(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 879 082 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
10.07.2024 Bulletin 2024/28

(21) Application number: **20162674.4**

(22) Date of filing: **12.03.2020**

(51) International Patent Classification (IPC):
F01K 13/02 *(2006.01)* ***F01K 23/06*** *(2006.01)*
F01K 23/10 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F01K 13/02; F01K 23/065; F01K 23/101

(54) **A TANK PRESSURE REGULATION SYSTEM FOR A WASTE HEAT RECOVERY SYSTEM**

TANKDRUCKREGELSYSTEM FÜR EIN ABWÄRMERÜCKGEWINNUNGSSYSTEM

SYSTÈME DE RÉGULATION DE PRESSION DE RÉSERVOIR POUR UN SYSTÈME DE RÉCUPÉRATION DE CHALEUR PERDUE

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(43) Date of publication of application:
15.09.2021 Bulletin 2021/37

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Processed by Luminess, 75001 PARIS (FR)

Description

TECHNICAL FIELD

[0001] The present disclosure generally relates to tank pressure regulation system for a waste heat recovery system. The present disclosure further relates to a method for controlling a tank pressure regulation system, and to a waste heat recovery system for a vehicle.

BACKGROUND

[0002] Generally, waste heat recovery systems are configured to capture and input waste heat from one process to another process, or back into the original process, as an additional source of energy. WO2019/117794 discloses an example arrangement and method for controlling a WHR-system. Furthermore, WO2019/117788 discloses a device and a method for volume compensation and pressure control of a working medium in a WHR-system.

[0003] Waste heat recovery systems often operates using the Rankine cycle or organic Rankine cycle. Systems operating with this cycle typically consist of a heater, an expander, a condenser and a pump that circulates a working fluid to control the waste heat recovery process. To feed the pump with a working fluid an expansion tank may be fitted to the system with a rubber membrane to separate the working fluid from surrounding air.

[0004] When heating up the working fluid, it evaporates to steam and push the working fluid in the system forward and pass the expander. To manage the expanding steam on the highpressure side, the expansion tank allows the working fluid to be stored without risk of hazardous pressure increase in the system.

[0005] Work is extracted from the cycle for example through e.g. an expander or a turbine arranged downstream of the evaporator. Naturally, there is a desire to improve the efficiency of the work extraction from waste heat recovery systems.

SUMMARY

[0006] The subject-matter of the present disclosure generally relates to a tank pressure regulation system that can provide for more efficient recovery of work in waste heat recovery system. Further, with the proposed tank pressure regulation system, more heat flux can also be extracted from the waste heat recovery system.

[0007] According to a first aspect of the present invention, there is provided a tank pressure regulation system, as defined in claim 1, for a waste heat recovery system comprising an expansion tank to allow for a working fluid of the waste heat recovery system to expand.

[0008] The tank pressure regulation system comprising a compressor comprising an inlet for withdrawing gas and an outlet for providing pressurized gas, and a valve arrangement connectable in fluid communication with the expansion tank and with the inlet and outlet of the compressor. The valve arrangement is responsive to a control signal to alternately connect the outlet of the compressor to the expansion tank to thereby increase the pressure in the expansion tank, and connect the inlet of the compressor to the expansion tank to withdraw gas from the expansion tank to thereby reduce the pressure in the expansion tank.

[0009] The pressure in the expansion tank is regulated based on the present condensation temperature of the working fluid.

[0010] The inventor realized that by regulating the pressure in the expansion tank of the waste heat recovery system based on the condensation temperature of the working fluid, the cooling capacity of a condenser in the waste heat recovery system is fully utilized. In other words, the condensation temperature of the working fluid is shifted to substantially match the temperature of the cooling media in the condenser but such that the condenser may still fully condense the working fluid.

[0011] For example, when the temperature of the cooling medium in a condenser of the waste heat recovery system is lower than the present condensation point for the working fluid of the waste heat recovery system, a lower pressure can be used in the expansion tank to move the condensation point downward to substantially match the temperature of the cooling media in the condenser. Accordingly, the pressure on the condenser side of the expander may be lowered which enables to extract more work.

[0012] To this end, the pressure in the expansion tank may be regulated further based on a temperature of a condenser cooling media upstream of the expansion tank in the waste heat recovery system.

[0013] Preferably, the pressure in the expansion tank may be controlled such that a condensation temperature for the working fluid is equal to or exceed a present temperature of a condenser cooling media of a condenser arranged upstream of the expansion tank in the waste heat recovery system.

[0014] The pressure in the expansion tank may even be regulated to a pressure that is below ambient pressure, i.e. to an under-pressure in the expansion tank.

[0015] The condensation temperature may for example be determined by determining the present pressure of the working fluid in the waste recovery system, and based on the present pressure, the condensation temperature may be determined. For example, the present condensation temperature may be found in a table or map of pressure versus condensation temperature for the working fluid at hand, or via a mathematical expression of condensation temperature versus pressure.

[0016] In a second aspect of the invention, the inventors propose a method, as defined in claim 14, for controlling a tank pressure regulation system for a waste heat recovery system comprising a condenser having a condenser cooling media upstream of an expansion tank configured to allow for a working fluid of the waste heat recovery system to expand.

[0017] The method comprises increasing, when a temperature of the condenser cooling media exceeds a present condensation temperature for the working fluid, the pressure of the working fluid in the expansion tank.

[0018] The method further comprises reducing, when a temperature of the condenser cooling media is below the present condensation temperature for the working fluid, the pressure of the working fluid in the expansion tank.

[0019] Further features of, and advantages with, embodiments of the present disclosure will become apparent when studying the appended claims and the following description. The skilled person realize that different features of the present invention may be combined to create embodiments other than those described in the following, without departing from the scope of the present invention.

BRIEF DESCRIPTION OF DRAWINGS

[0020] These and other aspects of the present invention will now be described in more detail, with reference to the appended drawings showing example embodiments of the invention, wherein:

FIG. 1 schematically illustrates a waste heat recovery system for a vehicle according to embodiments of the present disclosure;

FIG. 2 is an example Rankine cycle diagram;

FIG. 3A illustrate a diagram of a tank pressure regulation system according to embodiments of the present disclosure;

FIG. 3B illustrate a diagram of a tank pressure regulation system according to embodiments of the present disclosure; and

FIG 4 is a flow-chart of method steps according to embodiments of the present disclosure.

DETAILED DESCRIPTION

[0021] In the present detailed description, various embodiments according to the present disclosure are described. However, embodiments of the present disclosure may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided for thoroughness and completeness, and to fully convey the scope of the invention to the skilled person. Like reference characters refer to like elements throughout.

[0022] Fig. 1 illustrates a waste heat recovery system 100 for a vehicle. The waste heat recovery system 100 comprises a tank pressure regulation system 300 for regulating the pressure in an expansion tank 102. The tank pressure regulation system 300 is described in further detail below with reference to subsequent drawings.

[0023] The waste heat recovery system 100 further comprises at least one heat exchanger 104 for evaporating the working fluid, and an expander 106 for receiving the evaporated working fluid and for extracting work through expansion of the evaporated working fluid.

[0024] Further, the waste heat recovery system 100 comprises a condenser 108 arranged to receive and liquify the evaporated working fluid by heat exchange with a condenser cooling media. A pump 109 is arranged for circulating the working fluid in the waste heat recovery system, the pump 109 is connected to fluid communication lines downstream of the expansion tank 102 and upstream of the at least one heat exchanger 104.

[0025] The general operation of the waste heat recovery system will now be described with reference to fig. 1, and with reference to fig. 2 which illustrates a temperature-entropy diagram of a Rankine cycle. A Rankine cycle is *per se* known in the art.

[0026] The pump 109 inputs work into the system by increasing the pressure of the working fluid circulating in the system 100. The working fluid is in liquid form at the pump 109 and the pressure of the working fluid is increased by the work input by the pump 109, this corresponds to moving from point 1 to point 2 in the Rankine cycle diagram.

