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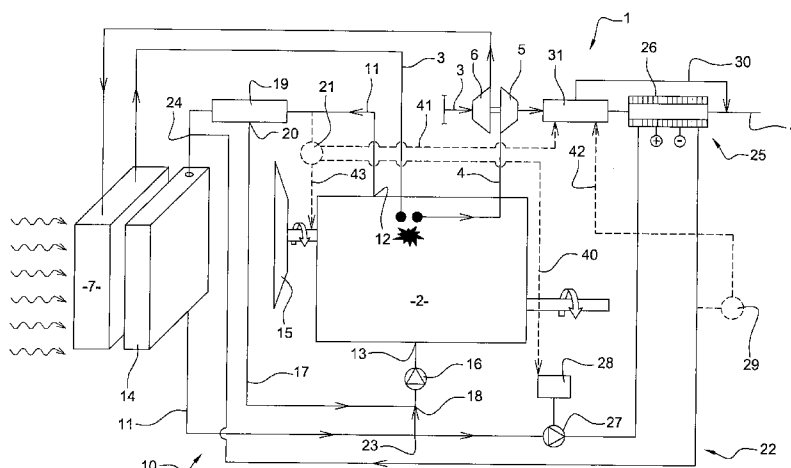


Fig. 1

(57) Abstract: The vehicle engine arrangement has an engine coolant circuit (10) comprising: a main line (11) with a radiator (14) and a main pump (16) located downstream from the radiator; a by-pass line (17) for by-passing the radiator; a control valve (19) for controlling the amount of coolant flowing through the radiator and the by-pass line; a thermoelectric device (25) for producing electricity from a heat flux between hot exhaust gases and the coolant flowing in a derivation line (22). The derivation line (22) has an inlet (23) connected to the main line downstream from the radiator (14) and upstream from the main pump (16) and an outlet (24) connected to the main line upstream from the radiator (14) and downstream from the control valve (19), said derivation line further comprising an auxiliary pump (27).

VEHICLE COMBUSTION ENGINE ARRANGEMENT COMPRISING A THERMOELECTRIC DEVICE

Field of the invention

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The present invention relates to a combustion engine arrangement for an automotive vehicle, especially an industrial vehicle. More specifically, the invention relates to such an engine arrangement comprising a thermoelectric device capable of producing electricity by the conversion of a heat flux between
10 the hot exhaust gases and the engine coolant.

Technological background

A conventional internal combustion engine arrangement comprises
15 an exhaust line capable of collecting exhaust gases from the engine, for example through an exhaust manifold. A significant amount of energy is included in said exhaust gases, which have a high speed and a high temperature.

Several systems have been designed to recover at least part of this
20 energy, in order to improve the vehicle efficiency, more particularly the engine arrangement efficiency, which has a direct impact on fuel consumption.

One conventional system consists of equipping the exhaust line with one or several thermoelectric devices using Seebeck effect. Such thermoelectric devices are capable of producing electricity by the conversion of
25 a heat flux between the hot exhaust gases flowing in the exhaust line and a cold source. The generated electricity can then be used for the operation of various elements of the vehicle, and/or can be stored in an energy storage component such as a battery.

Among possible solutions, one option is to use the engine coolant
30 as the cold source. There is typically provided a coolant circuit having a main line equipped with a radiator, through which the engine coolant flows from an engine outlet to an engine inlet. An auxiliary line connected to the main line carries at least part of the engine coolant towards the thermoelectric device and then back to the engine.

35 Such conventional engine arrangements are not fully satisfying, because the various components of the engine arrangement are generally not

used at their full capacity all the time, making the overall efficiency lower than what it could be.

In particular, for engine arrangements which are installed on vehicles, the flow rate and temperature of the exhaust gases, on the one hand, and of the engine coolant, on the other hand, can vary in a quite wide range, depending on the engine operating conditions. Indeed, in a vehicle, the load on the engine arrangement, which is linked to the torque which is required from the engine, varies within wide proportions. This is in strong contrast for example to many stationary engine arrangements, for example used to drive electric generators, where the load on the engine arrangement is relatively constant. Thus, in a vehicle application, the thermoelectric device is exposed to varying levels of heat flux and temperature levels, which has a major impact on the thermoelectric device conversion efficiency. However, because of the specific design of conventional engine arrangements, the thermoelectric device may not be used to its optimal potential in some vehicle operating conditions.

