlet port, the opening of the aperture depending on an angular position of a shutter within a respective valve body.

[0059] The first valve can comprise an axial through path, which is not adjustable, so that the bypass of the first valve can be obtained by following said path, which leads to the outlet PU, to which the different ports P1, P2, etc. are connected.

[0060] According to a preferred variant of the invention, which can be combined with any one of the variants described above, the engine comprises an EGR circuit, namely a circuit used to recirculate exhaust gases through the engine itself in order to reduce Nox generated during the combustion taking place in the internal combustion engine. Hereinafter, for greater simplicity, the internal combustion engine E will simply be referred to as "engine". The exhaust gas recirculation circuit can comprise a first heat exchanger EGRC, which defines a further user of the cooling circuit, so that the first valve 1 comprises a fourth port (see figure 5), which is operatively connected to the outlet of the first heat exchanger.

[0061] When the engine is associated with a gearbox GB, the latter generally has an oil lubrication and cooling circuit with a relative third heat exchanger, which, for greater simplicity, is indicated with the same symbol GB as the entire gearbox. The outlet of said third exchanger is connected to a third inlet port P3 of the first valve 1. Furthermore, the internal combustion engine E itself comprises an oil lubrication circuit and a relative second heat exchanger OIL Exch, which is cooled by means of the refrigerant of the circuit according to the invention. Therefore, the first valve 1 comprises a fifth inlet port P5, which is operatively connected to the outlet of the second heat exchanger OIL Exch.

[0062] Different users, besides the engine itself, have been listed, each of said users being optional; furthermore, further users can be provided and be connected to the first valve 1, preferably by means of relative ports.

[0063] According to a preferred variant of the invention, which can be combined with any one of the preceding variants, the internal combustion engine E comprises an exhaust pipe EP, on which an exhaust gas treatment device ATS is arranged. Downstream of the ATS, according to the exhaust gas circulation direction, on the exhaust pipe EP there is a heat recuperator EX. Exch.. It consists of a gas/liquid heat exchanger, in which the liquid coincides with the refrigerant, whereas the gas coincides with the exhaust gas produced by the internal combustion engine.

[0064] Said heat recuperator allows the heat of the exhaust gas to be recovered before being released into the atmosphere. It helps adjust the temperature of the refrigerant.

[0065] An inlet of the heat recuperator is connected in a point of the cooling circuit between the outlet of the valve 1 and the inlet of the valve 2, whereas the outlet of the exchanger feeds a dedicated inlet aperture of the valve 2 and, through the latter, the engine E, more precisely the users defined by engine itself, among which there are the cylinder head, the engine block and, optionally, the EGR cooler EGR C, the engine oil cooler OIL Exch. and the cooler of the oil of the gearbox GB, which, despite not being part of the engine, generally receives the refrigerant from the engine itself.

[0066] A valve 3 can be placed in the exhaust gas circuit, thus allowing the gases to completely bypass the heat recuperator Ex. Exch..

[0067] It is optional, since the second valve 2 is decisive in allowing or not allowing the heat recuperator to be inserted in the cooling circuit, but it is useful to prevent the refrigerant fluid from boiling inside said exchanger under exhaust gas high temperature conditions, while the heat recuperator is excluded from the circulation of refrigerant by the second valve.

[0068] Owing to the above, the cooling circuit, despite having to fulfil a limited engine cooling function under cold start conditions, is activated in order to accumulate heat and allow the refrigerant, first, and the users, as a consequence, to reach the best thermal operating conditions.

[0069] It should also be clear that the drawings do not show the portion of the cooling circuit that splits the refrigerant pumped by the pump CP among the different users: these details, which are usually incorporated in the channels obtained, through casting, in the crankcase of the engine, are known to a person skilled in the art.

[0070] The cooling circuit can get into the engine through one single inlet or can get into the different users from the outside.

[0071] According to a preferred variant of the invention, the refrigerant flows into the engine E through one single opening made in the engine block, which allows access

to the liner of the engine block and, from the liner, the refrigerant flows into the cylinder head, cools the exhaust manifold integrated in the cylinder head and flows out of the engine through a first outlet opening CH1, which is connected to the first port P1, a second outlet port CH2, which is connected to the bypass connection CB1 for the first valve, and a third opening, which opens up in the liner of the engine block.

[0072] A preferred control method to control the valves 1 and 2 in relation to the operating conditions of the engine is described below. Said method, in the example discussed herein, entails the presence of different users besides the internal combustion engine and entails the presence of one user. It is evident that one or more users can be absent and the presence of the heat recuperator is completely optional.