[0027] From the pump 109, the pressurized working fluid reaches the heat exchangers 104 through transfer pipe 110a and transfer pipe 110b that is connected between the heat exchangers 104. Note that a single heat exchanger may equally well be used instead of the here illustrated dual heat exchangers. In the heat exchangers 104, the working fluid is heated at substantially constant pressure by heat exchange with exhaust gases from the combustion chamber 112. The working fluid is vaporized in the heat exchangers 104, which corresponds to moving from point 2 to point 3 in the Rankine cycle diagram in fig. 2.

[0028] Different options for the operation of the heat exchangers are conceivable, but in this presently shown example, exhaust gases are transferred from the exhaust outlet of the exhaust chamber through gas transfer pipes 114a and exhaust manifold 115 before the exhaust gas reaches the heat exchangers 104. The exhaust manifold 115 is optionally connected to one side of a turbocharger 118. A charged air cooler 119 is optionally connected between the other side of the turbocharger 118 and an inlet manifold 121 of the engine 134. The heat exchangers 104 are provided with bypass pipes 120 connected upstream of each heat exchanger 104 via by-pass valves 122. An optional catalytic converter 124 is fluidly connected between the heat exchangers 104.

[0029] The vaporized working fluid reaches the expander 106 through transfer pipe 110c connected between the heat exchanger 104 and the expander 106, and optionally via a filter 126. Further, a bypass valve 113 and a safety valve 117 may be arranged in parallel with the expander 106.

[0030] In the expander 106, the vaporized working fluid expands through a piston expander which generates work, $W_{expander}$ and corresponds to moving from point 3 to point 4 in the Rankine cycle diagram. Subsequently, through the transfer pipe 110d, the vaporized working fluid enters the condenser 108 where it is condensed through heat exchange with a cooling media to become a liquid working fluid again. This corresponds to moving from point 4 to point 1 in the Rankine cycle diagram of fig. 2. The working fluid enters the expansion tank 102 through transfer pipe 110e.

[0031] The piston expander is here shown connected to a clutch 130 which may switch between providing the work outputted from the piston expander to a generator 132 e.g. configured to charge a battery, or to provide work to the combustion engine 134 of the vehicle.

[0032] From the Rankine cycle diagram of fig. 2 it is understood that the further the drop from point 3 to point 4, the more work can be extracted in the expander 106. The lines P1-P5 in fig. 2 indicates lines of constant pressure. The inventors realized that if the pressure at point 4 can be controlled, under the constraint that the working liquid is condensable in the condenser, more work can be extracted. In other words, lowering the pressure on the condenser side of the expander 106 enables a larger amount of work to be extracted. To this end, the pressure of the working liquid is controlled in the expansion tank 102 so that the condensation temperature of the working liquid is low but at a level that still enables the cooling media in the condenser to fully condense the vaporised working fluid leaving the expander. In this way may the amount of extractable work be increased.

[0033] Accordingly, the pressure in the expansion tank 102 is regulated based on the condensation temperature of the working fluid. Further, the pressure in the expansion tank is regulated based on a temperature of a condenser cooling media of the condenser 108 upstream of the expansion tank 102 in the waste heat recovery system. The condenser cooling media is transferred to the condenser through transfer pipe 111a, withdraws heat from the vaporized working fluid, and is led from the condenser through transfer pipe 111b. The temperature of the condenser cooling media is measured along the transfer pipe 111a, preferably at the inlet 111c of the condenser 108 in order to obtain an accurate measure of the temperature of condenser cooling media in the condenser.

[0034] Preferably, the pressure in the expansion tank 102 is controlled such that a condensation temperature for the working fluid is equal to or exceed a present temperature of a condenser cooling media upstream of the expansion tank in the waste heat recovery system.

[0035] By means of embodiments herein, the points 1 and 4 in the diagram in fig. 2 may be shifted between pressure lines. For example, by lowering the pressure of the working fluid in the expansion tank 102 in response to that the temperature of the cooling media is below the condensation temperature of the working fluid, the points 1 and 4 may be shifted down to points 1' and 4', thereby increasing the available $W_{expander}$.

[0036] The cooling media in the condenser 108 may be ambient air or a cooling liquid such as water flowing through the pipes 111a-b.

[0037] Fig. 3A and Fig. 3B illustrate a diagram of a tank pressure regulation system 300 according to embodiments of the present disclosure. The tank pressure regulation system 300 comprises a compressor 302 comprising an inlet 304 for withdrawing gas and an outlet 306 for providing pressurized gas.

[0038] Further, a conceptually shown valve arrangement 310 is connectable in fluid communication with the expansion tank 102 and with the inlet 304 and outlet 306 of the compressor 302. Here, the valve arrangement 310 is fluidly connected with the inlet 304 and the outlet 306 of the compressor 302.

[0039] The valve arrangement 310 is connected to an inlet 313 of the expansion tank 102 so that gas, such as air, may be pumped into or out from the expansion tank 102 by the compressor 302 via the valve arrangement 310.

[0040] The compressor, when operative, receives gas through the inlet 304, which generally is an air intake of the compressor. The received air is pressurized and output through the outlet 306. In other words, if the inlet 304 is connected to the expansion tank inlet 313, and the compressor 302 is operational, gas is extracted from the expansion tank 102, pressurized and output at the outlet 306 of the compressor. The outlet 306 may in such case output the pressurized gas to the ambient atmosphere as is the case in fig. 3A. On the other hand, if the inlet 304 is connected to ambient air and the outlet 306 is connected to the expansion tank inlet 313, and the compressor 302 is operational, gas is extracted from ambient air, pressurized and output at the outlet 306 of the compressor and into the expansion tank 102, as is the case in fig. 3B.

[0041] The valve arrangement 310 is responsive to a control signal S to alternately connect the outlet 306 of the compressor 302 to the expansion tank 102 to thereby increase the pressure in the expansion tank, see fig. 3B, and to alternately connect the inlet 304 of the compressor 302 to the expansion tank 102 to withdraw gas from the expansion tank 102 to thereby reduce the pressure in the expansion tank 102, see fig. 3A. The pressure in the expansion tank 102 is regulated based on the present condensation temperature of the working fluid.

[0042] The present condensation temperature may be determined based on the present pressure of the working fluid in the waste heat recovery system.

[0043] Turning now to fig. 3A, with the compressor 302 connected with its inlet 304 to the expansion tank 102, it can extract gas from the expansion tank 102. Thereby the pressure inside the expansion tank 102 and therefore also the pressure of the working fluid 312 is reduced. The pressure of the working fluid may even be reduced to below ambient pressure, i.e. the pressure outside the expansion tank 102. Reducing the pressure of the working fluid lowers the condensation temperature of the working fluid. Accordingly, in response to a given temperature of the cooling media in the condenser 108, the pressure of the working fluid is reduced to a level that still enables for the cooling media in the condenser 108 to liquify the working fluid from the expander 106. Thus, the pressure in the expansion tank 102 is controlled such that a condensation temperature for the working fluid is equal to or exceed a present temperature of a condenser cooling media upstream of the expansion tank 102 in the waste heat recovery system.

[0044] Turning to fig. 3B, with the compressor 302 connected with its outlet 306 to the expansion tank 102, the compressor can provide pressurized gas into the expansion tank 102. Thereby, the pressure inside the expansion tank 102 and therefore also the pressure of the working fluid 312 is increased. The pressure may be increased to above ambient pressure. Increasing the pressure increases the condensation temperature of the working fluid. This may be needed if the cooling capacity of the cooling media in the condenser is not sufficient to liquify the vaporised working fluid from the expander 106.

[0045] The the pressure in the expansion tank 102 may be regulated to be maintained within a pressure range including ambient pressure.

[0046] The valve arrangement may be a four-way solenoid valve 310 although other types of valve arrangement are conceivable such as valve arrangements comprising more than one valve to achieve the same function as a four-way valve. A four-way solenoid valve is per se known in the art, but for sake of completeness, a spring 311 is arranged to provide a biasing force towards one of the configurations. For example, the spring 311 may cause a force that strives for pushing the valve 310 into the configuration shown in fig. 3A, whereas the spring 311 is being compressed for forcing the valve 310 into the configuration shown in fig. 3B.

