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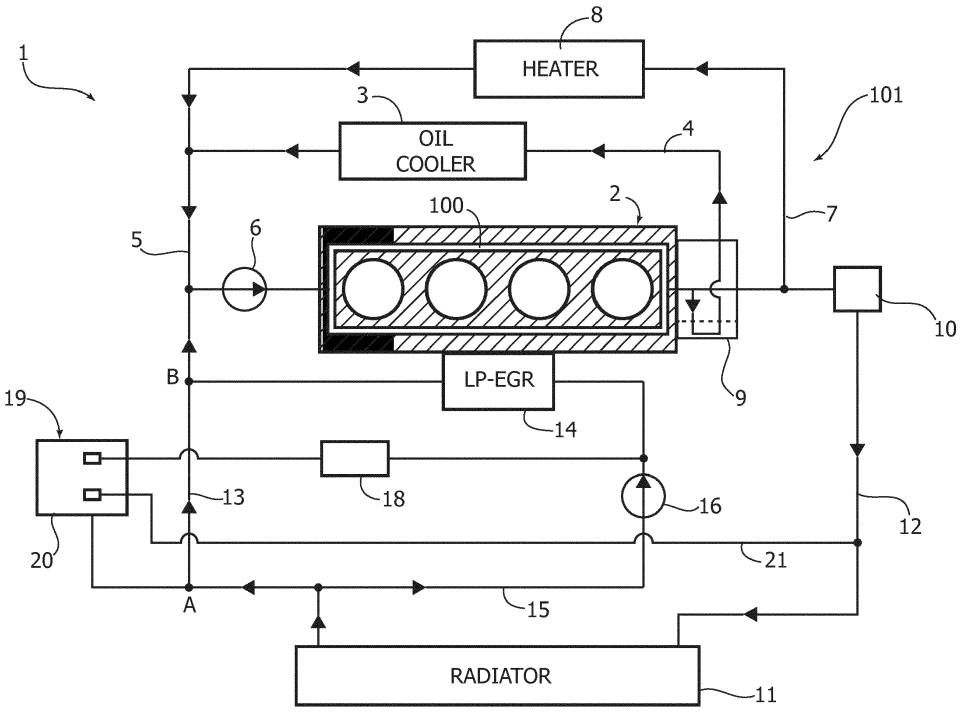
Amended claims in accordance with Rule 137(2) EPC.

(54) A COOLING SYSTEM FOR AN INTERNAL COMBUSTION ENGINE OF A MOTOR-VEHICLE

(57) A cooling system for an internal combustion engine of a motor-vehicle, comprising both a cooler of the exhaust gases recirculated in a high-pressure EGR circuit, which is traversed by the cooling fluid leaving the engine, and a cooler (14) of the exhaust gases recirculated in a low-pressure EGR circuit, which is inserted into an auxiliary line (15) connected in parallel with a main line (13), which brings the cooling fluid leaving the radiator (11) back again into the engine. A pump (16) is inserted along the auxiliary line (15), which is adapted to be activated only when a flow through said auxiliary line (15) and through said low-pressure EGR cooler (14) is required. By this arrangement, addition of a low-pressure EGR cooler, in an engine originally designed without this component, becomes simple and inexpensive.

FIG. 1



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Description

Field of the invention

[0001] The present invention relates to cooling systems for internal combustion engines of motor-vehicles, of the type comprising:

- a circuit for a cooling fluid of the engine, including an inner circuit portion inside the engine and an outer circuit portion outside the engine,
- in which said outer circuit portion inside the engine includes:
  - a main pump to activate the circulation of the cooling fluid in the circuit,
  - an oil cooler for cooling the lubrication oil of the engine, connected in the circuit in such a way that cooling fluid leaving the engine passes through said oil cooler and returns towards said main pump to be fed again into the engine,
  - a heater for the passenger compartment of the motor-vehicle, connected to the circuit in such a way that cooling fluid leaving the engine passes through said passenger compartment heater and returns towards said main pump to be fed again into the engine,
  - a radiator for cooling the cooling fluid of the engine, connected in the circuit in such a way that cooling fluid leaving the engine passes through said radiator and returns towards said main pump to be fed again into the engine,
  - a thermostatically-controlled or electronically-controlled distribution valve to regulate the flow of cooling fluid leaving the engine towards the radiator,
  - a high-pressure EGR cooler forming part of a high-pressure exhaust gas recirculation (EGR) circuit, connected to the engine cooling circuit in such a way that cooling fluid leaving the engine passes through said high-pressure EGR cooler and returns towards said main pump to be fed again into the engine, and
  - a low-pressure EGR cooler forming part of a low-pressure exhaust gas recirculation (EGR) circuit and inserted into said cooling circuit.

[0002] The expressions "high-pressure EGR circuit" and "low-pressure EGR circuit" are used in the present description and in the claims that follow with reference to circuits known per se, which are used in internal combustion engines, and in particular in turbocharged diesel engines, in order to recirculate part of the flow of exhaust gases leaving the engine back into the combustion chambers of the engine cylinders. According to the most conventional technique, recirculation of exhaust gases is achieved by means of a high-pressure EGR circuit, which provides a direct connection between the outlet of the exhaust manifold of the engine and the inlet of the intake manifold of the engine. Along this connection, an EGR valve is provided, which is controlled to regulate the portion of the flow of exhaust gases leaving the exhaust manifold of the engine, to be recirculated into the intake manifold of the engine, along a portion of the intake duct downstream of the supercharging compressor, i.e. in an environment at a relatively high pressure (from which the expression "high-pressure EGR" derives). A heat exchanger is interposed in the high-pressure EGR circuit, for cooling the recirculated exhaust gases. According to an additional known technique, an internal combustion engine, in particular a turbocharged diesel engine, can also be provided with a low-pressure EGR circuit, which includes an exhaust gas recirculation duct that starts from the exhaust line of the engine, at a section thereof downstream of the exhaust gas treatment devices, and which brings the recirculated exhaust gases into the engine intake duct, upstream of the supercharging compressor (from which the expression "low-pressure EGR" derives). A heat exchanger is also interposed in the low-pressure EGR circuit, for cooling the recirculated exhaust gases.

Technical problem

[0003] The configuration of the engine cooling system varies widely depending on the designer's choices, which, in turn, are a function of the motor-vehicle class on which the engine is mounted and of the power of the engine. In simpler solutions, usually only a high-pressure EGR circuit used, while in high-class vehicles both a high-pressure EGR circuit and a low-pressure EGR circuit are preferably adopted.

[0004] Each selected engine configuration involves a specific design of the cooling system and a specific arrangement of its components and their connections. Consequently, modifying an engine cooling system to provide one or more additional components which were not originally provided for that engine, such as a low-pressure EGR circuit cooler, is usually a complicated and expensive task.

[0005] However, it would be desirable to provide a cooling system that is easily adaptable and that does not require major changes when it comes to passing from a simpler configuration to a more complex configuration of the engine and the various auxiliary systems associated therewith.

Object of the invention

[0006] It is therefore an object of the present invention to provide a cooling system having a configuration such that changes required for including additional components, for example a low-pressure EGR cooler, become simple and inexpensive.

[0007] In particular, one object of the present invention is to provide an engine cooling system that can be easily modified when passing from a configuration suitable for

an engine equipped only with a high-pressure EGR circuit to an engine configuration in which a low-pressure EGR circuit is also provided.

[0008] Finally, it is a further object of the invention to provide a cooling system that is also readily adaptable as a result of the adoption of additional accessory components, such as a cooling fluid for an injector of urea solution, forming part of a catalytic regeneration system for regeneration of the exhaust gases.