[0073] According to the method, the first valve is controlled according to at least one of the procedures listed below as the refrigerant flow rates increase starting from a condition of complete closing of the ports of the first valve:

- B) complete closing of all the apertures of the first valve;
- transition B) -> C), gradual opening of the first port (P1) to allow the refrigerant to only circulate through the cylinder head, up to
- C) complete opening of the first port (P1);
- transition C) -> D), gradual opening of the fourth and fifth ports to allow the refrigerant to also circulate through the first exchanger (EGR exch) and the oil lubrication exchanger of the internal combustion engine, up to
- D) complete opening of the fourth and fifth ports (P4, P5) ;
- transition D) -> E), gradual opening of the third port (P3) to allow the refrigerant to circulate through the third exchanger (GB), up to
- E) complete opening of the third port (P3);
- transition E) -> G), gradual opening of the second port (P2) to allow the refrigerant to circulate through the engine block (CB), up to
- G) complete opening of the second port (P2);
- F) complete closing of the fifth port (P5) in an intermediate position between E) and G), so as to exclude the second oil exchanger;
- H) complete closing of the third port (P3), so as to exclude the third heat exchanger (GB);
- transition I) -> L) gradual opening of the third and fifth ports (P3, P5) so as to allow the refrigerant to circulate through the third heat exchanger (GB) and the second exchanger (OIL Exch), up to
- L) complete opening of all the ports (P1, ...P5).

[0074] State A represents the fact that the bypass duct CB1 bypasses the first valve 1, thus allowing the refrigerant to circulate through the cylinder head of the engine and through the jacket of the turbocharger, regardless of

the operating condition of the first valve 1.

[0075] The first valve preferably has an outer cylindrical jacket and an inner shutter, which is also cylindrical, and the bypass CB1 is obtained in the first valve 1 by means of a path that is axial relative to the first valve.

[0076] The procedures listed above depend on the users available, some transitions and some operating conditions can be absent because the relative users are absent.

[0077] Furthermore, the procedures include both almost-static conditions and transitions and it has to be clear that, by adjusting the refrigerant flow rate with continuity through the different users, the corresponding operating conditions of the first valve 1 define a continuous sequence of states, even if the apertures made in the rotating shutter can be shaped so as to open and/or close in a quicker or less quick manner.

[0078] The first operating condition of the valve is identified with condition B) and not A), since there is an implicit condition of circulation of the refrigerant through the connection duct CB1, regardless of the operating condition of the first valve.

[0079] As far as the control of the second valve is concerned, it is controlled as the temperature of the refrigerant increases starting from a cold start by means of the following procedures:

- a) circulating the refrigerant through said heat recuperator (Ex. Exch.),
- transition a) -> b), gradually reducing the flow rate of the refrigerant circulating in the recuperator by increasing the flow rate of the refrigerant directly circulated, through a bypass duct BP, in the engine, up to
- c) complete exclusion of the recuperator and complete opening of the bypass duct;
- transition b) -> c), reducing the flow rate of the refrigerant circulated through the bypass duct by gradually increasing the flow rate of the refrigerant circulating through said at least one first radiator (RD1), up to
- d) a complete circulation of the refrigerant through said at least one radiator (RD1);
- transition c) -> d), opening the second radiator (RD2) arranged in series to and downstream of the first radiator (RD1) up to a complete in-series condition of the first and the second radiators, so as to abruptly lower the temperature of the refrigerating fluid in order to avoid an overheating of some components or in order to prevent a natural knock in a petrol engine;
- transition d) -> a), switching from a condition in which both the first and the second radiators (RD1, RD2) are included in the cooling circuit to a condition in which they are excluded and the fourth heat exchanger (EX. Exch.) is reintroduced in the cooling circuit.

[0080] This last transition is particularly useful when, at the end of a high load phase, the load drastically decreases and, therefore, a relatively high temperature of the refrigerant needs to be restored.

[0081] Below you can find a description of a joined control of the first and second valves starting from a cold start condition up to a steady running condition:

- (step 1) the first valve is kept in position B) and the second valve in position a) and, as the temperature of the refrigerant increases, the second valve remains still while the first valve carries out the aforementioned transition B) -> C),
- (step 2) the second valve, after having reached a predetermined temperature, starts to actuate the transition a) -> b);
- (step 3) the first valve carries out the transition C) -> D) by opening the circulation also in said first exchanger (EGRC) and second exchanger (OIL Exch);
- (step 4) as the temperature increases, the first valve remains still in position D while the second valve carries out the following transition b) -> c);
- (step 5) when the engine is warm, the cooling circuit of the engine block is opened and, subsequently, the following transitions are carried out

- E) -> F) and then
- F) -> G) and then
- G) -> H),

so that the oil of the engine and the oil of the gearbox can reach a threshold temperature ranging from 110° to 120°C without degradation, with a significant lowering of the viscosity and of the losses due to friction;

- (step 6) upon exceeding of said threshold temperature, said first valve carries out the transition I) -> L) so as to avoid reaching an oil degradation temperature of approximately 150°C;
- (step 7) in case of great vehicle loads, said second valve carries out the transition d) -> e) by also introducing said second radiator (RD2) in the cooling circuit;
- (step 8) in case of a drastic and abrupt reduction of the load, the second valve carries out the transition e) -> a) so as to bring the temperature of the fluid back to an ideal value.

[0082] This invention can be advantageously implemented by means of a computer program comprising coding means for carrying out one or more steps of the method, when the program is run on a computer. Therefore, the scope of protection is extended to said computer program and, furthermore, to computer readable means comprising a stored message, said computer readable means comprising program coding means to carry out one or more steps of the method, when the program is run on a computer.

[0083] The non-limiting example described above can

be subjected to variations, without for this reason going beyond the scope of protection of the invention, comprising all embodiments that, for a person skilled in the art, are equivalent to the content of the claims.