Besides, the cooling capacity of the engine coolant circuit is seldom fully used. In particular, when the vehicle is moving at a relatively high speed on a road having a small slope rate, only a small amount of the engine coolant flows through the radiator. In these conditions, the radiator cooling capacity is far from being fully used.

It therefore appears that, from several standpoints, there is room for improvement in engine arrangements regarding energy recovery by means of thermoelectric devices.

Summary

It is an object of the present invention to provide an improved vehicle engine arrangement which can overcome the drawbacks encountered in conventional engine arrangements.

Another object of the present invention is to provide a vehicle internal combustion engine arrangement which makes a better use of the capacity of the vehicle cooling circuit and of the thermoelectric device, depending on the engine operating condition, while also preventing any damage to said thermoelectric device.

According to the invention such a vehicle internal combustion engine arrangement comprises:

- an air intake line capable of carrying intake air towards an engine;
 - at least one exhaust line comprising an exhaust manifold capable of collecting exhaust gases from the engine;
 - 5 - an engine coolant circuit comprising:
 - a main line carrying a coolant from an engine outlet towards an engine inlet, said main line comprising a radiator and a main pump located downstream from the radiator
 - a by-pass line capable of carrying at least part of the coolant from the engine outlet to the engine inlet without flowing through the radiator;
 - 10 - a control valve being provided on the main line to control the amount of coolant flowing through the radiator and through the by-pass line;
 - 15 - a thermoelectric device capable of producing electricity by Seebeck effect by the conversion of a heat flux between the hot exhaust gases flowing in the exhaust line and the coolant flowing in a derivation line of the engine coolant circuit;
- wherein the control valve is located upstream from the radiator and
- 20 wherein the derivation line has an inlet connected to the main line downstream from the radiator and upstream from the main pump and an outlet connected to the main line upstream from the radiator and downstream from the control valve, said derivation line further comprising an auxiliary pump.
- With the vehicle engine arrangement according to the invention,
- 25 and more particularly thanks to the auxiliary pump dedicated to the derivation line, the engine coolant can flow towards the thermoelectric device even when the engine coolant temperature is low. Indeed, in such operating conditions, all of the engine coolant flows in the by-pass line and would return to the engine inlet if no auxiliary pump was provided. This would be all the more detrimental
- 30 to the overall efficiency as the thermoelectric device can produce more electricity when the cold source temperature is low compared with the hot source. Therefore, and contrary to prior art solutions, the invention makes it possible to benefit from these advantageous operating conditions in order to get more electrical energy produced by the thermoelectric device.
- 35 Moreover, by carrying the engine coolant from the thermoelectric device back to the main line upstream from the radiator, the invention makes it

possible to cool the engine coolant before it enters the engine, thanks to an additional passage through the radiator. This does not impair the engine coolant circuit efficiency since, most of the time, in conventional engine arrangements, the cooling capacity of the radiator is not fully used. The invention provides an energy recovery device that does not require a more powerful radiator but instead benefits from the previously non used cooling capacity of a conventional radiator.

According to a preferred implementation of the invention, the engine arrangement may further comprise a by-pass pipe of the thermoelectric device and a valve located on the exhaust line, upstream from the thermoelectric device, capable of controlling the amount of exhaust gases flowing through the thermoelectric device and through the by-pass pipe.

Such a by-pass pipe and a valve make it possible to regulate the power of the hot source (i.e. the exhaust gases) of the thermoelectric device. As a consequence, the heat transfer to the engine coolant can be limited when needed, especially when the vehicle is climbing a slope. Moreover, this protects the thermoelectric device in case the hot source temperature is higher than the highest admissible temperature of said thermoelectric device.

Advantageously, there can be provided control means capable of regulating the opening degree of said valve as a function of the temperature of the coolant in the main line. More specifically, if the coolant temperature is quite high, it can be useful to close the valve in order to by-pass the thermoelectric device and thus prevent the engine coolant from being further heated, leading to fan engagement.

Moreover, the engine arrangement can comprise control means capable of regulating the opening degree of said valve as a function of the temperature of the coolant in the derivation line. The purpose of such a regulation is to avoid boiling of the engine coolant in the thermoelectric device, which could lead to dramatic damages in several components (pump, etc.) or even in the engine. This security function can be achieved through a temperature sensor located on the derivation line, for example downstream from the thermoelectric device.

