(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
1 May 2014 (01.05.2014)

WIPO | PCT

(10) International Publication Number
WO 2014/064483 A1

(51) International Patent Classification:
F01K 15/02 (2006.01) *F01K 25/08* (2006.01)
F01K 23/06 (2006.01) *F01N 5/02* (2006.01)

(21) International Application Number:
PCT/IB2012/002620

(22) International Filing Date:
23 October 2012 (23.10.2012)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **RENAULT TRUCKS** [FR/FR]; 99 route de Lyon, F-69800 Saint Priest (FR).

(72) Inventors; and
(71) Applicants *(for US only)*: **ESPINOSA, Nicolas** [FR/FR]; 2, rue Baudrand, F-69540 Irigny (FR). **SIMON, Lionel** [FR/FR]; 67 bis Avenue Lacassagne, F-69003 Lyon (FR). **MALEGUE, Jean-Baptiste** [FR/FR]; 142 rue Marino Simonetti, F-69150 Decines Charpieu (FR).

(74) Agent: **PUTET, Gilles**; Volvo Corporate IP TER E70 2 12, Renault Trucks, 99, route de Lyon, F-69806 Saint-Priest (FR).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

[Continued on next page]

(54) Title: RANKINE SYSTEM AND ENGINE ARRANGEMENT COMPRISING A RANKINE SYSTEM

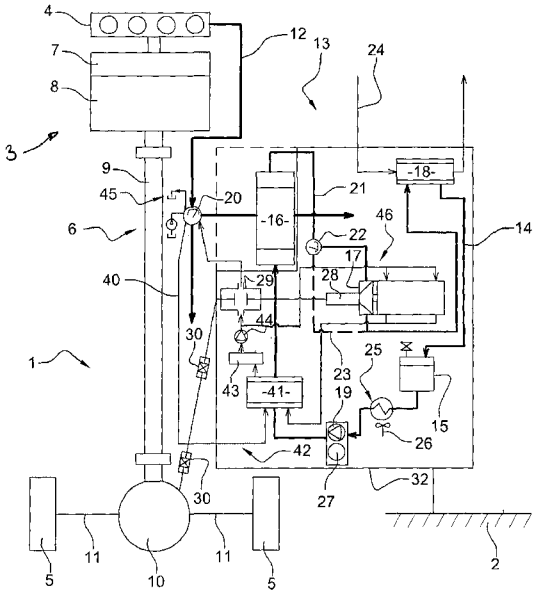


Fig. 1

(57) Abstract: The engine arrangement (3) comprises: - an internal combustion engine (4) and an exhaust line (12) capable of collecting exhaust gases from said engine (4); - a Rankine system (13) carrying a working fluid in a loop, in which said working fluid is successively evaporated in a heat exchanger (16) by means of the exhaust gases, expanded in an expander (17), condensed in a condenser (18) and compressed in a pump (19); - an exhaust directional valve (20) located in the exhaust line (12) and capable of directing part of the exhaust gases towards the heat exchanger (16); - a valve cooling circuit (40) carrying a fluid having cooling properties for cooling said exhaust directional valve (20), said valve cooling circuit (40) being disjoined from the engine cooling circuit (24).

WO 2014/064483 A1

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

RANKINE SYSTEM AND ENGINE ARRANGEMENT COMPRISING A RANKINE SYSTEM

Field of the invention

The present invention relates to a Rankine system, to an engine arrangement comprising a Rankine system, and to a vehicle comprising such an engine arrangement.

Technological background

For many years, attempts have been made to improve the efficiency of internal combustion engines of vehicles, which has a direct impact on fuel consumption.

For this purpose, an engine can conventionally be equipped with a waste heat recovery system, i.e. a system making use of a heat source produced by the vehicle operation, such as the hot exhaust gases which contain a lot of thermal energy that would otherwise be lost.