[0084] When reading the description above, a skilled person can carry out the subject-matter of the invention without introducing further manufacturing details.

10 Claims

1. An internal combustion engine (E) comprising an engine block (CB), in which at least a piston is coupled in a respective cylinder, and a cylinder head (CH) coupled with said engine block, a cooling circuit (CO) of the internal combustion engine including

- at least one first radiator (RD),
- a circulation pump (CP) for circulating a refrigerant through a plurality of users, among which said cylinder head and said engine block are included, and
- a valve assembly (V) arranged to control a fraction which is part of the refrigerant circulated through the radiator (RD),

the valve assembly (V) consisting of

- a first valve (1) having at least two inlet ports (P1, P2, P3 ...) wherein a first inlet port (P1) is operatively connected with said cylinder head (CH) and a second inlet port (P2) is connected with said engine block (CB) and an outlet port (PU),
- a second valve having at least one first inlet port (21) operatively connected with said outlet port (PU) of the first valve (1) and at least two further ports (I2, I3; I2 - I5), of which a first (I2) is directly connected with said circulation pump (CP) and a second (I3; I3, I4) is indirectly connected with said circulation pump (CP) through said at least one first radiator (RD; RD1; RD1, RD2) ;

wherein said second valve is arranged to define an operating temperature of the refrigerant and said first valve is arranged to selectively adjust the flow rates of refrigerant circulating through said at least two inlet ports (P1, P2, P3, ...).

2. The engine according to claim 1, wherein said second valve is arranged to adjust a mixing between refrigerant flowing out of said plurality of users and refrigerant flowing out of said at least one radiator.

3. The engine according to claim 1 or 2, wherein said first valve and/or said second valve is/are of the rotating shutter type, wherein an aperture corresponds

respectively to each inlet and outlet port, the opening of the aperture depending on an angular position of a shutter within a respective valve body.

4. The engine according to any one of the claims from 1 to 3, further comprising an EGR exhaust gas recirculation device and a respective first heat exchanger (EGRC) cooled by means of said refrigerant fluid, and wherein said first valve (1) comprises a fourth inlet port (P4) operatively connected with said first heat exchanger. 5
5. The engine according to any one of the preceding claims from 1 to 4, wherein said internal combustion engine further comprises an oil lubrication circuit and a respective second heat exchanger (OIL Exch) cooled by means of said refrigerating fluid and wherein said first valve (1) comprises a fifth inlet port (P5) operatively connected with said second heat exchanger. 10
6. The engine according to any one of the preceding claims from 1 to 5, wherein said internal combustion engine comprises a transmission including a gearbox (GB) further comprises a respective oil lubrication circuit and a respective third heat exchanger (GB) cooled by means of said refrigerant fluid, and wherein said first valve (1) comprises a third inlet port (P3) operatively connected with said third heat exchanger. 15
7. The engine according to any one of the preceding claims from 1 to 6, further comprising an exhaust pipe (EP) and a fourth heat exchanger (Ex. Exch) arranged on said exhaust pipe for recovering heat from exhaust gases produced by the internal combustion engine before being released into the environment, and wherein said fourth heat exchanger is operatively connected 20
 - with said cooling circuit in a point arranged immediately downstream of said first valve (1) and
 - with a second inlet port (I5) of said second valve (2), wherein said second valve is arranged to define a temperature of the refrigerant by adjusting a mixing between refrigerant circulated in said internal combustion engine (E) with refrigerant circulated through said fourth heat exchanger (EX. Exch) or refrigerant circulated through said internal combustion engine with refrigerant circulated through said at least one first radiator (RD1). 25
8. The engine according to claim 7, further comprising a second radiator (RD2) connectable in series and downstream of said first radiator (RD1) or by-passable and wherein said second radiator (RD2) has a respective inlet (RD2_1) operatively connected with 30
 - an outlet (RD1_2) of said first radiator (RD1) and a respective outlet (RD2_2) connected with a third inlet port (I4) of said second valve, and wherein said second valve is adapted to adjust a mixing of refrigerant drained from the outlet of said first radiator and from the outlet of said second radiator. 35
9. The engine according to any one of the preceding claims from 1 to 8, wherein said cylinder head (CH) comprises a first opening (CH1) operatively connected with said first port (P1) of said first valve (1) and a second opening (CH2) connected with said first inlet port (21) of the second valve (2) by means of a connection duct (CB1). 40
10. The engine according to claim 9, further comprising a turbocharger (TB) cooled by means of said refrigerant and wherein a cooling jacket of the turbocharger is operatively arranged on said connection duct (CB1) between said second opening of the cylinder head and said first inlet port (21) of the second valve (2). 45
11. A vehicle comprising an internal combustion engine according to claim 9 or 10 and wherein a heater (CBH) of a vehicle cabin is arranged on said connection duct (CB1) between said jacket and said first inlet port (21) of the second valve (2). 50
12. A control method for controlling the valve assembly (V) of an internal combustion engine (E) according to any one of the claims from 1 to 10, wherein said second valve (2) is controlled so as to reach a predetermined target temperature of the circulated refrigerant, while said first valve (1) is controlled independently of the second valve so as to reach predetermined target flow rates on each of the users. 55
13. The control method according to claim 12 comprising at least one of the following listed procedures as the flow rates of the refrigerant increase starting from a condition of complete closure of the ports of the first valve:
 - B) complete closure of all the apertures of the first valve;
 - transition B) -> C) gradual opening of the first port (P1), to enable a circulation of refrigerant only through the cylinder head up to
 - C) complete opening of the first port (P1);
 - transition C) -> D) gradual opening of the fourth and fifth ports to enable a circulation of refrigerant also through the first exchanger (EGR exch) and the oil lubrication exchanger of the internal combustion engine, up to
 - D) complete opening of the fourth and fifth ports (P4, P5) ;
 - transition D) -> E) gradual opening of the third