The engine arrangement can further comprise control means capable of regulating the flow output of the auxiliary pump as a function of the temperature of the coolant in the main line. Thus, the flow rate of the engine coolant through the thermoelectric device is regulated, which makes it possible

to improve the overall efficiency of the thermoelectric device. In concrete terms, if the coolant temperature is quite low, the flow output of the auxiliary pump is preferably set at its maximum because the colder the cold source is, the higher the thermoelectric device efficiency can be. On the contrary, if the coolant
5 temperature is high and the valve is open, the flow output of the auxiliary pump can be reduced or stopped to avoid unnecessary power consumption.

Besides, it can be provided a first temperature sensor designed to measure the temperature of the coolant in the main line, said first temperature sensor being located on the main line upstream from the radiator, and
10 preferably upstream from the control valve. Said first temperature sensor provides the information which enables the control of the valve and/or of the auxiliary pump.

The engine arrangement can further comprise a second temperature sensor designed to measure the temperature of the coolant in the
15 derivation line, said second temperature sensor being located on the derivation line downstream from the thermoelectric device.

According to one embodiment, the by-pass line outlet is connected to the main line downstream from the derivation line inlet. Thus, all of the engine coolant entering the thermoelectric device has first passed through the
20 radiator and hence has been cooled. This ensures that the coolant entering the thermoelectric device is as cold as possible, resulting in the highest possible efficiency of the thermoelectric device.

Advantageously, the engine arrangement also comprises a fan located close to said radiator in order to improve the heat exchange between
25 the coolant and ambient air, said arrangement further comprising control means capable of regulating the speed of rotation of the fan as a function of the temperature of the coolant in the main line. In concrete terms, the fan may start turning when the engine coolant temperature is higher than a predetermined threshold.

30 The thermoelectric device can be connected to a battery and/or to one or more vehicular component that are electrically operated.

These and other advantages will become apparent upon reading the following description in view of the drawing attached hereto representing, as non-limiting examples, embodiments of a vehicle according to the invention.

Brief description of the drawings

The following detailed description of several embodiments of the invention is better understood when read in conjunction with the appended drawing being understood, however, that the invention is not limited to the specific embodiments disclosed.

Figure 1 is a schematic drawing of an internal combustion engine arrangement according to an embodiment of the invention.

Detailed description

As illustrated in figure 1, an internal combustion engine arrangement 1 typically comprises an engine block 2 defining a plurality of cylinders (not shown). Intake air is carried towards the engine, for feeding the cylinders, through an air intake line 3 which can comprise an intake manifold. The gases formed in each cylinder can be collected by at least one exhaust line 4, which may comprise an exhaust manifold, and the exhaust gases are then carried towards the atmosphere through exhaust line 4 which may comprise various exhaust gases after treatment systems and silencers.

The engine 1 may include a turbocharger comprising a turbine 5 located on the exhaust line 4 and a compressor 6 located on the air intake line 3, said compressor being driven by the turbine 5. After being compressed by the compressor 6, and before entering the engine, air flowing in the intake line 3 may go through a charge air cooler 7 which can be provided in the intake line 3.

The internal combustion engine 1 further comprises an engine coolant circuit 10 in which an engine coolant can flow.

The engine coolant circuit 10 comprises a main line 11 carrying the coolant from an engine outlet 12 towards an engine inlet 13. Main line 11 includes a radiator 14. A fan 15 may be located close to radiator 14. Fan 15 can be started up when necessary in order to increase the air flow through the radiator, thus increasing the cooling efficiency. Main line 11 also comprises a main pump 16 located downstream from radiator 14 for establishing a flow of coolant through the engine and in the main line 11. Pump 16 can be driven by the engine 1, or by an auxiliary motor.

The engine coolant circuit 10 also comprises a by-pass line 17 capable of carrying at least part of the coolant from the engine outlet 12 to the engine inlet 13 without flowing through the radiator 14. The by-pass line outlet 18 is connected to the main line 11 upstream from main pump 16.