One example of a waste heat recovery system is a Rankine system, which comprises a circuit in which a working fluid flows in a closed loop and undergoes successive processes according to the Rankine thermodynamic cycle:

- the working fluid, which is a liquid at this stage, is pumped, i.e. compressed, from low to high pressure;
- the high pressure working liquid is evaporated into a gas by the heat source, for example by the exhaust gases. In practice, an exhaust directional valve is located in the exhaust line to direct part of the exhaust gases towards a heat exchanger so as to evaporate the working fluid;
- the working gas is expanded in an expander;
- finally, the working gas is condensed in a condenser.

As a result, at least part of the thermal energy of the heat source used to evaporate the working fluid is recovered in the expander under the form mechanical energy. It is conventional to transform that mechanical energy into electricity thanks to a generator driven by the expander, but it is also known to mechanically connect an output shaft of the expander to the driveline of the

vehicle so that the energy recovered in the expander is re-used directly in mechanical form to assist in propelling the vehicle.

However, in practice, the implementation of a Rankine system on a vehicle presents a number of problems.

In particular, the electronic control unit of the exhaust directional valve cannot withstand too high temperatures, for example temperatures higher than 150-200°C, and therefore needs cooling insofar as the exhaust gases temperature can be as high as 400-600°C. The same is true of the valve mechanism itself, where excessive temperatures can affect the movements of mobile parts, the fluid tightness and the overall durability.

The conventional systems used for cooling said valve are not fully satisfactory.

Besides, such systems can be quite complex, in particular if they involve the implementation of long fluid pipes on the vehicle, this ultimately resulting in installation and maintenance complexity.

It therefore appears that engine arrangements comprising a Rankine system could be improved.

Summary

It is an object of the present invention to provide an improved Rankine system and an improved engine arrangement comprising a Rankine system which can overcome some drawbacks of the prior art.

It is another object of the invention to improve the cooling of the directional valve by providing a simpler and more efficient system.

According to the invention such Rankine system can be used in an engine arrangement having an internal combustion engine and an exhaust line capable of collecting exhaust gases from said engine.

The Rankine system carries a working fluid in a loop in which said working fluid is successively evaporated in a heat exchanger by means of the an engine heated fluid, such as the exhaust gases, expanded in an expander, condensed in a condenser and compressed in a pump.

A directional valve is provided which is capable of directing at least part of the engine heated fluid towards the heat exchanger. In the engine arrangement, the directional valve is located in the exhaust line and is for

example capable of directing part of the exhaust gases towards the heat exchanger.

The Rankine system has a valve cooling circuit, dedicated to the Rankine system, and carrying a valve cooling fluid for cooling said directional valve. In the engine arrangement, said dedicated valve cooling circuit is disjoined from an engine cooling circuit.

The terms "disjoined from the engine cooling circuit" mean that the valve cooling circuit has no common parts with the engine cooling circuit in which an engine cooling fluid and the valve cooling fluid may mix. Therefore, the fluid used to cool the exhaust directional valve is not the engine cooling fluid.

Providing a valve cooling circuit which is disjoined from the engine cooling circuit makes it possible to arrange said valve cooling circuit far from the engine, without requiring long pipes for the valve cooling fluid. For example, the valve cooling circuit can be installed close to the exhaust directional valve, at a median or a rear part of the vehicle. If the Rankine system is also located at the median or rear part of the vehicle, the valve cooling circuit can more generally be used for fulfilling other functions related to the Rankine system. This further allows the Rankine system to be separated from the engine arrangement.

Besides, with the invention, it may be envisaged to further provide a valve cooling circuit that is a separate and closed circuit, dedicated to the Rankine system. As a result, the installation and maintenance operations are considerably facilitated. Furthermore, it makes it possible to design the Rankine system as an add-on system that can be retrofitted to conventional vehicles.

According to another aspect, the invention relates to a vehicle comprising an engine arrangement as previously described.

The term "vehicle" embraces all types of vehicles, including industrial vehicles, trucks, construction equipment machines such as excavators, lauders, haulers, compactors, etc.

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

Brief description of the drawings

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

Figure 1 is a schematic representation of a vehicle comprising an engine arrangement equipped with a Rankine system, according to an embodiment the invention.