- port (P3) to enable a circulation of refrigerant through the third exchanger (GB), up to
- E) complete opening of the third port (P3);
 - transition E) -> G) gradual opening of the second port (P2) to enable the refrigerant to circulate through the engine block (CB), up to
 - G) complete opening of the second port (P2);
 - F) complete closure of the fifth port (P5) in an intermediate position between E) and G), so as to exclude second oil exchanger;
 - H) complete closure of the third port (P3), so as to exclude the third heat exchanger (GB);
 - transition I) -> L) gradual opening of the third and fifth ports (P3, P5) so as to enable the refrigerant to circulate through the third heat exchanger (GB) and the second exchanger (OIL Exch), up to
 - L) complete opening of all the ports (P1, ...P5).
- 14.** The control method according to claim 13, comprising at least one of the following listed procedures as the refrigerant temperature increases starting from a cold start and carried out through said second valve:
- a) circulating the refrigerant through said heat exchanger (Ex. Exch.),
 - transition a) -> b) gradually reducing the flow rate of refrigerant circulating in the recuperator by increasing a flow rate of circulated refrigerant, through a bypass duct (BP) directly in the engine, up to
 - c) complete exclusion of the recuperator and a complete opening of the bypass duct;
 - transition c) -> d) reducing the flow rate of refrigerant circulated through the bypass duct by gradually increasing a flow rate of refrigerant circulating through said at least one first radiator (RD1), up to
 - d) a complete circulation of the refrigerant through the at least one radiator (RD1);
 - transition e) -> f) opening the second radiator (RD2) arranged in series and downstream of the first radiator (RD1) up to a complete serialization of the first and the second radiators, so as to abruptly lower the temperature of the refrigerating fluid to avoid an overheating of any components or to prevent a natural detonation in a petrol engine;
 - transition f) -> a) switching from a condition in which both the first and the second radiators (RD1, RD2) are included in the cooling circuit to a condition in which they are excluded and the fourth heat exchanger (EX. Exch.) is reintroduced in the cooling circuit.
- 15.** The method according to claim 14, carried out from a cold start condition to a regime condition:
- (step 1) the first valve is kept in the position B) and the second valve in the position a), and as the temperature of the refrigerant increases, the second valve remains still while the first valve carries out the aforementioned transition B) -> C),
 - (step 2) the second valve, after having reached a predetermined temperature, starts to actuate the transition a) -> b);
 - (step 3) the first valve carries out the transition C) -> D) by opening the circulation also in said first exchanger (EGRC) and second exchanger (OIL Exch);
 - (step 4) as the temperature increases, the first valve remains still in the position D) while the second valve carries out the following transition c) -> d);
 - (step 5) when the engine is warm, also the cooling circuit of the engine block is opened and subsequently the following transitions are achieved
 - E) -> F) and then
 - F) -> G) and then
 - G) -> H),
 so that the oil of the engine and the oil of the gearbox can reach a threshold temperature comprised between 110° - 120°C without degradation, with a significant lowering of the viscosity and the losses by friction;
 - (step 6) at the exceeding of said threshold temperature, said first valve carries out the transition I) -> L) so as to avoid reaching a degradation temperature of the oil, of approximately 150°C;
 - (step 7) in the case of high vehicle loads, said second valve carries out the transition e) -> f) by introducing also said second radiator (RD2) in the cooling circuit;
 - (step 8) in the case of drastic and abrupt reduction of the load, the second valve carries out the transition f) -> a) so as to bring the temperature of the fluid to an optimal value.
- 16.** A computer program comprising program coding means adapted to carry out the control method of claim 15, when said program is made to run on a computer.
- 17.** Computer readable means comprising a recorded program, said computer readable means comprising program coding means adapted to carry out the control method of claim 15, when said program is made to run on a computer.