[0047] The expansion tank 102 comprises an expandable container 102a and a rigid container 102b accommodating the expandable container 102a. The expandable container 102a which may be made from rubber or another flexible material is arranged to accommodate the working fluid 312. The expandable container 102a is adapted to be expandable such that the working fluid is allowed to expand therein. The rigid container 102b is arranged to be in fluid communication with the valve arrangement 310. The pressure in the rigid container 102b is controllable by the compressor 302 and valve arrangement 310. The rigid container 102b may be made from metal or hard plastic materials. The pressure in the rigid container 102b may be considered configured to be controllable by the compressor 302 and the valve arrangement 310.

[0048] In some possible embodiments, an air drier 322 for dehydrating air is connected on an air side port 324 of the valve arrangement 310. The air drier 322 advantageously dehydrates the air that is being withdrawn from ambient atmosphere and pressurized into the tank 102.

[0049] In embodiments a control unit 320 of the tank pressure regulation system 300, see figs. 3A-B, may be configured to receive signals *T, P* indicative of a temperature, i.e. signal *T* of a condenser cooling media, and indicative of the present pressure i.e. signal *P* in of the working fluid in the waste heat recovery system. The pressure *P* can be measured anywhere in the waste heat recovery system since the system is closed, i.e. the pressure of the working fluid should be the same across the system. For example, the pressure of the working fluid may be measured in the transfer pipe 110d between the evaporator 106 and the condenser 108 or in transfer pipe 110e between the condenser 108 and the expansion tank 102, or in the expansion tank itself. The pressure *P* is used to determine the present condensation temperature of the working fluid 312, and to provide the control signal *S* to the valve arrangement 310 based on the received signals. The pressure *P* is measured by a suitable pressure sensor arranged at the location where the pressure is measured, and the temperature *T* is measured by a temperature sensor, preferably arranged at the inlet 111c of the condenser 108.

[0050] The control unit 320 may, based on the measured pressure *P* determine a present condensation temperature of the working fluid. Using prior knowledge of the characteristics of the working fluid the present condensation temperature can be determined given the pressure. For example, a look-up table or a map of pressure versus condensation temperature may be used for finding the present condensation temperature given the pressure *P* if the working fluid is known. By comparing the determined condensation temperature to the temperature of the cooling media in the condenser, the control unit 302 may conclude that the temperature of the condenser media exceeds the present condensation temperature for the working fluid, and in response control the valve arrangement 310 to increase the pressure in the expansions tank. In contrast, if the the control unit 302 concludes that the temperature of the condenser media is below the present condensation temperature for the working fluid, the control unit 302 may control the valve arrangement such that the pressure of the working fluid in the expansion tank is reduced.

[0051] According to embodiments herein, the working fluid may be ethanol which has a condensation temperature of 78,4 C° at a pressure of 1 bar. However, other working fluids are conceivable such as acetone that has a condensation temperature of 56 C° at a pressure of 1 bar. Generally, the invention is applicable to any working fluid and the specific choice depends on the implementations at hand.

[0052] Embodiments of the present disclosure provide for controlled condensation setpoint for the working fluid, which enables using same waste heat recovery system architecture for both diesel engines as for petrol engines.

[0053] Fig. 4 is a flow-chart of method steps according to embodiments of the present disclosure. The method is for controlling a tank pressure regulation system for a waste heat recovery system comprising a condenser having a condenser cooling media upstream of an expansion tank configured to allow for a working fluid of the waste heat recovery system to expand. As step S102 the temperature of the cooling media is determined.

[0054] When a temperature of the condenser cooling media exceeds a present condensation temperature for the working fluid, increasing, the pressure of the working fluid in the expansion tank in step S104.

[0055] When a temperature of the condenser cooling media is below the present condensation temperature for the working fluid, reducing the pressure of the working fluid in the expansion tank in step S 106.

[0056] The method returns to determining the temperature of the cooling media again. The method may thus be continuously repeated in other to continuously control the pressure in the expansion tank and thereby also the condensation temperature of the working fluid according to the available cooling power in the condenser.

[0057] The method may comprise determining the present pressure of the working fluid in the waste heat recovery system, and determining the present condensation temperature of the working fluid based on the present pressure of the working fluid.

[0058] The present disclosure includes a control unit for controlling a tank pressure regulation system for a waste heat recovery system comprising an expansion tank to allow for a working fluid of the waste heat recovery system to expand, the control unit being configured to: acquire a signal *T* indicative of a temperature of a condenser cooling media upstream of the expansion tank in the waste heat recovery system; control, when the signal indicates a temperature exceeding a present condensation temperature for the working fluid, a valve arrangement in fluid communication with the expansion tank to connect an outlet of a compressor to the expansion tank to thereby increase the pressure of the working fluid, and control, when the signal indicates a temperature below the present condensation temperature for the working fluid, the valve arrangement to connect the inlet of the compressor to the expansion tank to withdraw gas from the expansion tank to thereby reduce the pressure in the expansion tank.

[0059] The control unit is configured acquire data indicative of the present pressure *P* of the working fluid in the waste heat recovery system, and determine the present condensation temperature of the working fluid based on the acquired data and a predetermined relation between pressure and condensation temperature for the working fluid. Such predetermined relation may be a map or lookup table including a relation between pressure and condensation temperature of the present working fluid. The relation may also be in the form of a mathematical function.

[0060] A control unit may include a microprocessor, microcontroller, programmable digital signal processor or another programmable device, as well as be embedded into the vehicle/power train control logic/hardware. The control unit may also, or instead, include an application-specific integrated circuit, a programmable gate array or programmable array logic, a programmable logic device, or a digital signal processor. Where the control unit includes a programmable device such as the microprocessor, microcontroller or programmable digital signal processor mentioned above, the processor may further include computer executable code that controls operation of the programmable device. The control unit may comprise modules in either hardware or software, or partially in hardware or software and communicate using known transmission buses such as CAN-bus and/or wireless communication capabilities. Thus, communication between control units, or between control units and audio capturing devices, image capturing systems, image capturing devices, etc. may be accomplished by various means know in the art. For example, the communication may be hardwired, using known transmission buses such as CAN-bus and/or wireless communication capabilities.

[0061] A control unit of the present disclosure is generally known an ECU, electronic control unit.

[0062] There is further provided, according to aspects of the present disclosure, a vehicle comprising a waste heat recovery system as described herein.

[0063] The valve arrangement may be configured to respond to a control signal to alternately connect the outlet of the compressor to the expansion tank to thereby increase the pressure in the expansion tank, and connect the inlet of the compressor to the expansion tank to withdraw gas from the expansion tank to thereby reduce the pressure in the expansion tank.

[0064] Further, the pressure in the expansion tank may be configured to be regulated based on the present condensation temperature of the working fluid.

[0065] Further, the pressure in the expansion tank may be configured to be regulated based on a temperature of a condenser cooling media upstream of the expansion tank in the waste heat recovery system.

[0066] The valve arrangement may be configured to respond to a control signal to connect the compressor to the expansion tank to reduce the pressure in the expansion tank

The person skilled in the art realizes that the present invention by no means is limited to the preferred embodiments described above. On the contrary, many modifications and variations are possible within the scope of the appended claims.

[0067] In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single processor or other unit may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measured cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

Claims

1. A tank pressure regulation system (300) for a waste heat recovery system (100) comprising an expansion tank (102) to allow for a working fluid of the waste heat recovery system (100) to expand, an expander (106) for receiving evaporated working fluid and for extracting work through expansion of the evaporated working fluid, and a condenser (108) arranged to receive the evaporated working fluid and for liquefying the evaporated working fluid by heat exchange with a condenser cooling media, the tank pressure regulation system (300) comprising:

a compressor (302) comprising an inlet (304) for withdrawing gas and an outlet (306) for providing pressurized gas, and
a valve arrangement (310) connectable in fluid communication with the expansion tank (102) and with the inlet (304) and outlet (306) of the compressor (302), wherein, when in use and connected to the compressor (302) and the expansion tank (102), the valve arrangement (310) is responsive to a control signal to alternately connect the outlet (306) of the compressor (302) to the expansion tank (102) to thereby increase the pressure in the expansion tank (102), and connect the inlet (304) of the compressor (302) to the expansion tank (102) to withdraw gas from the expansion tank (102) to thereby reduce the pressure in the expansion tank (102),
the tank pressure regulation system is **characterized in that** it further comprises
a control unit (320) configured to acquire a signal indicative of a present pressure of the working fluid in the waste heat recovery system (100), and determine the present condensation temperature of the working fluid based on the present pressure of the working fluid, and to provide the control signal to the valve arrangement (310) to regulate the pressure in the expansion tank (102) based on the present condensation temperature of the working fluid to a pressure below ambient pressure.