Detailed description of the invention

As this is schematically and partially illustrated in Figure 1, a vehicle 1, such as a truck, may comprise a chassis 2.

The vehicle 1 further comprises an engine arrangement 3 comprising an internal combustion engine 4 installed on the chassis 2. The engine 4 is able to drive the drive wheels 5 of the vehicle 1, which partly support the chassis 2, through a driveline 6. The driveline 6 can include mainly a clutch 7, a gearbox 8, a propulsion shaft 9, and at least one drive axle comprising for example a differential 10 and a drive shaft 11 for each of a left and of a right drive wheel 5.

An exhaust line 12 is provided for collecting the exhaust gases from the engine 4, i.e. the gases which result from the combustion in the engine.

The vehicle 1 is also equipped with a Rankine system 13. The system 13 is preferably installed on the chassis 2. The Rankine system 13 comprises a circuit 14 forming a loop and including a tank 15 for a working fluid. In said circuit 14, the working fluid is successively evaporated in a heat exchanger 16 by heat exchange with an engine heated fluid, typcially the exhaust gases flowing in the exhaust line 12, expanded in an expander 17, condensed in a condenser 18, and compressed in a pump 19.

More specifically, the engine arrangement 3 comprises an exhaust directional valve 20 located in the exhaust line 12 and capable of directing part of the exhaust gases towards the heat exchanger 16, which here is an evaporator. The rest of the exhaust gases continue in the exhaust line without

flowing through the heat exchanger 16. Owing to the high temperature of the exhaust gases which flow in the heat exchanger 16, the working fluid is evaporated into a gas. The engine exhaust gases could be exhaust gases circulating in a recirculation circuit for being fed to the engine intake. Other heated engine fluids could also be used as heat source for the Rankine system. The Rankine system could have several heat exchangers where the working fluid would be heated successively by several different engine heated fluids.

By acting on the exhaust directional valve, it is possible to control the amount of gases directed to the heat exchanger and to by-pass partly or totally the heat exchanger 16 for limiting the amount of heat that is provided to the Rankine system 13. Such strategy may be used especially when the cooling capacity of the vehicle 1 is not high enough to cool the working fluid in the condenser 18, or when, to match the required cooling capacity, it would be necessary to actuate an engine driven or electrically driven fan.

The line 21 of circuit 14 which connects the heat exchanger 16 and the expander 17 can include a valve 22 capable of directing all or part of the working fluid flow in a by-pass line 23 of the expander 17, typically for the starting or shut down phases of the Rankine system 13. The expander may be a Pelton turbine, but other types of expanders can be used, such as a centrifugal turbine, a screw expander, a piston expander, etc...

Downstream from the expander 17, the gas is condensed in the condenser 18. The condenser 18 can be arranged at the front part of the vehicle 1, so that the working fluid can be condensed by heat exchange with ambient air moving through the condenser due to the vehicle motion.

Alternatively, as depicted in the figure, the condenser 18 can be designed to condense the working fluid by heat exchange with the engine cooling fluid, or another relatively low temperature circuit. In this embodiment, the condenser 18 is thus an indirect condenser arranged on a portion of the engine cooling circuit 24. The working fluid can be ethanol, while the engine cooling fluid can be a mixture of water and glycol. Nevertheless, other working fluids could be used, for example water, a refrigerant fluid such as rf245fa, etc... Also, other engine cooling fluids could be used

This embodiment is advantageous in that it does not require the condenser 18 to be arranged at the front part of the vehicle 1, where only limited space is generally available. Moreover, such an arrangement does not require long pipes in the working fluid circuit 14 between the front part of the

vehicle 1 and the other components of the Rankine system 13, which can be located at the median or even the rear part of the vehicle 1, since the condenser 18 can be located closer to these other components. Furthermore, condensing the working fluid with this implementation may allow reducing the size of the condenser since the cooling agent is a liquid rather than air.