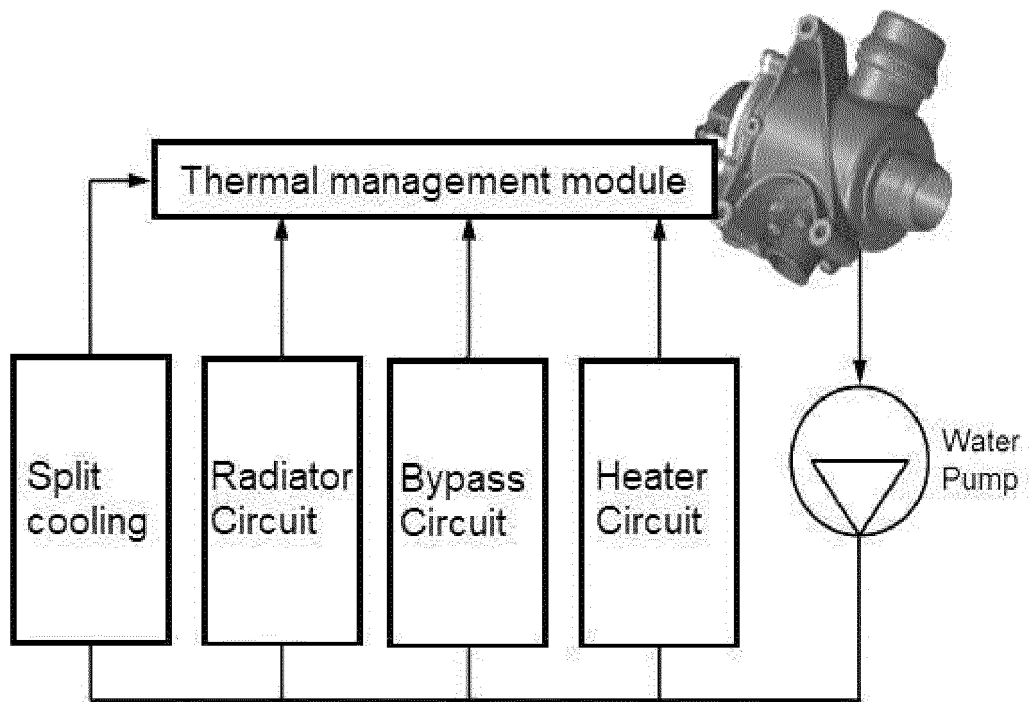


Fig. 1 (Prior Art)