Summary of the invention

[0009] In view of achieving the aforesaid objects, the present invention relates to a cooling system having all of the characteristics disclosed at the beginning of this description and further characterized in that:

- the radiator outlet is connected to the inlet of the cooling circuit in the engine, both by a main line, and by an auxiliary line arranged in parallel to the main line, in such a way that cooling fluid leaving the radiator can flow into the engine through said main line and through said auxiliary line,
- said low-pressure EGR cooler is inserted along said auxiliary line, so that it is traversed by the cooling fluid flowing along said auxiliary line, and
- an auxiliary pump is also inserted along said auxiliary line, which is adapted to be activated only when a flow through said auxiliary line and through said low-pressure EGR cooler is required.

Advantages and additional features of the invention

[0010] The main advantage of the above-described structure and arrangement lies in that if a low-pressure EGR circuit is added in an engine originally designed without this component, it is not necessary to radically modify the configuration of the cooling system, because it is not necessary to modify the line for the fluid leaving the engine, for the purpose of causing the cooling fluid leaving the engine to go through anhigh-pressure EGR cooler and a low-pressure EGR cooler arranged in series. In the invention, the low-pressure EGR cooler is traversed by the aforesaid auxiliary line, which is an easily-integrated component in the system, without any need of a substantial modification to the configuration and arrangement of the line for the cooling fluid leaving the engine.

[0011] With respect to a conventional solution in which the cooling fluid leaving the engine flows through a high-pressure EGR cooler and a low-pressure EGR cooler arranged in series, a further advantage of the system of the invention lies in that the fluid that follows through the low-pressure EGR cooler is fluid coming from the radiator, which is therefore at a relatively lower temperature (e.g. about 82°C) than that of the fluid leaving the high-pressure EGR cooler (about 90°C). The low-pressure EGR cooler is therefore more efficient.

[0012] According to a preferred embodiment, the aforesaid auxiliary pump is a pump driven by an electric motor. The electric motor driving the auxiliary pump is controlled by an electronic control unit, which is programmed to control the activation of the auxiliary pump as a function of the engine operating conditions, and as a function of a series of predetermined parameters, in particular as a function of the activation of the low-pressure EGR circuit and, for example, as a function of temperature values detected by one or more temperature sensors associated with the EGR circuits of the engine.

[0013] Preferably, the electric motor of the auxiliary pump is controlled (for example in a pulse width modulation (PWM) mode, by modulating its duty cycle) as a function of the climatic conditions and/or parameters relating to harmful exhaust emissions.

[0014] In an additional embodiment, the cooling system also comprises an additional line that starts from said auxiliary line, downstream of the aforesaid auxiliary pump and passing through a cooler for an urea solution injector forming part of a catalytic regeneration system, said additional line ending in an urea solution tank associated with said engine.

[0015] As can be seen, therefore, the additional circuit forming part of the cooling system according to the invention can also be advantageously used to obtain a cooling function of auxiliary components which the engine can be provided with. Again, this result is achieved without any significant modification to the entire engine cooling system.

[0016] In steady state operation of the engine, when the circulation of cooling fluid through the radiator is activated, the cooling fluid leaving the radiator returns to the engine through the main line of the cooling system, but, when the aforesaid auxiliary pump is activated, the cooling fluid also flows through the aforesaid auxiliary line, so as to provide also cooling of the recirculated exhaust gases in the low-pressure EGR circuit. Instead, during the warm-up step, after turning on the engine, when the circulation through the radiator is not activated, most of the flow of cooling fluid leaving the engine passes through the oil cooler and, if necessary, the passenger compartment heater, and then returns to the engine inlet, while, if the aforesaid auxiliary pump is not activated, there is no flow of the fluid in the aforesaid auxiliary line. In this condition, the amount of fluid that is heated in the engine is less than the entire capacity of the cooling system, so that the warm-up step is shortened. When, however, during the warm-up step, the auxiliary pump is activated, it generates an independent circulation of cooling fluid from the auxiliary line to the main line (in a reversed circulation direction with respect to that of normal operation) so as to obtain cooling of the recirculated exhaust gases in the low-pressure EGR circuit already during warm-up.