Besides, this can improve the Rankine system efficiency and avoid the necessity to deactivate it. Indeed, in some operating conditions, the cold provided by ambient air moving through a condenser located at the front part of the vehicle is not enough to cool and condensate the working fluid. This can typically happen at high loads, and/or when outside air temperature is fairly high. In this case, in order to prevent the working fluid from overheating or from reaching too high pressure levels, or to prevent the activation of the vehicle fan in order to provide additional cold to the condenser, which would have negative consequences on the overall energy consumption of the vehicle, the Rankine system can need to be deactivated. This drawback can be avoided or at least minimized with the illustrated arrangement of the condenser 18 making use of the engine cooling fluid.

Another advantage of this embodiment is that it allows minimizing the amount of working fluid, and makes the starting phases of the Rankine system 13 easier, in particular because cavitation problems are avoided.

The condensed working fluid then flows to the tank 15.

In certain systems, and typically depending on the type of working fluid used, the Rankine system 13 may further comprise a sub-cooler 25 which is located upstream from the pump 19. The sub-cooler 25, preferably located downstream from the tank 15, can be air-cooled and can in that case include a sub-cooler fan 26. Such a sub-cooler 25 makes it possible to lower the working fluid temperature by around 2-3°C, which may further limit the risk of cavitation at the pump inlet.

Finally, the pump 19, which may be driven by an electric motor 27, pumps the working fluid, which is a liquid at this stage, from low to high pressure before it enters the heat exchanger 16.

According to a possible implementation, the expander can have an output shaft 28 which can be mechanically connected to the engine crankshaft or to the driveline. More precisely, although it could be connected to any part of the driveline, the output shaft may advantageously be connected to the drive wheels differential 10. More specifically, the vehicle 1 can comprise a viscous

coupling unit 29, such as a hydrodynamic torque converter, which connects mechanically the drive wheels differential 10 and the expander shaft 28, in order to transfer torque from the expander to the driveline while allowing different speed ratios between the two. Also, especially in the case of a high-speed expander such as a pelton turbine or a centrifugal turbine, a speed reducing transmission can be interposed between the expander and the driveline, preferably between the expander and the viscous coupling unit if such unit is provided.

Recovering the energy from the expander 17 mechanically may be more advantageous than recovering said energy electrically, insofar as the amount of electricity so produced often exceeds the vehicle needs and therefore cannot be fully used, which is not satisfactory. Moreover, mechanically connecting the expander shaft 28 to the drive wheels differential 10 is one of the best options, since it makes it possible to directly provide additional torque with a satisfactory yield and since it is of greater flexibility in application.

Cardan joints or universal joints 30 are preferably interposed between the viscous coupling unit 29 and the drive wheels differential 10, to provide an adaptation means between the viscous coupling unit 29, which is preferably installed on the chassis 2, and the drive wheels differential 10, which is arranged on the vehicle drive axle and which therefore moves relative to the chassis due to the axle suspensions. Such joints are further advantageous in that they have very low mechanical losses.

Therefore, such an engine arrangement is simple in terms of coupling and efficiency.

According to an aspect of the invention, the engine arrangement 3 further comprises a valve cooling circuit 40 carrying a valve cooling fluid for cooling the exhaust directional valve 20.

Such a valve cooling circuit can be especially useful where the exhaust directional valve comprises an electronic control unit which is integrated in immediate vicinity with the valve mechanism itself, the latter being directly exposed to the heat of the exhaust gases. Indeed, the electronic control unit of such an exhaust directional valve 20 cannot withstand too high temperatures, for example temperatures higher than 150-200°C, and therefore it can need cooling insofar as the exhaust gases temperature can be as high as 400-600°C. Additionally or alternatively, the valve cooling circuit can be useful

for cooling the valve mechanism itself, where excessive temperatures can affect the movements of mobile parts, the fluid tightness and the overall durability.

The valve cooling circuit 40 is disjoined from the engine cooling circuit 24, i.e. has no common parts with the engine cooling circuit 24 in which the engine cooling fluid would be mixed with the valve cooling fluid.

By providing a valve cooling circuit 40 which is disjoined from the engine cooling circuit 24 it is possible to arrange said valve cooling circuit 40 at a distance from the engine 4. For example, the valve cooling circuit 40 can be installed close to the Rankine system 13, at a median or rear part of the vehicle 1, and can more generally be used for fulfilling other functions related to the Rankine system 13. This further allows the Rankine system 13 to be separated from the engine arrangement.