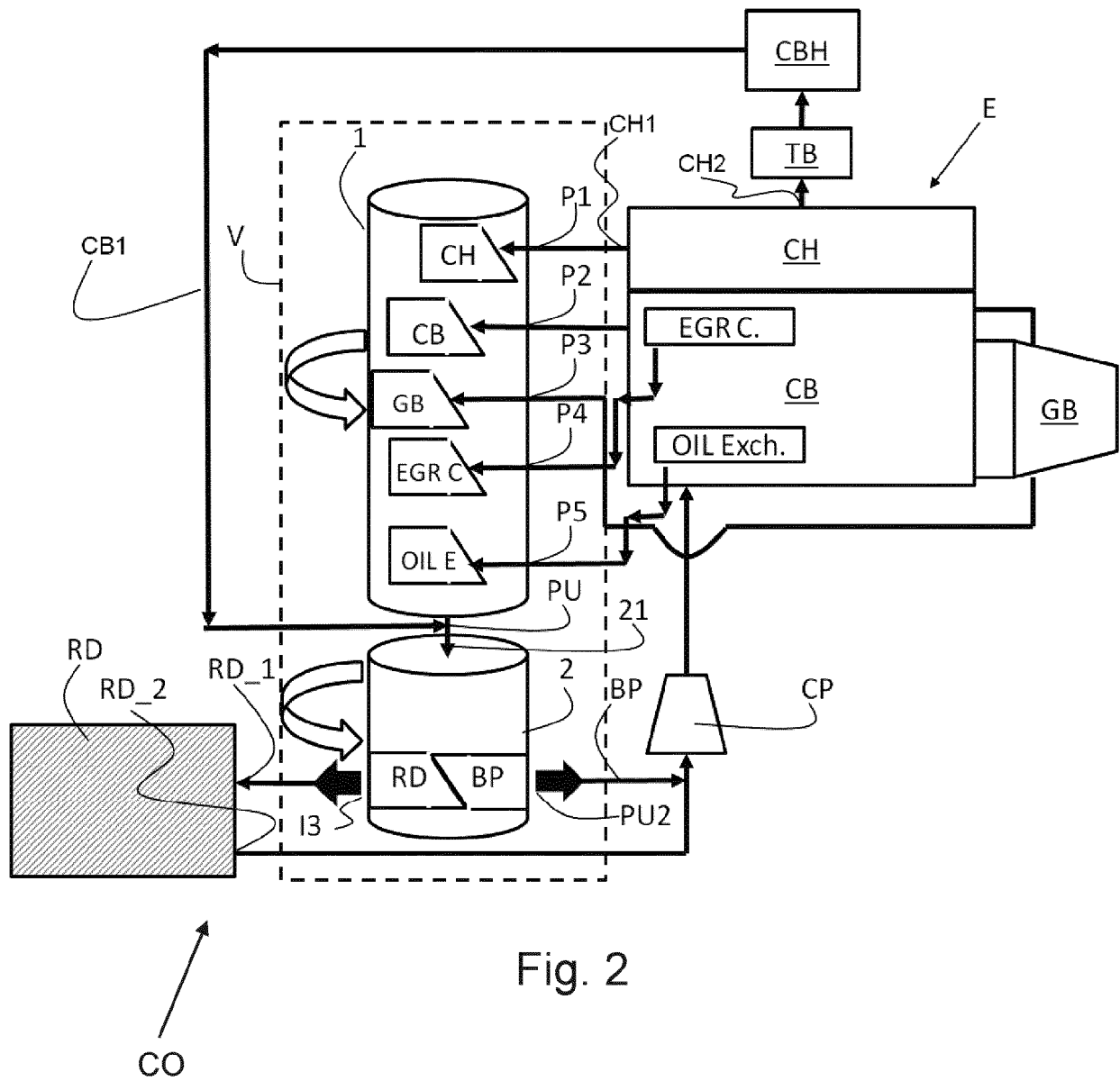
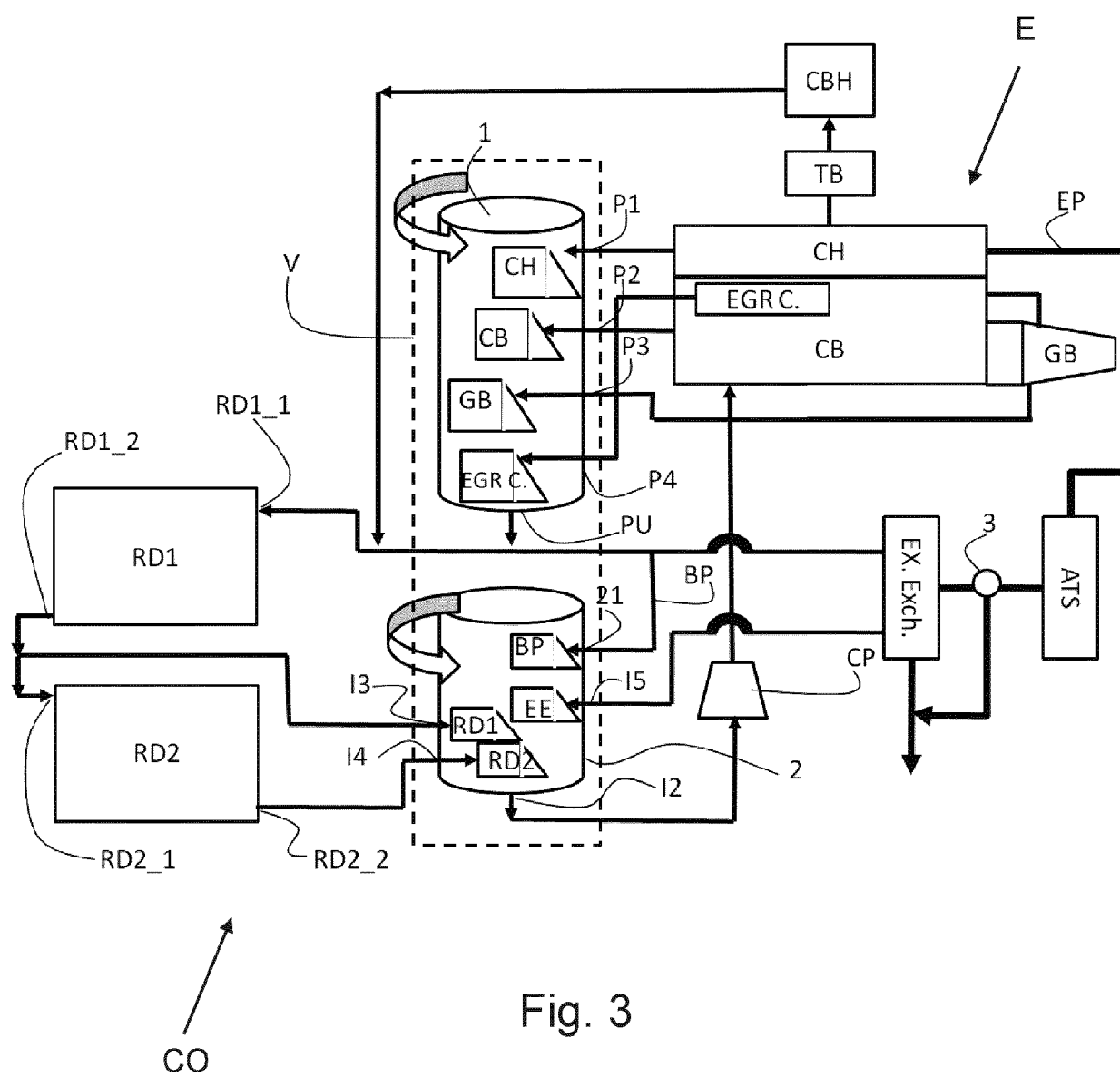