5 A control valve 19 is provided on the main line, at the inlet 20 of the by-pass line 17, to control the amount of coolant flowing through the radiator 14 and through the by-pass line 17. The control valve can be embodied as a three way proportional valve electronically controlled as a function of the temperature of the coolant at the engine outlet 12 but, advantageously, it can be embodied
10 in a much simpler fashion as a wax thermostat requiring no electronic control. The thermostat 19 is located upstream from radiator 14.

A first temperature sensor 21 is provided on main line 11, upstream from radiator 14 and upstream from thermostat 19. Said first temperature sensor 21 is designed to measure the temperature T_A of the coolant in main
15 line 11, at the outlet 12 of the engine block 2.

The engine coolant circuit 10 further comprises a derivation line 22 having an inlet 23 connected to the main line 11 downstream from the radiator 14 and upstream from the outlet 18 of the by-pass line 17. The derivation line has an inlet 24 connected to the main line 11 upstream from the
20 radiator 14 and downstream from the thermostat 19, therefore also downstream of the inlet of the bypass line.

The engine 1 is equipped with at least one thermoelectric device 25 capable of producing electricity by Seebeck effect. The thermoelectric device 25 comprises thermoelectric elements 26 which are subject, directly or
25 indirectly, on one side to a hot source, namely the hot exhaust gases flowing in the exhaust line 4, and, on the other side, to a relatively cold temperature of a cold source, namely the engine coolant flowing in the derivation line 22 of the engine coolant circuit 10.

The thermoelectric elements 15 may comprise materials such as
30 Bi_2Te_3 , PbTe , Mg_2Si , MnSi , SiGe , or other appropriate materials which can convert the temperature difference between the hot source and the cold source into an electric voltage, thereby converting a heat flux between the hot and cold sources into electric power.

In the illustrated embodiment, the thermoelectric device 25 is
35 substantially cylindrical and surrounds the exhaust line 4. The thermoelectric elements 26 are arranged between:

- an inner wall located close to or in contact with the exhaust line 4, so as to be thermally connected to the exhaust line, in order to achieve a good heat transfer from the hot exhaust gases to the thermoelectric elements 26;

- 5 - and an outer wall which is thermally connected to the derivation line 22, in order to achieve a good heat transfer from the other side of said thermoelectric elements 26 to the coolant.

Furthermore, the thermoelectric device 25 is connected to an electrical circuit which may comprise one or more battery and/or one or more vehicular component that are electrically operated. The electrical circuit is preferably equipped with means for controlling the electrical current within said circuit.

In other words, the cold side of the thermoelectric device 25 is arranged in parallel to the radiator 14, by means of the derivation line 22.

15 The derivation line 22 further comprises an auxiliary pump 27 which may be driven by an electric motor 28, and which is located upstream from the thermoelectric device 25, i.e. between the derivation line inlet 23 and the thermoelectric device 25. Control means 40 are provided in order to regulate the flow output of the auxiliary pump 27 as a function of the temperature T_A of the coolant in main line 11, at the outlet of the engine block 2, for example by varying the speed of the pump, its capacity, etc... The flow output of the pump can also be controlled, in combination, as a function of the temperature T_B of the coolant in derivation line 22.

25 A second temperature sensor 29 is therefore provided on the derivation line 22, downstream from the thermoelectric device 25. Said second temperature sensor 29 is designed to measure the temperature T_B of the coolant in the derivation line 22, at the outlet of the thermoelectric device 25.

The internal combustion engine arrangement 1 further comprises, on the exhaust line 4, a by-pass pipe 30 of the thermoelectric device 25. At the upstream junction between the exhaust line 4 and the by-pass pipe 30, there is provided a valve 31 capable of controlling the amount of exhaust gases flowing through the thermoelectric device 25 and through the by-pass pipe 30. As a result, the thermoelectric device 25 can be fully or partially by-passed when needed. In particular, when the exhaust gases temperature exceeds the highest admissible temperature of said thermoelectric elements 26, said thermoelectric device 25 can be fully by-passed to protect it from overheating.

Control means 41 are provided in order to regulate the opening degree of valve 31 as a function of the temperature T_A of the coolant in main line 11. Furthermore, control means 42 are provided in order to regulate the opening degree of valve 31 as a function of the temperature T_B of the coolant in derivation line 22. Additional control means 43 are also provided in order to regulate the speed of rotation of fan 15 as a function of the temperature T_A of the coolant in main line 11.