The valve cooling circuit 40 can comprise a cooler 41 capable of cooling the valve cooling fluid. This can be necessary as said valve cooling fluid is distinct from the engine cooling fluid and therefore cannot be cooled by the radiator and fan of the engine cooling circuit 24.

According to an embodiment, said cooler 41 can further be a heat exchanger arranged in the Rankine system 13, between the pump 19 and the heat exchanger 16, in which there is heat exchange between the Rankine working fluid and the valve cooling fluid so as to pre-heat the working fluid before it enters the heat exchanger 16.

If the working fluid is so preheated, the heat exchanger 16 can be downsized, and therefore more easily installed in a limited place on the chassis 2.

The cooler 41 can be located either on the main line of the valve cooling circuit 40 or on a diversion line thereof.

Furthermore, the valve cooling fluid can further be used as the viscous fluid in the viscous coupling unit 29.

Preferably, the valve cooling circuit 40 and the working fluid circuit 14 of the Rankine system 13 are separate circuits with respect to the fluids, in that the valve cooling fluid and the working fluid do not mix. The two fluids could be of similar composition, but are preferably of different composition. For example the valve cooling fluid can advantageously be oil.

According to the embodiment depicted in figure 1, the valve cooling circuit 40 can be part of a fluid circuit 42 which further comprises a lubricating

loop 46, for example in view of lubricating the expander 17 of the Rankine system 13. The valve cooling fluid is then used as a lubricant for the expander 17, and possibly for other components of the Rankine system. In this embodiment, the bearings of the expander 17 are therefore not lubricated by the working fluid, nor by the engine cooling fluid, but by the valve cooling fluid. In particular, the lubricating loop 46 is disjoined from the engine cooling circuit 24.

More specifically, the fluid circuit 42 can comprise on the one hand the valve cooling circuit 40 which may form a closed loop including the viscous coupling unit 29. In said valve cooling circuit 40, the valve cooling fluid flows successively through the exhaust directional valve 20, for example especially around the electronic control unit of said exhaust directional valve 20, the cooler 41, a filter 43, a pump 44, and through the viscous coupling unit 29. The valve cooling circuit 40 can further include a valve actuation portion 45, the same fluid being further used to actuate the exhaust directional valve 20, when such valve is hydraulically actuated.

On the other hand, the fluid circuit 42 can comprise the lubricating loop 46. For example, the lubricating loop 46 branches from the valve cooling circuit 40 between the pump 44 and the viscous coupling unit 29 and returns to said valve cooling circuit 40 upstream from the cooler 41. With this arrangement, the valve cooling circuit 40 and the lubricating loop 46 substantially form two separate loops, even if they share some portions and components. Alternatively, the fluid circuit 42 may comprise one and a single loop in which the fluid flows successively through every component, the valve cooling circuit 40 and the lubricating loop 46 being coincident.

The invention can provide a fluid circuit 42 dedicated to the Rankine system 13 and separate from other circuits, in particular from the engine cooling circuit 24, and from the circuit 14 of the Rankine system 13. Thus, the Rankine system 13 can more easily be designed as an add-on system that can be retrofitted to conventional vehicles.

The various components of the Rankine system 13 can be installed on the vehicle at different places, possibly far from each other.

Alternatively, according to an advantageous implementation of the invention, at least the tank 15, the expander 17 and the pump 19 of the Rankine system 13 can be fixed on a frame 32 capable of being removably installed on the chassis 2, and all or at least most of the components of the

valve cooling circuit 40 (except the directional valve itself for example) can also be installed on said frame 32.

In other words, instead of being installed independently of each other directly or indirectly on the chassis 2, said components can be mounted on one single frame 32, which may additionally form a kind of housing. Thus, these components are not installed directly on the chassis 2 but on the frame 32, said frame 32 being installed on the chassis 2. For example, the frame 32 can be mounted on a lateral beam of the chassis 2. In practice, the Rankine system 13 can be arranged at the rear part of the vehicle 1, which is less complex than installing said system near the engine 4, where little space is available due to other existing systems (such as turbo-compressors, turbo compound arrangements, etc.)