Fig. 2



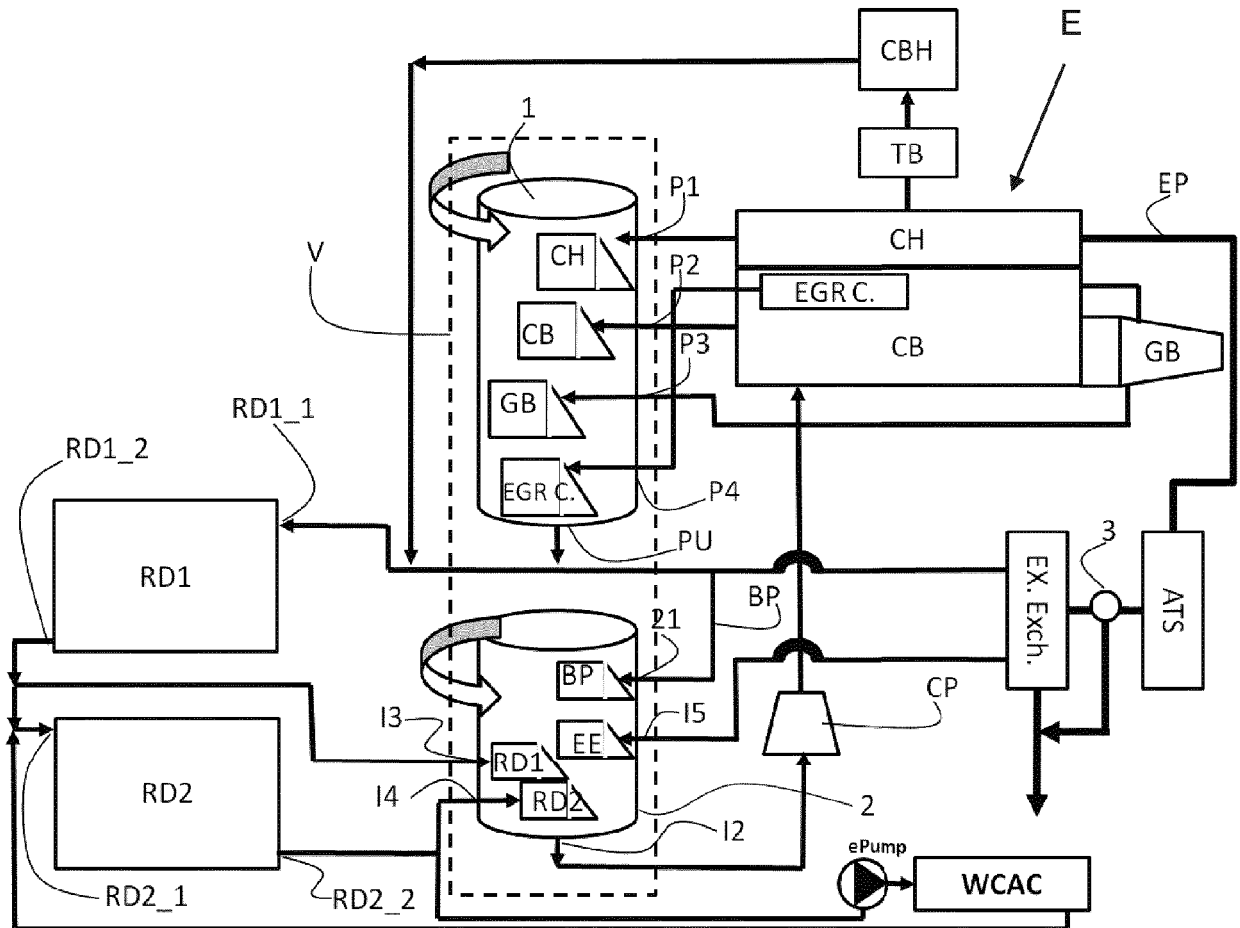


Fig. 4

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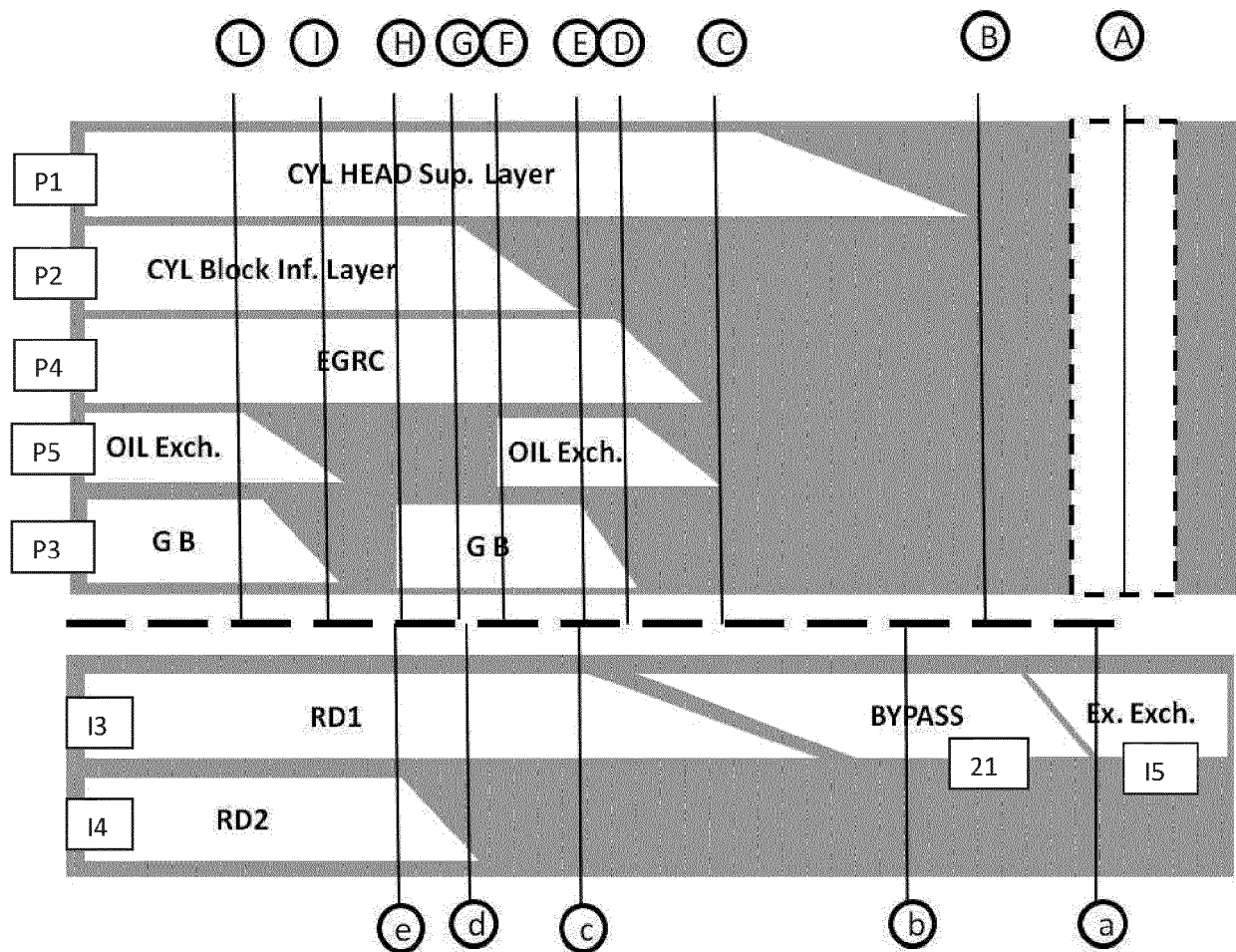