Several possible modes of operation of the engine arrangement are now described.

When T_A is lower than a first threshold T_1 , generally around 80°C , thermostat 19 is closed, i.e. all of the engine coolant flows through by-pass line 17, since it is not necessary, or even not desirable, to further cool the engine 1 by means of radiator 14. This happens for example when the vehicle is moving at a relatively high speed, and/or on a relatively flat road, and/or with a small load and/or when the weather is very cold. T_A may for example be between 40°C and 60°C .

In this operating condition, the auxiliary pump 27 is driven by the electric motor 28 at its maximum speed, in order to carry as much engine coolant as possible towards the thermoelectric device 25. Indeed, as the engine coolant temperature is low, the thermoelectric device efficiency is high. Besides, valve 31 is fully open so that all of the exhaust gases flows in the exhaust line 4 and so that a maximum quantity of heat is transferred to the thermoelectric elements 26.

When T_A becomes higher than T_1 and remains lower than a second threshold T_2 , generally around 90°C , thermostat 19 is partly open. Then, part of the engine coolant flows through radiator 14 in order to be cooled, and the remaining amount of engine coolant flows through by-pass line 17. T_1 is therefore the regulating temperature of engine 1 by means of thermostat 19.

Part of the engine coolant passing through the radiator 14 is directed towards the thermoelectric device 25 by means of the auxiliary pump 27, and then returns to the radiator inlet in order to be cooled before flowing either to the engine inlet 13 or to thermoelectric device 25 again. With the engine arrangement design above described, and contrary to prior art arrangements, the invention makes it possible to better use the cooling capacity of the radiator, as thermoelectric device 25 receives colder water than if it was taken from engine outlet 12.

When T_A is equal to T_2 , the thermostat 19 is fully open.

Above T_2 , which can happen for example when the vehicle climbs a hill, several means may be implemented in order to avoid T_A to further increase. The valve 31 may be progressively opened to limit the amount of exhaust gases flowing in the exhaust line 4, close to the thermoelectric device 25. As a consequence, less heat is transferred to the thermoelectric device 25 which limits the increase in the coolant temperature, and the auxiliary pump 27 output flow may be reduced or stopped progressively.

When T_A reaches a third threshold T_3 , generally around 95°C , the valve 31 is fully opened, in order to prevent the engine coolant from boiling and to avoid the starting up of fan 15.

Fan 15 is started up when T_A reaches a fourth threshold T_4 , generally around 100°C . It is estimated that such an operating condition occurs less than 5% of the time on typical roads. The cooling capacity of radiator 14 is then greatly increased. However, the thermoelectric device 25 is not used, because this would lead to an increase in the cooling needs. This would not be profitable since the power used by the fan is much higher than the power obtained by means of the thermoelectric device.

A fifth threshold T_5 , generally around 110°C , corresponds to an alarm temperature indicating that the risk of the coolant boiling is high. The fan 15 is then working at its full speed. When T_A is still increasing above T_5 , the engine output power is progressively reduced to avoid any break-down.

Besides, if the second temperature sensor 29 measures a too high temperature T_B (typically above 110°C), valve 31 is forced to its fully opened position for security reasons, in order to prevent the coolant from boiling.

A significant advantage of the invention is that it provides a cold cooling source on a vehicle for a thermoelectric element which has minimum drawbacks on the vehicle cooling circuit, and at minimum cost. No additional heat exchanger is required, and there is no need to modify the frontal face of the vehicle to install such a heat exchanger. This would result in a modification of the air flow which could lead to a more frequent fan engagement, thereby reducing or even cancelling the fuel savings.

Moreover, the invention makes it possible that the cold source of the thermoelectric device be at a minimum temperature most of the time, which greatly increases the thermoelectric device efficiency.

To improve the engine arrangement, several parameters, such as the opening degree of valve 31, can be controlled with predictive road information (for instance if a hill is anticipated).

5 The invention has been described in an engine arrangement comprising only one exhaust line. It can also be implemented in an arrangement having two parallel exhaust lines, which can each have a separate exhaust manifold or which can share a common exhaust manifold. In both cases, only one or both of the exhaust lines can be implemented according to the invention.