Detailed description of a preferred embodiment

[0017] Further characteristics and advantages of the invention will become apparent from the following description with reference to the appended Figure 1, provided purely by way of non-limiting example, which illustrates a diagram of a preferred embodiment of the cooling system according to the invention.

[0018] In Figure 1, numeral 1 designates, in its entirety, a cooling system for an internal combustion engine 2 including a circuit portion 100 inside the engine 2 and a circuit portion 101 outside the engine. The engine portion 101 outside the engine includes a heat exchanger for cooling the engine lubrication oil (oil cooler) designated by reference 3. The oil cooler 3 is connected to the circuit in such a way that the cooling fluid leaving the engine flows through a line 4 and through the oil cooler 3, and then through a line 5 towards the inlet of a main pump 6 serving to activate the circulation of the cooling fluid in the circuit. The pump 6, which in the most conventional solution is mechanically driven by the engine shaft, causes the cooling fluid to flow back into the engine. In parallel to the line 4, a line 7 is provided through which the cooling fluid leaving the engine flows through a passenger compartment heater 8 and then flows again through the line 5 towards the pump 6 and to the inlet of the inner circuit inside the engine.

[0019] The attached drawing does not show the details relating to the aforesaid connections or to any regulation valves interposed therein.

[0020] According to the prior art, the line 4 leaving the engine 2 also flows through a heat exchanger 9 for cooling the recirculated exhaust gases in a high-pressure EGR circuit.

[0021] The outlet of the cooling circuit system from the engine is also connected by means of a valve 10 to the inlet of a radiator 11 for cooling the engine cooling fluid. The valve 10 can be thermostatically-controlled, or electronically-controlled, according to any prior art. When it is opened, the valve causes the cooling fluid leaving the engine to flow into a line 12 that flows into the inlet of the radiator 11. The radiator 11 outlet is connected through a main line 13 to the inlet of the pump 6, in such a way that the cooling fluid that flows through the radiator 11, when the valve 10 is opened, is made to flow from the pump 6 back into the engine again.

[0022] Reference number 14 designates a heat exchanger for cooling recirculated exhaust gases in a low-pressure EGR circuit that is associated with the engine 2.

[0023] In the embodiment illustrated herein, the cooling system comprises an auxiliary line 15 arranged in parallel to the main line 13 that leaves at a point A of the main line 13 and flows again into the main line 13 at a point B, downstream of point A. An auxiliary pump 16 is inserted into the auxiliary line 15, this pump being preferably driven by an electric motor controlled by the electronic control unit of the cooling system of the engine, for example in a PWM mode

[0024] In steady state operation of the engine 2, when the valve 10 is opened, the cooling fluid leaving the engine flows, in part, through the line 12 into the radiator 11, and from there it returns, through the main line 13, to the inlet of the pump 6 and inside the engine. Still according to the prior art, in this condition of steady state operation, part of the cooling flow passes through the heat exchanger 9, and by means of the line 4, is then conveyed through the oil cooler 3, and then returns to the pump 6 inlet and inside the engine 2. If the electronic control unit activates the heating of the passenger compartment, in a way known per se, there is also a flow of cooling fluid through the line 7 and through the passenger heater 8, whereupon the cooling fluid returns to the inlet of the main pump 6 and into the engine.

[0025] In the aforesaid operating condition, whenever the electronic control system must activate cooling of the recirculated exhaust gases in the low-pressure EGR circuit, the system activates the electric pump 16, in such a way that the fluid leaving the radiator 11 flows along both the main line 13 and the auxiliary line 15, through the exchanger with recirculated exhaust gases in the low-pressure EGR circuit. The flows along the main line 13 and the auxiliary line 15 converge together at point B of the main line to then return to the inlet of the main pump 6 and then inside the engine.