With this implementation, the installation and maintenance of the Rankine system 13 are made much easier. The Rankine system 13 can thus be designed as an add-on system that can be retrofitted to conventional vehicles, especially that can be integrated in a long haul truck without requiring significant changes. Furthermore, the Rankine system 13, with its valve cooling circuit 40, is more compact, partly because no long pipes are required for the valve cooling circuit.

The heat exchanger 16, which is generally arranged on the exhaust line, can preferably be located outside the frame 32, in the sense that it is not fixed on the frame but for example directly or indirectly on a lateral beam. Nevertheless, the heat exchanger is preferably located in the vicinity of the frame, i.e. in the vicinity of the components which are fixed on the frame. Therefore, in this implementation, the heat exchanger 16 is not necessarily removed from the vehicle 1 together with the other components of the Rankine system 13 which are installed on the frame 32 when the frame is removed from the vehicle.

As regards the condenser 18, it can be fixed on the frame 32, or it can be arranged outside the frame 32, in the sense that it is not fixed on the frame, but preferably in the vicinity of the frame.

One significant advantage of the invention is the possibility of providing a fluid circuit 42 dedicated to the Rankine system 13, separate from the engine cooling circuit 24 and from the Rankine circuit 14, in which flows a fluid having cooling, lubricant and viscosity properties so as to fulfil numerous functions. This fluid circuit 42 is then both a cooling and lubricant circuit for the

various components of the Rankine system 13. This fluid circuit 42 further preferably comprises its own filter 43, and its own pump 44.

Preferably, said fluid circuit 42 can be integrated in the frame 32, typically at the median or rear part of the vehicle 1. As a result, the installation and maintenance operations are considerably facilitated. Furthermore, it makes it possible to design the Rankine system as an add-on system that can be retrofitted to conventional vehicles.

The invention is of course not limited to the embodiment described above as an example, but encompasses all technical equivalents and alternatives of the means described as well as combinations thereof.

CLAIMS

1. An engine arrangement comprising:

- an internal combustion engine (4) and an exhaust line (12) capable of collecting exhaust gases from said engine (4);
- a Rankine system (13) carrying a working fluid in a loop, in which said working fluid is successively evaporated in a heat exchanger (16) by heat exchange with the exhaust gases, expanded in an expander (17), condensed in a condenser (18) and compressed in a pump (19);
- an exhaust directional valve (20) located in the exhaust line (12) and capable of directing at least part of the exhaust gases towards the heat exchanger (16);

characterized in that it further comprises a valve cooling circuit (40) carrying a valve cooling fluid for cooling said exhaust directional valve (20), said valve cooling circuit (40) being disjoined from an engine cooling circuit (24).

2. The engine arrangement according to claim 1, characterized in that the valve cooling circuit (40) comprises a cooler (41) capable of cooling the valve cooling fluid, said cooler (41) being further arranged in the Rankine system (13), between the pump (19) and the heat exchanger (16), so as to pre-heat the working fluid before it enters the heat exchanger (16) by heat exchange in the cooler (41) between the valve cooling fluid and the working fluid.

3. The engine arrangement according to claim 1 or 2, characterized in that the expander has an output shaft (28) which is mechanically connected to a driveline of the vehicle through a viscous coupling unit (29) comprising viscous fluid, and in that the valve cooling fluid circulating in the valve cooling circuit is further used as the viscous fluid in the viscous coupling unit (29).

4. The engine arrangement according to any one of claims 1 to 3, characterized in that the valve cooling fluid is distinct from the working fluid.

5. The engine arrangement according to any one of claims 3 or 4, characterized in that the valve cooling circuit (40) forms a closed loop which includes the viscous coupling unit (29).