10 Of course, the invention is not restricted to the embodiment described above by way of non-limiting example, but on the contrary it encompasses all embodiments thereof.

CLAIMS

1. A combustion engine arrangement for a vehicle comprising:
- an air intake line (3) capable of carrying intake air towards an engine (1);
 - at least one exhaust line (4) comprising an exhaust manifold capable of collecting exhaust gases from the engine (1);
 - an engine coolant circuit (10) comprising:
 - a main line (11) carrying a coolant from an engine outlet (12) towards an engine inlet (13), said main line (11) comprising a radiator (14) and a main pump (16) located downstream from the radiator (14);
 - a by-pass line (17) capable of carrying at least part of the coolant from the engine outlet (12) to the engine inlet (13) without flowing through the radiator (14);
 - a control valve (19) being provided on the main line (11) to control the amount of coolant flowing through the radiator (14) and through the by-pass line (17);
 - a thermoelectric device (25) capable of producing electricity by Seebeck effect by the conversion of a heat flux between the hot exhaust gases flowing in the exhaust line (4) and the coolant flowing in a derivation line (22) of the engine coolant circuit (10);
- characterized in that the control valve (19) is located upstream from the radiator (14) and in that the derivation line (22) has an inlet (23) connected to the main line (11) downstream from the radiator (14) and upstream from the main pump (16) and an outlet (24) connected to the main line (11) upstream from the radiator (14) and downstream from the control valve (19), said derivation line (22) further comprising an auxiliary pump (27).
2. The combustion engine arrangement according to claim 1, characterized in that it further comprises a by-pass pipe (30) of the thermoelectric device (25) and a valve (31) located on the exhaust line (4), upstream from the thermoelectric device (25), capable of controlling the amount of exhaust gases flowing through the thermoelectric device (25) and through the by-pass pipe (30).

3. The combustion engine arrangement according to claim 2, characterized in that it comprises control means (41) capable of regulating the opening degree of said valve (31) as a function of the temperature (T_A) of the coolant in the main line (11).

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4. The combustion engine arrangement according to claim 2 or claim 3, characterized in that it comprises control means (42) capable of regulating the opening degree of said valve (31) as a function of the temperature (T_B) of the coolant in the derivation line (22).

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5. The combustion engine arrangement according to any one of claims 1 to 4, characterized in that it comprises control means (40) capable of regulating the flow output of the auxiliary pump (27) as a function of the temperature (T_A) of the coolant in the main line (11) and of the temperature (T_B) of the coolant in the derivation line (22).

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6. The combustion engine arrangement according to one of claims 1 to 5, characterized in that it comprises a first temperature sensor (21) designed to measure the temperature (T_A) of the coolant in the main line (11), said first temperature sensor (21) being located on the main line (11) upstream from the radiator (14), and preferably upstream from the control valve (19).

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7. The combustion engine arrangement according to one of claims 1 to 6, characterized in that it comprises a second temperature sensor (29) designed to measure the temperature (T_B) of the coolant in the derivation line (22), said second temperature sensor (29) being located on the derivation line (22) downstream from the thermoelectric device (25).

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8. The combustion engine arrangement according to any one of claims 1 to 7, characterized in that the by-pass line outlet (18) is connected to the main line (11) downstream from the derivation line inlet (23).

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9. The combustion engine arrangement according to any one of claims 1 to 8, characterized in that it comprises a fan (15) located close to said radiator (14) in order to improve the heat exchange between the coolant and ambient air, said arrangement further comprising control means (43) capable of

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regulating the speed of rotation of the fan (15) as a function of the temperature (T_A) of the coolant in the main line (11).

10. The combustion engine arrangement according to any one of
5 claims 1 to 9, characterized in that the thermoelectric device (25) is connected to a battery.

11. The combustion engine arrangement according to any one of
claims 1 to 9, characterized in that the thermoelectric device (25) is connected
10 to one or more vehicular component that are electrically operated.

12. An automotive vehicle, characterized in that it comprises a combustion engine arrangement according to any of the preceding claims.