2. The tank pressure regulation system (300) according to claim 1, wherein the pressure in the expansion tank (102) is regulated further based on a temperature of a condenser cooling media of the condenser (108) upstream of the expansion tank (102) in the waste heat recovery system (100).

3. The tank pressure regulation system (300) according to claim 2, wherein when the temperature of the condenser cooling media decreases, the valve arrangement (310) is responsive to connect the compressor (302) to the expansion tank (102) to reduce the pressure in the expansion tank.

4. The tank pressure regulation system (300) according to any one of the preceding claims, wherein the pressure in the expansion tank (102) is controlled such that a condensation temperature for the working fluid is equal to or exceed a present temperature of a condenser cooling media upstream of the expansion tank (102) in the waste heat recovery system.

5. The tank pressure regulation system (300) according to any one of the preceding claims, wherein the pressure in the expansion tank (102) is regulated to be maintained within a pressure range including ambient pressure.

6. The tank pressure regulation system (300) according to claim 5, wherein the pressure range includes a pressure below ambient pressure.

7. The tank pressure regulation system (300) according to any one of the preceding claims, wherein the valve arrangement (310) comprises a four-way valve (310).

8. The tank pressure regulation system (300) according to any one of the preceding claims, the expansion tank (102) comprising an expandable container (102a) and a rigid container (102b) accommodating the expandable container (102a), the expandable container (102a) being arranged to accommodate the working fluid and the rigid container (102b) being arranged to be in fluid communication with the valve arrangement (310), wherein the pressure in the rigid container is controllable by the compressor (302) and valve arrangement (310).

9. The tank pressure regulation system (300) according to any one of claims 2 to 8, wherein the cooling media in the condenser (108) is ambient air, wherein the control signal is based on a temperature of the ambient air.

10. The tank pressure regulation system (300) according to any one of the preceding claims, wherein the control unit (320) is configured to receive signals indicative of a temperature of a condenser cooling media, and indicative of the present pressure of the working fluid to thereby determine the present condensation temperature of the working fluid, and to provide the control signal to the valve arrangement (310) based on the received signals.

11. The tank pressure regulation system (300) according to any one of the preceding claims, comprising an air drier (322) for dehydrating air being withdrawn from ambient atmosphere on an air side port (324) of the valve arrangement.

12. The tank pressure regulation system (300) according to any one of the preceding claims, wherein the present condensation temperature is determined based on the present pressure of the working fluid in the waste heat recovery system (100).

13. A waste heat recovery system (100) for a vehicle, the waste heat recovery system comprising:

a tank pressure regulation system (300) according to any one of the preceding claims,
at least one heat exchanger (104) for evaporating the working fluid;
an expander (106) for receiving the evaporated working fluid and for extracting work through expansion of the evaporated working fluid;
a condenser (108) arranged to receive the evaporated working fluid and for liquefying the evaporated working fluid by heat exchange with a condenser cooling media, and
a pump (109) for circulating the working fluid in the waste heat recovery system, the pump is connected to fluid communication lines downstream of the expansion tank and upstream of the at least one heat exchanger.

14. A method for controlling a tank pressure regulation system for a waste heat recovery system comprising a condenser having a condenser cooling media upstream of an expansion tank configured to allow for a working fluid of the waste heat recovery system to expand, the method comprising:

increasing (S104), when a temperature of the condenser cooling media exceeds a present condensation temperature for the working fluid, the pressure of the working fluid in the expansion tank,
reducing (S106), when a temperature of the condenser cooling media is below the present condensation temperature for the working fluid, the pressure of the working fluid in the expansion tank, wherein based on the present condensation temperature for the working fluid, the pressure is reduced to below ambient pressure.

15. A control unit (320) for controlling a tank pressure regulation system (300) for a waste heat recovery system (100) comprising an expansion tank (102) to allow for a working fluid of the waste heat recovery system to expand, the control unit being configured to:

acquire a signal indicative of a temperature of a condenser cooling media of a condenser (108) arranged upstream of the expansion tank (102) in the waste heat recovery system (100);
control, when the signal indicates a temperature exceeding a present condensation temperature for the working fluid, a valve arrangement (310) in fluid communication with the expansion tank (102) to connect an outlet of a compressor (302) to the expansion tank (102) to thereby increase the pressure of the working fluid, and
control, when the signal indicates a temperature below the present condensation temperature for the working fluid, the valve arrangement (310) to connect the inlet (304) of the compressor (302) to the expansion tank (102) to withdraw gas from the expansion tank (102) to thereby reduce the pressure in the expansion tank (302), wherein based on the present condensation temperature for the working fluid, the pressure is reduced to below ambient pressure.

Patentansprüche

1. Behälterdruckregelsystem (300) für ein Abwärmerückgewinnungssystem (100), umfassend einen Ausgleichsbehälter (102), um die Ausdehnung eines Arbeitsfluids des Abwärmerückgewinnungssystems (100) zuzulassen, einen Expander (106) zur Aufnahme von verdampftem Arbeitsfluid und zum Extrahieren von Arbeit durch die Ausdehnung des verdampften Arbeitsfluids, und einen Kondensator (108), der dazu angeordnet ist, das verdampfte Arbeitsfluid aufzunehmen, und zum Verflüssigen des verdampften Arbeitsfluids durch den Wärmeaustausch mit einem Kondensatorkühlmedium, wobei das Behälterdruckregelsystem (300) Folgendes umfasst:

einen Verdichter (302), umfassend einen Einlass (304) zum Entnehmen von Gas und einen Auslass (306) zum Vorsehen von Druckgas, und eine Ventilanordnung (310), die mit dem Ausgleichsbehälter (102) und mit dem Einlass (304) und dem Auslass (306) des Verdichters (302) in Fluidverbindung bringbar ist, wobei die Ventilanordnung (310) während der Verwendung und wenn sie mit dem Verdichter (302) und dem Ausgleichsbehälter (102) verbunden ist, auf ein Steuersignal reagiert, um abwechselnd den Auslass (306) des Verdichters (302) mit dem Ausgleichsbehälter (102) zu verbinden, um dadurch den Druck im Ausgleichsbehälter (102) zu erhöhen, und den Einlass (304) des Verdichters (302) mit dem Ausgleichsbehälter (102) zu verbinden, um Gas aus dem Ausgleichsbehälter (102) zu entnehmen, um dadurch den Druck im Ausgleichsbehälter (102) zu verringern,
wobei das Behälterdruckregelsystem **dadurch gekennzeichnet ist, dass** es ferner eine Steuereinheit (320) umfasst, die dazu ausgelegt ist, ein Signal zu empfangen, das einen vorhandenen Druck des Arbeitsfluids im Abwärmerückgewinnungssystem (100) angibt, und die vorhandene Kondensationstemperatur des Ar-

beitsfluids anhand des vorhandenen Drucks des Arbeitsfluids zu bestimmen und der Ventilanordnung (310) das Steuersignal zu senden, um den Druck im Ausgleichsbehälter (102) anhand der vorhandenen Kondensationstemperatur des Arbeitsfluids auf einen Druck unter Umgebungsdruck zu regeln.

2. Behälterdruckregelsystem (300) nach Anspruch 1, wobei der Druck im Ausgleichsbehälter (102) ferner anhand der Temperatur eines Kondensatorkühlmediums des Kondensators (108) vor dem Ausgleichsbehälter (102) im Abwärmerückgewinnungssystem (100) geregelt wird.