Fig. 5

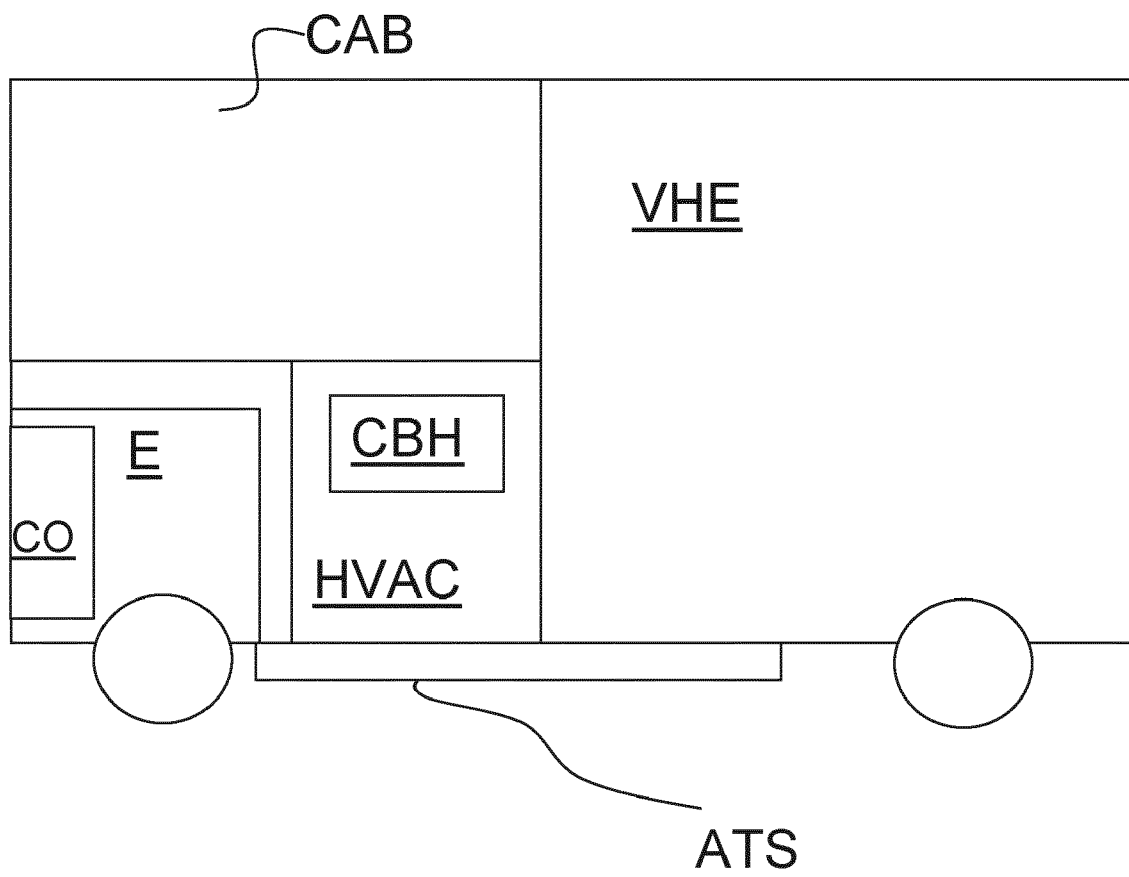


Fig. 6



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A	* figures 1-2 *	7-9	
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Place of search Munich		Date of completion of the search 7 December 2020	Examiner Schwaller, Vincent
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