[0026] During warm-up, when the valve 10 is closed and the circulation through the radiator 11 is deactivated, the flow of the cooling fluid through the oil cooler 3 and possibly through the passenger compartment heater 8 is anyhow implemented, according to the conventional art. In this stage, if activation is required of the cooling of the recirculated exhaust gases in the low-pressure EGR circuit, the electronic control unit activates the electric pump 16 to activate a flow of cooling fluid through the auxiliary line 15 and through the heat exchanger 14. In this case, an auxiliary circulation of the cooling fluid is created through the auxiliary line 15 from point A to point B, after which the cooling fluid flows along the main line in the reverse direction with respect to that of normal operation, i.e. from point B to point A, to close the circuit again through the auxiliary line 15.

[0027] The attached Figure 1 shows a preferred embodiment in which the system also comprises an additional line 17 starting from the auxiliary line 15 at a point C downstream of the auxiliary pump 16 and passing through a heat exchanger 18 for cooling a urea solution injector forming part of a catalytic regeneration system of the exhaust gases associated with the engine 2. The line 17 ends in the expansion vessel for the cooling system. The chamber 20 is connected to the line 12 of the cooling circuit by means of an additional line 21, according to a conventional technique (degassing circuit)

[0028] As can be seen, the cooling system according to the invention includes an auxiliary circuit, formed of the auxiliary line 15 and the pump 16, and optionally by the additional line 17, which is a sort of separate system, which can be easily added to a cooling system suitable

for an engine with a simpler configuration when this engine must be provided with additional components and equipment that also require cooling.

[0029] Naturally, without prejudice to the principle of the invention, the details of construction and the embodiments may vary widely with respect to those described and illustrated purely by way of example, without departing from the scope of the present invention.

Claims

1. A cooling system for an internal combustion engine of a motor-vehicle, comprising:

- a circuit (1) for an engine cooling fluid, including an inner circuit portion (100) inside the engine (2) and an outer circuit portion (101) outside the engine (2),
- wherein said outer circuit portion (101) outside the engine includes:

  - a main pump (6) to activate a circulation of the cooling fluid in the circuit (1),
  - an oil cooler (3) for the lubrication oil of the engine, connected in the circuit in such a way that cooling fluid leaving the engine passes through said oil cooler (3) and returns towards said main pump (6) to be fed again into the engine (2),
  - a heater (8) for the passenger compartment of the motor-vehicle, connected in the circuit in such a way that cooling fluid leaving the engine passes through said passenger compartment heater (8) and returns towards said main pump (6) to be fed again into the engine,
  - a radiator (11) for cooling the cooling fluid, connected in the circuit in such a way that cooling fluid leaving the engine passes through said radiator (11) and returns towards said main pump (6) to be fed again into the engine,
  - a thermostatically-controlled or electronically-controlled distribution valve (10) to regulate the flow of cooling fluid leaving the engine towards the radiator (11),
  - a high-pressure EGR circuit cooler for cooling recirculated exhaust gases in a high-pressure exhaust gas recirculation (EGR) circuit, connected to the engine cooling circuit in such a way that cooling fluid leaving the engine passes through said high-pressure EGR circuit cooler (9) and returns towards said main pump (6) to be fed again into the engine, and
  - a low-pressure EGR circuit cooler (14) for cooling recirculated exhaust gases in a low-pressure exhaust gas recirculation (EGR) circuit, inserted into said cooling circuit (1).

said system being **characterized in that**:

- the radiator outlet (11) is connected to the inlet of the cooling circuit in the engine, both by a main line (13), and by an auxiliary line (15) arranged in parallel to the main line, in such a way that cooling fluid leaving the radiator (11) can flow into the engine, passing through said main line (13) and through said auxiliary line (15),
- said low-pressure EGR circuit cooler (14) is inserted along said auxiliary line (15) so that it is traversed by cooling fluid flowing along said auxiliary line (15), and
- a pump (16) is inserted along said auxiliary line (15), which is adapted to be activated only when a flow through said auxiliary line (15) and through said low-pressure EGR cooler (14) is required.

2. A cooling system according to claim 1, **characterized in that** said auxiliary pump (16) is driven by an electric motor.