3. Behälterdruckregelsystem (300) nach Anspruch 2, wobei, wenn die Temperatur des Kondensatorkühlmediums abnimmt, die Ventilanordnung (310) reagiert, um den Verdichter (302) mit dem Ausgleichsbehälter (102) zu verbinden, um den Druck im Ausgleichsbehälter zu verringern.

4. Behälterdruckregelsystem (300) nach einem der vorstehenden Ansprüche, wobei der Druck im Ausgleichsbehälter (102) derart gesteuert ist, dass die Kondensationstemperatur des Arbeitsfluids gleich oder höher als eine vorhandene Temperatur eines Kondensatorkühlmediums vor dem Ausgleichsbehälter (102) im Abwärmerückgewinnungssystem ist.

5. Behälterdruckregelsystem (300) nach einem der vorstehenden Ansprüche, wobei der Druck im Ausgleichsbehälter (102) geregelt wird, um innerhalb eines Druckbereichs, einschließlich Umgebungsdruck, gehalten zu werden.

6. Behälterdruckregelsystem (300) nach Anspruch 5, wobei der Druckbereich einen Druck unter Umgebungsdruck einschließt.

7. Behälterdruckregelsystem (300) nach einem der vorstehenden Ansprüche, wobei die Ventilanordnung (310) ein Vier-Wege-Ventil (310) umfasst.

8. Behälterdruckregelsystem (300) nach einem der vorstehenden Ansprüche, wobei der Ausgleichsbehälter (102) einen dehnbaren Behälter (102a) und einen den dehnbaren Behälter (102a) fassenden starren Behälter (102b) umfasst, wobei der dehnbare Behälter (102a) dazu angeordnet ist, das Arbeitsfluid zu fassen und der starre Behälter (102b) dazu angeordnet ist, mit der Ventilanordnung (310) in Fluidverbindung zu stehen, wobei der Druck im starren Behälter vom Verdichter (302) und von der Ventilanordnung (310) steuerbar ist.

9. Behälterdruckregelsystem (300) nach einem der Ansprüche 2 bis 8, wobei das Kühlmedium im Kondensator (108) Umgebungsluft ist, wobei das Steuersignal auf der Temperatur der Umgebungsluft basiert.

10. Behälterdruckregelsystem (300) nach einem der vorstehenden Ansprüche, wobei die Steuereinheit (320) dazu ausgelegt ist, Signale zu empfangen, die eine Temperatur des Kondensatorkühlmediums angeben und den vorhandenen Druck des Arbeitsfluids angeben, um dadurch die vorhandene Kondensationstemperatur des Arbeitsfluids zu bestimmen und der Ventilanordnung (310) anhand der empfangenen Signale das Steuersignal zu senden.

11. Behälterdruckregelsystem (300) nach einem der vorstehenden Ansprüche, umfassend einen Lufttrockner (322) zum Dehydrieren von Luft, die aus der Umgebungsatmosphäre an einem luftseitigen Anschluss (324) der Ventilanordnung entnommen wird.

12. Behälterdruckregelsystem (300) nach einem der vorstehenden Ansprüche, wobei die vorhandene Kondensationstemperatur anhand des vorhandenen Drucks des Arbeitsfluids im Abwärmerückgewinnungssystem (100) bestimmt wird.

13. Abwärmerückgewinnungssystem (100) für ein Fahrzeug, wobei das Abwärmerückgewinnungssystem Folgendes umfasst:

ein Behälterdruckregelsystem (300) nach einem der vorstehenden Ansprüche, mindestens einen Wärmetauscher (104) zum Verdampfen des Arbeitsfluids;
einen Expander (106) zur Aufnahme von verdampftem Arbeitsfluid und zum Extrahieren von Arbeit durch die Ausdehnung des verdampften Arbeitsfluids;
einen Kondensator (108), der dazu angeordnet ist, das verdampfte Arbeitsfluid aufzunehmen und das verdampfte Arbeitsfluid durch den Wärmeaustausch mit einem Kondensatorkühlmedium zu verflüssigen, und
eine Pumpe (109) zum Zirkulieren des Arbeitsfluids im Abwärmerückgewinnungssystem, wobei die Pumpe mit Fluidkommunikationsleitungen nach dem Ausgleichsbehälter und vor dem mindestens einen Wärmetauscher verbunden ist.

14. Verfahren zum Steuern eines Behälterdruckregelsystems für ein Abwärmerückgewinnungssystem, umfassend einen Kondensator, der ein Kondensatorkühlmedium vor einem Ausgleichsbehälter aufweist, der dazu ausgelegt ist, die Ausdehnung eines Arbeitsfluids des Abwärmerückgewinnungssystems zuzulassen, wobei das Verfahren Folgendes umfasst:

Erhöhen (S104) des Drucks des Arbeitsfluids im Ausgleichsbehälter, wenn die Temperatur des Kondensatorkühlmediums die vorhandene Kondensationstemperatur des Arbeitsfluids übersteigt,
Verringern (S106) des Drucks des Arbeitsfluids im Ausgleichsbehälter, wenn die Temperatur des Kondensatorkühlmediums unter der vorhandenen Kondensationstemperatur des Arbeitsfluids liegt, wobei der Druck anhand der vorhandenen Kondensationstemperatur des Arbeitsfluids auf unter Umgebungsdruck verringert wird.

15. Steuereinheit (320) zum Steuern eines Behälterdruckregelsystems (300) für ein Abwärmerückgewinnungssystem (100), umfassend einen Ausgleichsbehälter (102), um die Ausdehnung eines Arbeitsfluids des Abwärmerückgewinnungssystems zuzulassen, wobei die Steuereinheit dazu ausgelegt ist:

ein Signal zu empfangen, das die Temperatur eines Kondensatorkühlmediums eines Kondensators (108), der vor dem Ausgleichsbehälter (102) im Abwärmerückgewinnungssystem (100) angeordnet ist, anzeigt;
zu steuern, dass eine Ventilanordnung (310) in Fluidverbindung mit dem Ausgleichsbehälter (102), wenn das Signal eine Temperatur anzeigt, die eine vorhandene Kondensationstemperatur des Arbeitsfluids übersteigt, einen Auslass eines Verdichters (302) mit dem Ausgleichsbehälter (102) verbindet, um dadurch den Druck des Arbeitsfluids zu erhöhen, und
zu steuern, dass die Ventilanordnung (310), wenn das Signal eine Temperatur anzeigt, die unter der vorhandenen Kondensationstemperatur des Arbeitsfluids liegt, den Einlass (304) des Verdichters (302) mit dem Ausgleichsbehälter (102) verbindet, um Gas aus dem Ausgleichsbehälter (102) zu entnehmen, um dadurch den Druck im Ausgleichsbehälter (302) zu verringern, wobei der Druck anhand der vorhandenen Kondensationstemperatur des Arbeitsfluids auf unter Umgebungsdruck verringert wird.

Revendications

1. Système de régulation de pression de réservoir (300) pour un système de récupération de chaleur résiduelle (100) comprenant un réservoir de détente (102) pour permettre la détente d'un fluide de travail du système de récupération de chaleur résiduelle (100), un détendeur (106) destiné à recevoir du fluide de travail évaporé et à extraire du travail par la détente du fluide de travail évaporé, et un condenseur (108) conçu pour recevoir le fluide de travail évaporé et pour liquéfier le fluide de travail évaporé par échange thermique avec une substance frigorigène de condenseur, le système de régulation de pression de réservoir (300) comprenant :

un compresseur (302) comprenant une entrée (304) pour prélever du gaz et une sortie (306) pour fournir du gaz sous pression, et
un dispositif de vanne (310) propre à être mis en communication fluidique avec le réservoir de détente (102) et avec l'entrée (304) et la sortie (306) du compresseur (302), le dispositif de vanne (310), lorsqu'il est utilisé et raccordé au compresseur (302) et au réservoir de détente (102), réagissant à un signal de commande pour, alternativement, raccorder la sortie (306) du compresseur (302) au réservoir de détente (102) de façon à augmenter la pression dans le réservoir de détente (102), et raccorder l'entrée (304) du compresseur (302) au réservoir de détente (102) afin de prélever du gaz du réservoir de détente (102) de façon à réduire la pression dans le réservoir de détente (102),
le système de régulation de pression de réservoir étant **caractérisé en ce qu'**il comprend en outre :
une unité de commande (320) conçue pour acquérir un signal indiquant une pression actuelle du fluide de travail dans le système de récupération de chaleur résiduelle (100), et déterminer la température de condensation actuelle du fluide de travail sur la base de la pression actuelle du fluide de travail, et pour transmettre le signal de commande au dispositif de vanne (310) afin de réguler la pression dans le réservoir de détente (102) sur la base de la température de condensation actuelle du fluide de travail de façon à l'amener à une pression inférieure à la pression ambiante.