6. The engine arrangement according to any one of claims 1 to 5, characterized in that the valve cooling circuit (40) is part of a fluid circuit (42) which further comprises a lubricating loop (46) including the expander (17) of the Rankine system (13), the valve cooling fluid being further used as a lubricant for the expander (17).

7. The engine arrangement according to claims 2 and 7 in combination, characterized in that the expander (17) is arranged in parallel with the cooler (41).

8. The engine arrangement according to any one of claims 1 to 7, characterized in that the valve cooling circuit (40) further includes a valve actuation portion (45), the valve cooling fluid being further used to actuate the directional valve (20).

9. The engine arrangement according to any one of claims 1 to 8, characterized in that at least the tank (15), the expander (17) and the pump (19) of the Rankine system (13) are fixed on a frame (32) capable of being removably installed on a vehicle chassis (2).

10. A vehicle comprising an engine arrangement (3) according to any one of claims 1 to 9.

11. A Rankine system for a vehicle having an engine, wherein said system carries a working fluid in a loop in which said working fluid is successively evaporated in a heat exchanger (16) by heat exchange with an engine heated fluid, expanded in an expander (17), condensed in a condenser (18) and compressed in a pump (19);

- a directional valve (20) capable of directing at least part of the engine heated fluid towards the heat exchanger (16);

characterized in that the system further comprises a dedicated valve cooling circuit (40) carrying a valve cooling fluid for cooling said directional valve (20).

12. The Rankine system according to claim 11, characterized in that the valve cooling circuit (40) comprises a cooler (41) capable of cooling the valve cooling fluid, said cooler (41) being further arranged in the Rankine system (13), between the pump (19) and the heat exchanger (16), so as to pre-heat the working fluid before it enters the heat exchanger (16) by heat exchange in the cooler (41) between the valve cooling fluid and the working fluid.

13. The Rankine system according to claim 11 or 12, characterized in that the expander has an output shaft (28) which is mechanically connected to a viscous coupling unit (29) comprising viscous fluid, and in that the valve cooling fluid circulating in the valve cooling circuit is further used as the viscous fluid in the viscous coupling unit (29).

14. The Rankine system according to any one of claims 11 to 13, characterized in that the valve cooling fluid is distinct from the working fluid.

15. The Rankine system according to any one of claims 13 or 14, characterized in that the valve cooling circuit (40) forms a closed loop which includes the viscous coupling unit (29).

16. The Rankine system according to any one of claims 11 to 15, characterized in that the valve cooling circuit (40) is part of a fluid circuit (42) which further comprises a lubricating loop (46) including the expander (17) of the Rankine system (13), the valve cooling fluid being further used as a lubricant for the expander (17).

17. The Rankine system according to claims 12 and 17 in combination, characterized in that the expander (17) is arranged in parallel with the cooler (41).

18. The Rankine system according to any one of claims 11 to 17, characterized in that the valve cooling circuit (40) further includes a valve actuation portion (45), the fluid being further used to actuate the directional valve (20).

19. The Rankine system according to any one of claims 11 to 18, characterized in that at least the tank (15), the expander (17) and the pump (19) of the Rankine system (13) are fixed on a frame (32) capable of being removably installed on a vehicle chassis (2).

20. The Rankine system according to any one of claims 11 to 19, characterized in that said valve cooling circuit (40) is disjoined from an engine cooling circuit (24).