3. A cooling system according to claim 2, **characterized in that** it comprises an additional line (17) starting from said auxiliary line (15), downstream of said auxiliary pump (16) and passing through a cooler (18) of an urea solution injector forming part of a catalytic regeneration system associated with said engine, said additional line (17) terminating in an expansion vessel (20) forming part of the cooling system.

Amended claims in accordance with Rule 137(2) EPC.

1. A motor-vehicle internal combustion engine with a cooling system comprising:

- a circuit (1) for an engine cooling fluid, including an inner circuit portion (100) inside the engine (2) and an outer circuit portion (101) outside the engine (2),
- wherein said outer circuit portion (101) outside the engine includes:

  - a main pump (6) to activate a circulation of the cooling fluid in the circuit (1),
  - an oil cooler (3) for the lubrication oil of the engine, disposed along an oil cooler line (4) connecting an engine outlet of said inner circuit portion with an inlet of said main pump (6), in such a way that cooling fluid

leaving the engine passes through said oil cooler (3) and returns towards said main pump (6) to be fed again into the engine (2),
- a heater (8) for the passenger compartment of the motor-vehicle, connected in the circuit in such a way that cooling fluid leaving the engine passes through said passenger compartment heater (8) and returns towards said main pump (6) to be fed again into the engine,
- a radiator (11) for cooling the cooling fluid, connected in the circuit in such a way that cooling fluid leaving the engine passes through said radiator (11) and returns towards said main pump (6) to be fed again into the engine,
- a thermostatically-controlled or electronically-controlled distribution valve (10) to regulate the flow of cooling fluid leaving the engine towards the radiator (11),
- a high-pressure exhaust gas recirculation circuit cooler (9) for cooling recirculated exhaust gases in a high-pressure exhaust gas recirculation circuit, connected to the engine cooling circuit in such a way that cooling fluid leaving the engine passes through said high-pressure exhaust gas recirculation circuit cooler (9) and returns towards said main pump (6) to be fed again into the engine, and
- a low-pressure exhaust gas recirculation circuit cooler (14) for cooling recirculated exhaust gases in a low-pressure exhaust gas recirculation circuit, inserted into said cooling circuit (1),

wherein:

- the radiator outlet (11) is connected to the inlet of the cooling circuit in the engine, both by a main line (13), and by an auxiliary line (15) arranged in parallel to the main line, in such a way that cooling fluid leaving the radiator (11) can flow into the engine, passing through said main line (13) and through said auxiliary line (15),
- said low-pressure exhaust gas recirculation circuit cooler (14) is inserted along said auxiliary line (15) so that it is traversed by cooling fluid flowing along said auxiliary line (15), and
- an auxiliary pump (16) is inserted along said auxiliary line (15), which is adapted to be activated only when a flow through said auxiliary line (15) and through said low-pressure exhaust gas recirculation cooler (14) is required,