2. Système de régulation de pression de réservoir (300) selon la revendication 1, dans lequel la pression dans le réservoir de détente (102) est régulée, d'autre part, sur la base d'une température d'une substance frigorigène de condenseur du condenseur (108) en amont du réservoir de détente (102) dans le système de récupération de chaleur résiduelle (100).

3. Système de régulation de pression de réservoir (300) selon la revendication 2, dans lequel, lorsque la température de la substance frigorigène de condenseur diminue, le dispositif de vanne (310) réagit pour raccorder le compresseur (302) au réservoir de détente (102) afin de réduire la pression dans le réservoir de détente.

4. Système de régulation de pression de réservoir (300) selon l'une quelconque des revendications précédentes, dans lequel la pression dans le réservoir de détente (102) est régulée de telle sorte qu'une température de condensation pour le fluide de travail soit égale ou supérieure à une température actuelle d'une substance frigorigène de condenseur en amont du réservoir de détente (102) dans le système de récupération de chaleur résiduelle (100).

5. Système de régulation de pression de réservoir (300) selon l'une quelconque des revendications précédentes, dans lequel la pression dans le réservoir de détente (102) est régulée de façon à être maintenue dans une plage de pression comprenant la pression ambiante.

6. Système de régulation de pression de réservoir (300) selon la revendication 5, dans lequel la plage de pression comprend une pression inférieure à la pression ambiante.

7. Système de régulation de pression de réservoir (300) selon l'une quelconque des revendications précédentes, dans lequel le dispositif de vanne (310) comprend une vanne à quatre voies (310).

8. Système de régulation de pression de réservoir (300) selon l'une quelconque des revendications précédentes, le réservoir de détente (102) comprenant un réceptacle dilatable (102a) et un réceptacle rigide (102b) contenant le réceptacle dilatable (102a), le réceptacle dilatable (102a) étant conçu pour contenir le fluide de travail et le réceptacle rigide (102b) étant conçu pour être en communication fluidique avec le dispositif de vanne (310), dans lequel la pression dans le réceptacle rigide est régulable au moyen du compresseur (302) et du dispositif de vanne (310).

9. Système de régulation de pression de réservoir (300) selon l'une quelconque des revendications 2 à 8, dans lequel la substance frigorigène dans le condenseur (108) est l'air ambiant, dans lequel le signal de commande est basé sur une température de l'air ambiant.

10. Système de régulation de pression de réservoir (300) selon l'une quelconque des revendications précédentes, dans lequel l'unité de commande (320) est conçue pour recevoir des signaux indiquant une température d'une substance frigorigène de condenseur, et indiquant la pression actuelle du fluide de travail pour déterminer ainsi la température de condensation actuelle du fluide de travail, et pour transmettre le signal de commande au dispositif de vanne (310) sur la base des signaux reçus.

11. Système de régulation de pression de réservoir (300) selon l'une quelconque des revendications précédentes, comprenant un sécheur d'air (322) destiné à déshydrater l'air prélevé du milieu ambiant sur un orifice côté air (324) du dispositif de vanne.

12. Système de régulation de pression de réservoir (300) selon l'une quelconque des revendications précédentes, dans lequel la température de condensation actuelle est déterminée sur la base de la pression actuelle du fluide de travail dans le système de récupération de chaleur résiduelle (100).

13. Système de récupération de chaleur résiduelle (100) pour un véhicule, le système de récupération de chaleur résiduelle comprenant :

un système de régulation de pression de réservoir (300) selon l'une quelconque des revendications précédentes ;
au moins un échangeur thermique (104) destiné à évaporer le fluide de travail ;
un détendeur (106) destiné à recevoir le fluide de travail évaporé et à extraire du travail par la détente du fluide de travail évaporé ;
un condenseur (108) conçu pour recevoir le fluide de travail évaporé et pour liquéfier le fluide de travail évaporé par échange thermique avec une substance frigorigène de condenseur ; et
une pompe (109) destinée à faire circuler le fluide de travail dans le système de récupération de chaleur résiduelle, la pompe étant raccordée à des conduites de communication fluidique en aval du réservoir de détente et en amont de l'au moins un échangeur thermique.

14. Procédé de commande d'un système de régulation de pression de réservoir pour un système de récupération de chaleur résiduelle comprenant un condenseur ayant une substance frigorigène de condenseur en amont d'un réservoir de détente conçu pour permettre la détente d'un fluide de travail du système de récupération de chaleur résiduelle, le procédé comprenant :

augmenter (S104), lorsqu'une température de la substance frigorigène de condenseur est supérieure à une température de condensation actuelle pour le fluide de travail, la pression du fluide de travail dans le réservoir de détente,
réduire (S106), lorsqu'une température de la substance frigorigène de condenseur est inférieure à la température de condensation actuelle pour le fluide de travail, la pression du fluide de travail dans le réservoir de détente, la pression étant réduite, sur la base de la température de condensation actuelle pour le fluide de travail, à une valeur inférieure à la pression ambiante.

15. Unité de commande (320) destinée à commander un système de régulation de pression de réservoir (300) pour un système de récupération de chaleur résiduelle (100) comprenant un réservoir de détente (102) pour permettre la détente d'un fluide de travail du système de récupération de chaleur résiduelle, l'unité de commande étant conçue pour :

acquérir un signal indiquant une température d'une substance frigorigène de condenseur d'un condenseur (108) placé en amont du réservoir de détente (102) dans le système de récupération de chaleur résiduelle (100) ;
commander, lorsque le signal indique une température supérieure à une température de condensation actuelle pour le fluide de travail, un dispositif de vanne (310) en communication fluidique avec le réservoir de détente (102) de sorte qu'il raccorde une sortie d'un compresseur (302) au réservoir de détente (102) de façon à augmenter la pression du fluide de travail ; et
commander, lorsque le signal indique une température inférieure à la température de condensation actuelle pour le fluide de travail, le dispositif de vanne (310) de sorte qu'il raccorde l'entrée (304) du compresseur (302) au réservoir de détente (102) afin de prélever du gaz du réservoir de détente (102) de façon à réduire la pression dans le réservoir de détente (102), la pression étant réduite, sur la base de la température de condensation actuelle pour le fluide de travail, à une valeur inférieure à la pression ambiante.