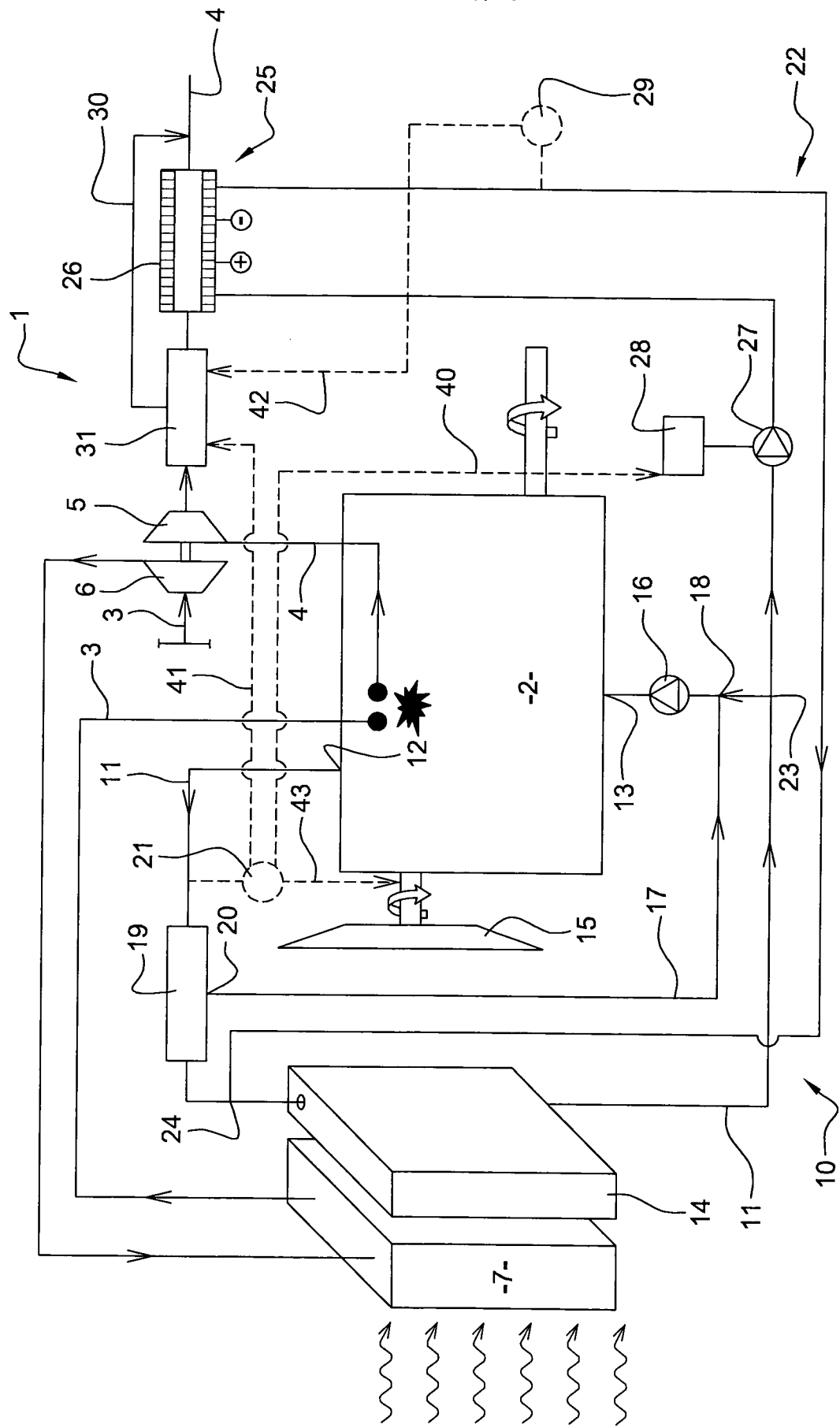


Fig. 1

INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER INV. F01N5/02 F01N9/00 H01L35/30 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/229649 A1 (YANG JIHUI [CA] ET AL) 17 September 2009 (2009-09-17) paragraph [0016] - paragraph [0020]; figure 2	1,2, 10-12
X	DE 10 2008 023832 A1 (BAYERISCHE MOTOREN WERKE AG [DE]) 19 November 2009 (2009-11-19) paragraph [0014] - paragraph [0019]; figure 1	1-3,12
A	EP 1 475 532 A2 (DENSO CORP [JP]) 10 November 2004 (2004-11-10) abstract; figure 1	1-3,10, 11
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
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