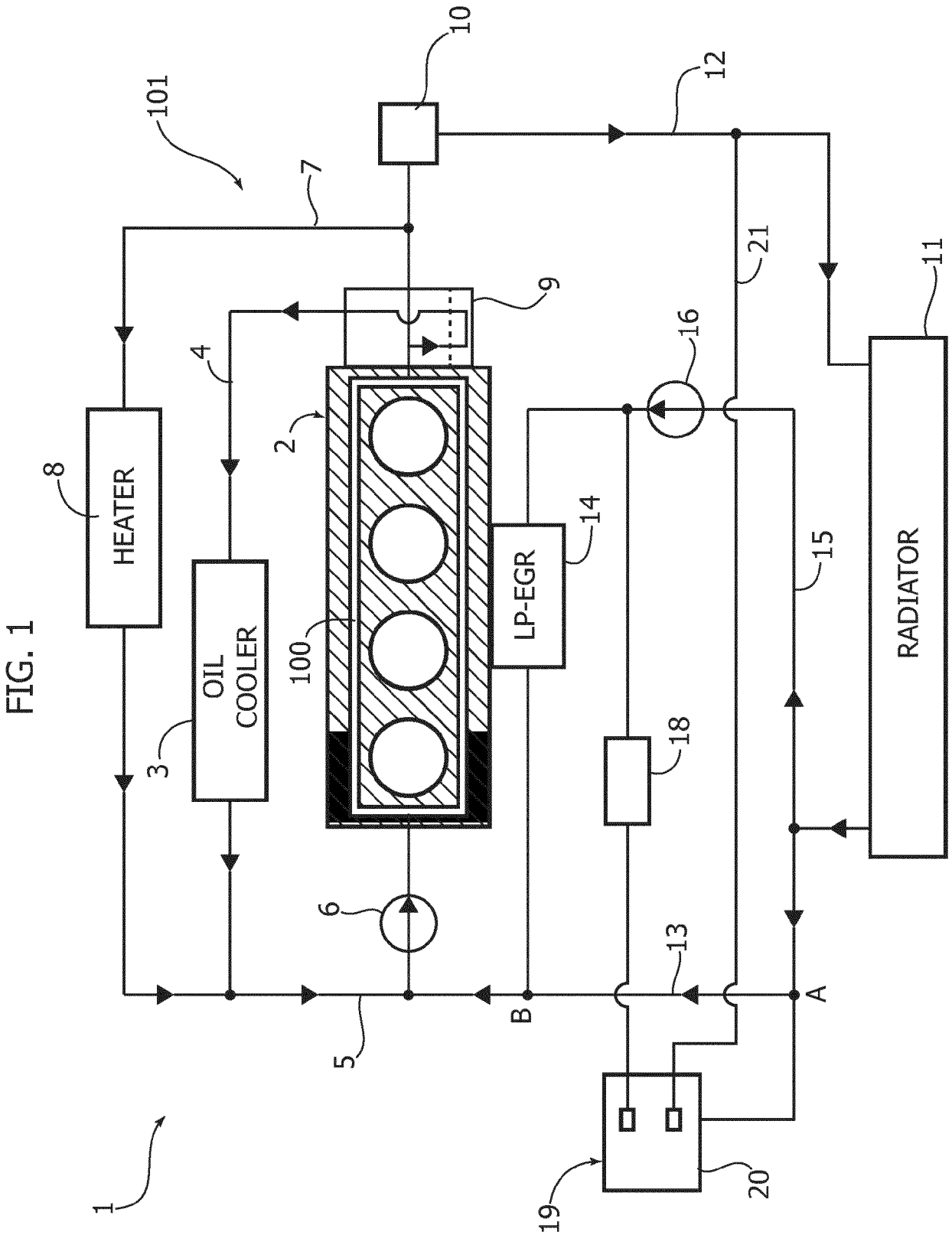
said engine being **characterized in that**:

- the high-pressure exhaust gas recirculation circuit cooler (9) is disposed along said oil cooler line (4) upstream of said oil cooler (3) so that cooling fluid leaving the engine passes through said high-pressure exhaust gas recirculation circuit cooler (9) before passing through said oil cooler (3),
- said distribution valve (10) is disposed along a line between said engine outlet and the inlet of the radiator (11),
- said auxiliary line (15) starts from a first point (A) of the main line (13) downstream of the outlet of the radiator (11) and converges into the main line (13) at a second point (B) downstream of the first point (A) and upstream of the main pump (6).

2. A cooling system according to claim 1, **characterized in that** said auxiliary pump (16) is driven by an electric motor.

3. A cooling system according to claim 2, **characterized in that** it comprises an additional line (17) starting from said auxiliary line (15), downstream of said auxiliary pump (16) and passing through a cooler (18) of an urea solution injector forming part of a catalytic regeneration system associated with said engine, said additional line (17) terminating in an expansion vessel (20) forming part of the cooling system.

FIG. 1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EUROPEAN SEARCH REPORT

Application Number
EP 17 18 1776

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	27 November 2017	Schwaller, Vincent

CATEGORY OF CITED DOCUMENTS

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