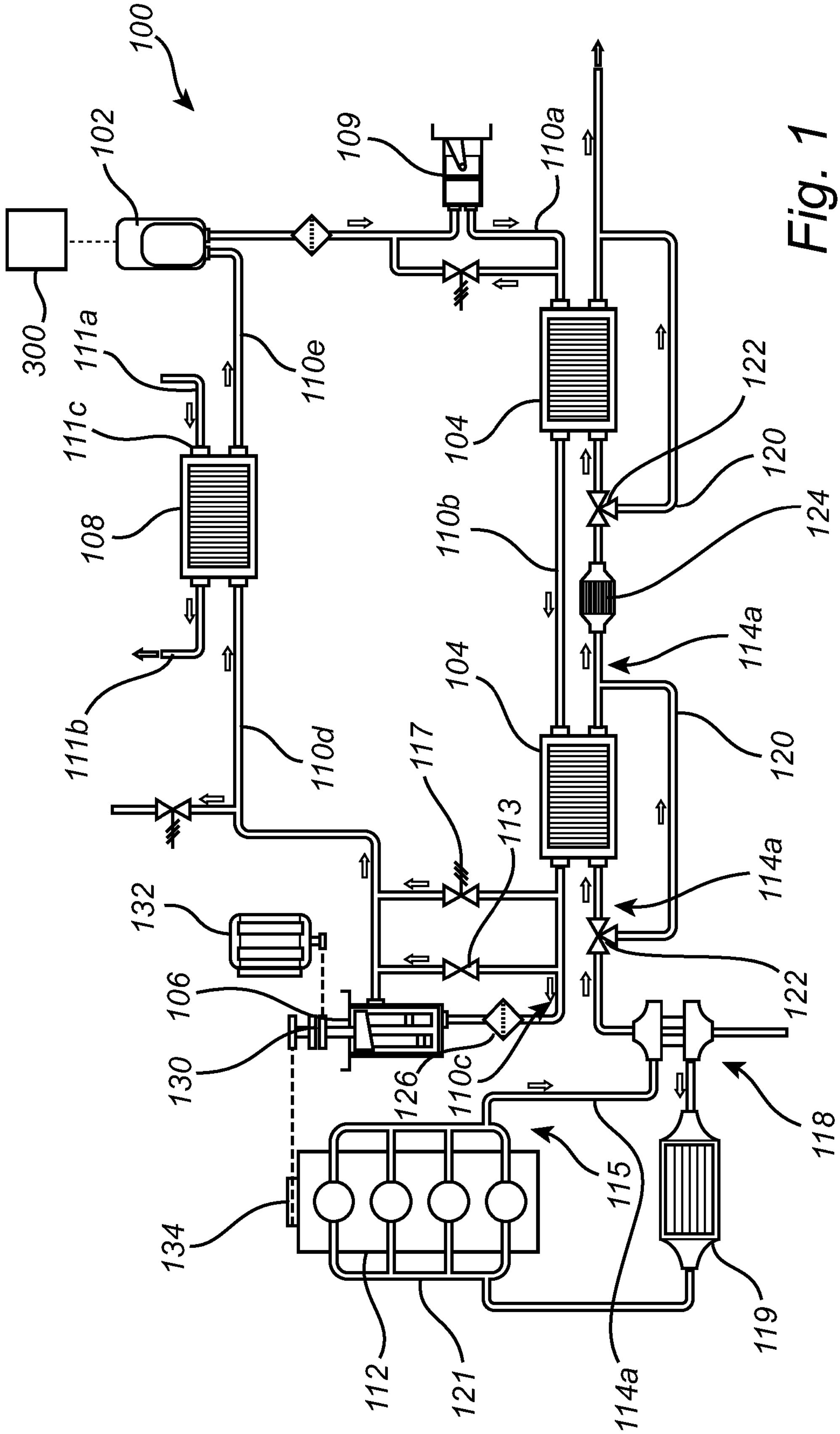
100
102
109
110a
300
111a
111c
110e
122
104
108
120
124
110b
114a
111b
110d
117
113
132
106
130
126
110c
134
115
118
119
112
121

Fig. 1

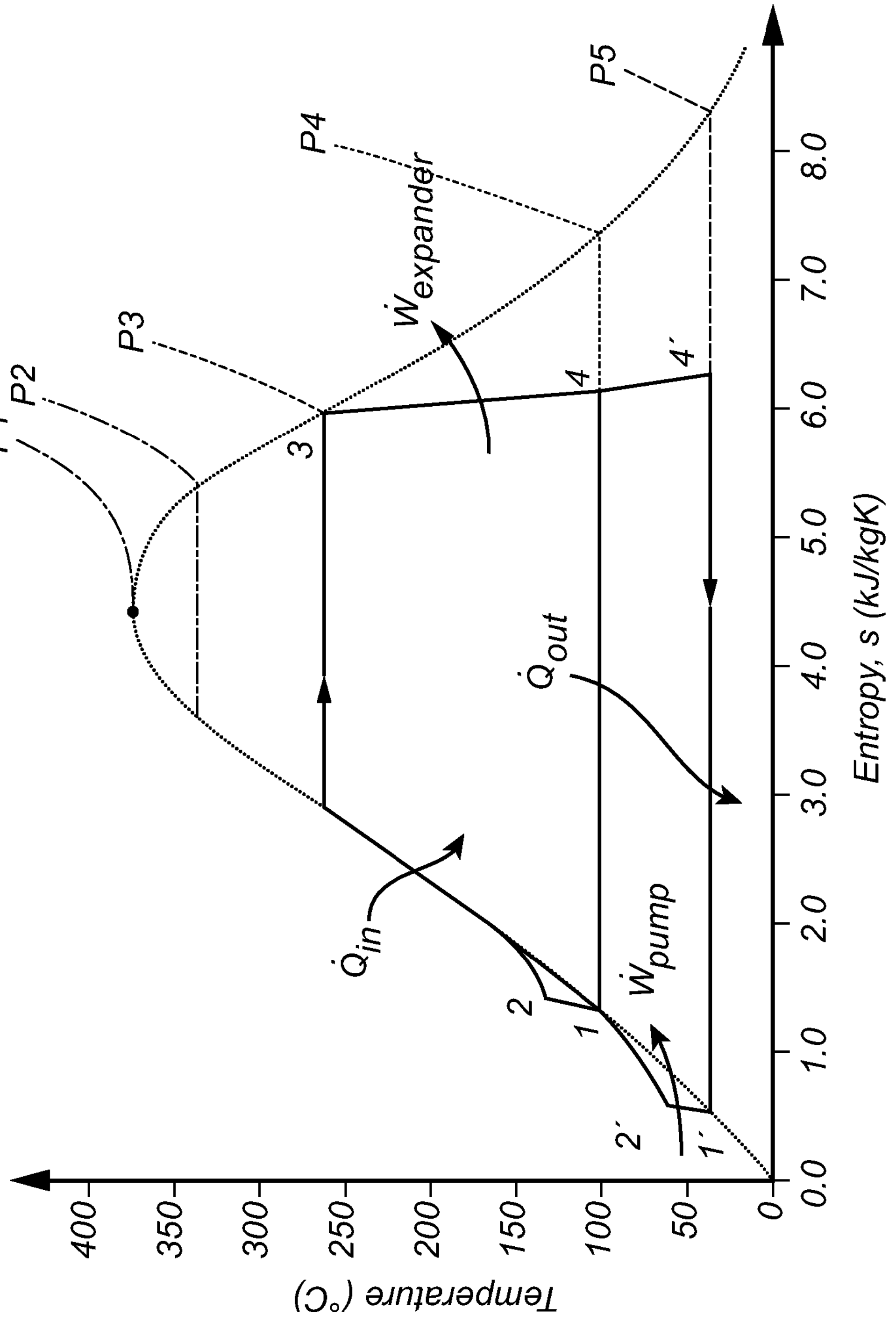
Temperature (°C)
0
50
100
150
200
250
300
350
400
Entropy, s (kJ/kgK)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
P1
P2
P3
P4
P5
1
2
3
4
1´
2´
4´
Q̇in
Q̇out
Ẇpump
Ẇexpander