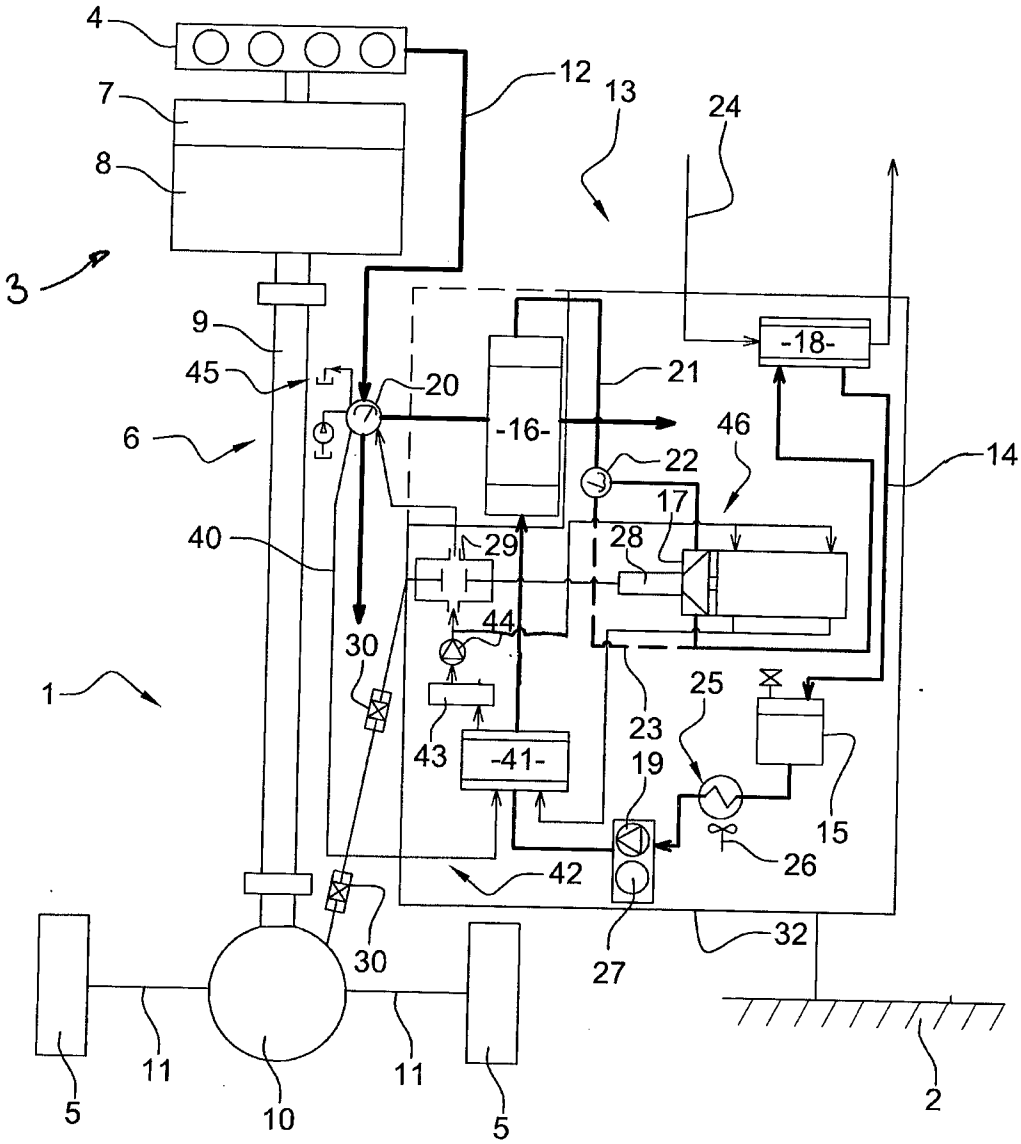

4
7
8
3
9
45
6
40
1
12
13
24
20
21
-16-
-18-
46
22
14
17
28
29
44
30
43
-41-
25
23
19
15
26
42
27
32
30
11
11
5
10
5
2

Fig. 1

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/002620

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01K15/02 F01K23/06 F01K25/08 F01N5/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01K F01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 450 283 B1 (TAGGETT MICHAEL BLAKE [US]) 17 September 2002 (2002-09-17) column 7, line 63 - column 8, line 54; figure 3	1-20
A	WO 2012/088532 A1 (CUMMINS IP INC [US]; ERNST TIMOTHY C [US]; MORRIS DAVE [US]) 28 June 2012 (2012-06-28) paragraph [0017] - paragraph [0021]; figure 1	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 August 2013	14/08/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Coquau, Stéphane

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2012/002620

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6450283 B1	17-09-2002	NONE	
WO 2012088532 A1	28-06-2012	US 2012192560 A1	02-08-2012
		WO 2012088532 A1	28-06-2012