Fig. 2

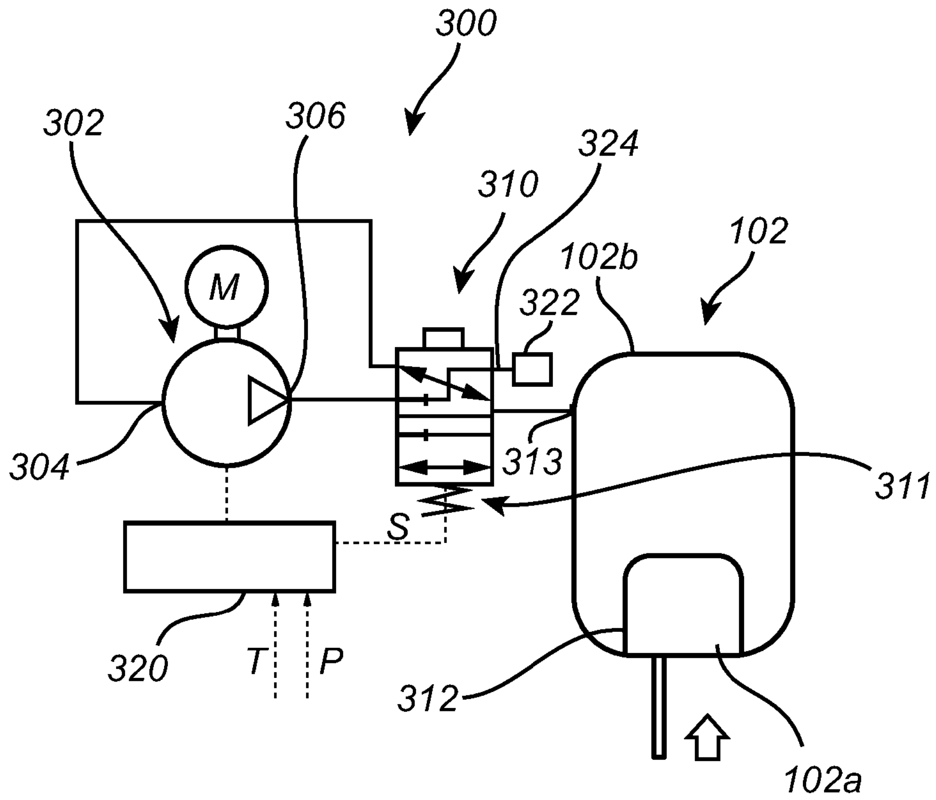
300
302
306
324
310
102
102b
322
M
304
313
311
S
320
T
P
312
102a

Fig. 3A

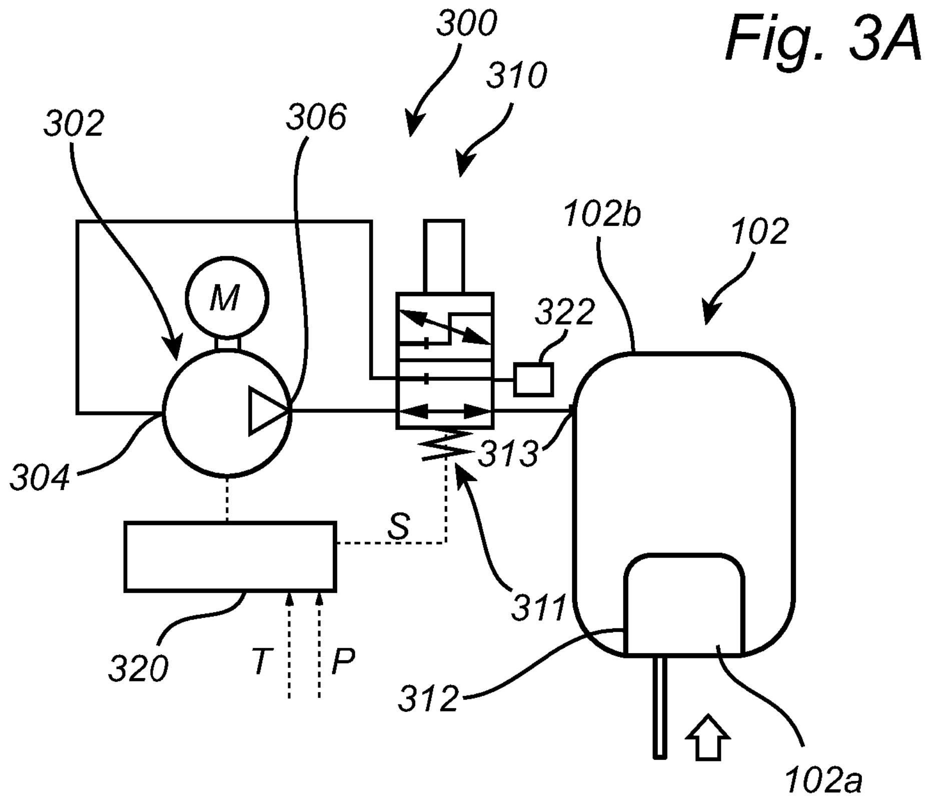
300
310
302
306
102b
102
M
322
304
313
S
311
320
T
P
312
102a

Fig. 3B

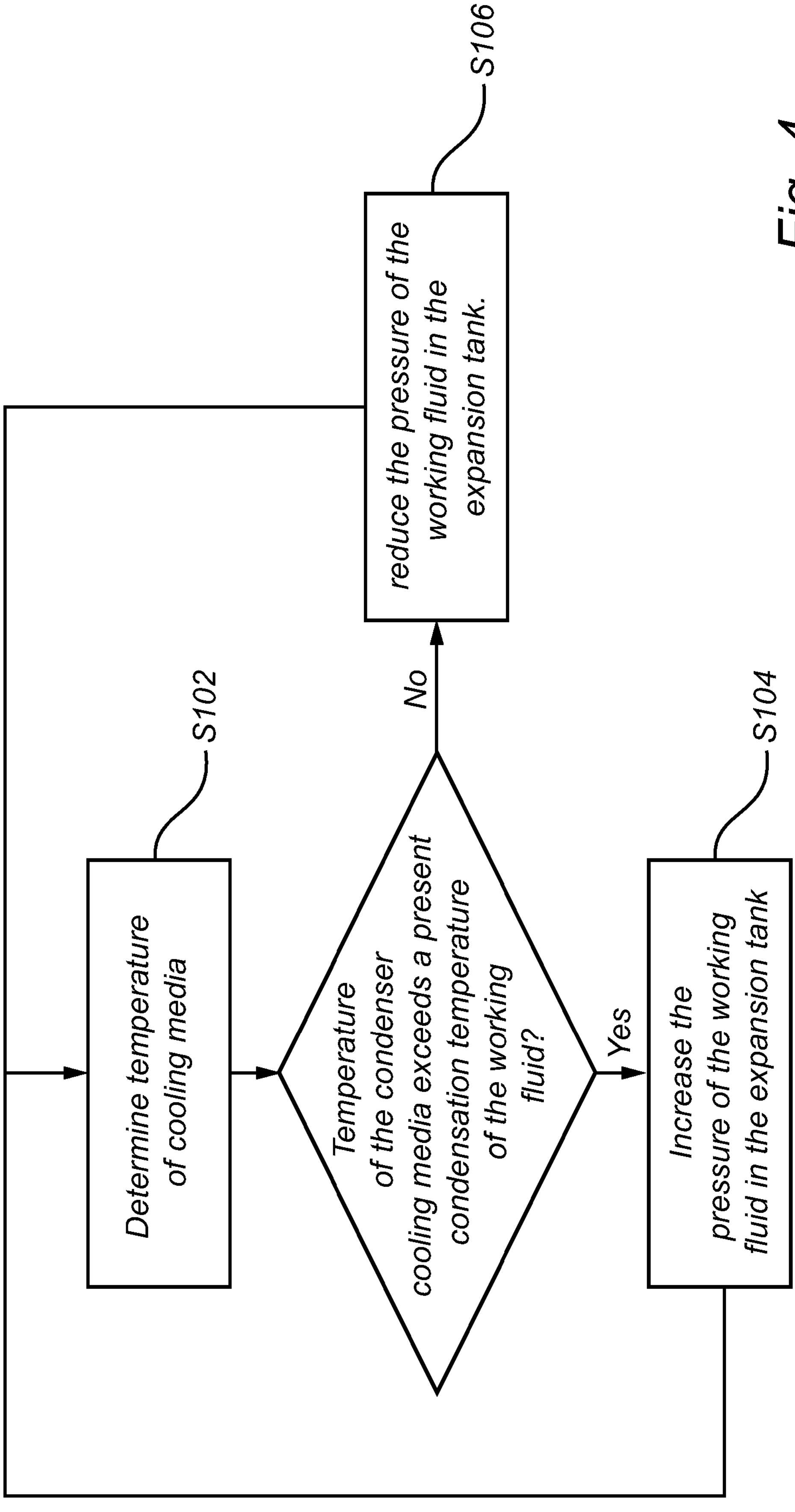
Determine temperature of cooling media
S102
Temperature of the condenser cooling media exceeds a present condensation temperature of the working fluid?
No
Yes
reduce the pressure of the working fluid in the expansion tank.
S106
Increase the pressure of the working fluid in the expansion tank
S104

Fig. 4

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2019117794 A **[0002]**
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