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

(11) EP 3 961 123 A1

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
02.03.2022 Bulletin 2022/09

(21) Application number: **20193703.4**

(22) Date of filing: **31.08.2020**

(51) International Patent Classification (IPC):
F25B 1/10 *(2006.01)* ***F25B 30/02*** *(2006.01)*
F25B 41/39 *(2021.01)* ***F25B 47/02*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F25B 1/10; F25B 30/02; F25B 41/39; F25B 47/025;
F25B 2339/047; F25B 2400/072; F25B 2400/13;
F25B 2400/23; F25B 2400/24

(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
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(71) Applicants:
- **Mitsubishi Electric R&D Centre Europe B.V.**
  Livingston EH54 5DJ (GB)
  Designated Contracting States:
  GB
- **Mitsubishi Electric Corporation**
  Tokyo 100-8310 (JP)
  Designated Contracting States:
  AL AT BE BG CH CY CZ DE DK EE ES FI FR GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(72) Inventor: **FREEMAN, James**
Livingston, EH54 5DJ (GB)

(74) Representative: **Pfenning, Meinig & Partner mbB**
Patent- und Rechtsanwälte
Theresienhöhe 11a
80339 München (DE)

(54) **VAPOUR-COMPRESSION HEAT PUMP SYSTEM AND METHOD FOR OPERATING A VAPOUR-COMPRESSION HEAT PUMP SYSTEM**

(57) A vapour-compression heat pump system and a method for operating a vapour-compression heat pump system is presented. The inventive system and method makes use of a thermal energy storage device which comprises a phase change material to receive and store heat from a superheated refrigerant vapour stream leaving the first compression stage, thereby also cooling the refrigerant close to its saturated vapour temperature, as desired. The system and method have the advantage that they allow a stable operation of the heat pump system. Furthermore, unlike prior art systems and methods, comfort conditions by cooling the indoor space during defrosting of the evaporator are not compromised and heat from the superheated refrigerant vapour exiting the first compression stage does not have to be rejected to an external fluid stream or recovered elsewhere within the cycle, i.e. the COP of the cycle is not limited and costs and complexity of the system and method are low.

EP 3 961 123 A1

Description

[0001] A vapour-compression heat pump system and a method for operating a vapour-compression heat pump system is presented. The inventive system and method makes use of a thermal energy storage device which comprises a phase change material to receive and store heat from a superheated refrigerant vapour stream leaving the first compression stage, thereby also cooling the refrigerant close to its saturated vapour temperature, as desired. The system and method have the advantage that they allow a stable operation of the heat pump system. Furthermore, unlike prior art systems and methods, comfort conditions by cooling the indoor space during defrosting of the evaporator are not compromised and heat from the superheated refrigerant vapour exiting the first compression stage does not have to be rejected to an external fluid stream or recovered elsewhere within the cycle, i.e. the COP of the cycle is not limited and costs and complexity of the system and method are low.

[0002] Heating, ventilation and air-conditioning (HVAC) systems in buildings account for approximately 25% of global energy consumption. In the UK domestic sector, space-heating and domestic hot water together account for 80% of total energy consumption. Under newly-proposed legislation in Europe, nearly-zero energy buildings (nZEB) are required to reduce their primary energy consumption through greater use of local renewables and high efficiency HVAC systems.

[0003] Air source heat pump (ASHP) systems use a vapour compression cycle to provide space-heating and domestic hot water, using outdoor ambient air as the heat source. In heating mode the temperature of the evaporator must be lower than the outdoor air to transfer heat into the cycle. In low-ambient temperature conditions, this can cause moisture from the air to condense on the surface of the evaporator, where it freezes forming a layer of ice that inhibits heat transfer. Periodic defrosting of the evaporator is performed in order to melt the ice so that heating operation can resume. Among the methods for evaporator defrosting, the most common is reverse cycle defrosting (RCD), in which a four-way valve is used to reverse the direction of heat flow such that heat from the indoor space heating circuit is used to melt the ice on the evaporator.

[0004] Heat pump systems designed for operation in low-ambient temperatures may incorporate two or more compression stages to deliver high temperatures. Compared to single-stage cycles, cycles with multiple compression stages can provide improved coefficient of performance (COP) at increased pressure ratios with reduced risk of working fluid degradation. In order for two-stage cycles to operate efficiently, intermediate gas cooling is typically implemented between the first and second compression stages. The exhaust gas discharged from the first compression stage is cooled down close to the saturated vapour temperature before undergoing the second compression stage. This in turn also reduces the superheated exhaust gas temperature at the discharge of the second compression stage.

[0005] US 5,269,151 A discloses a passive defrost system uses a heat-exchanger/storage defrost module containing a thermal storage material such as a phase change material to capture and store low grade, waste heat contained in the liquid refrigerant line of a refrigeration system.

[0006] CN 102 003 853 B discloses a multi-connected unit phase change energy storage hot liquid defrosting system.

[0007] CN 102 620 493 B discloses a heat pump defrosting system comprising a compressor, a four-way valve, an outdoor machine and an indoor machine, wherein the compressor is respectively connected with the outdoor machine and the indoor machine through the four-way valve and a refrigerant pipeline.

[0008] EP 3 244 141 A1 discloses a heat pump system including a refrigerant circuit, a compressor driver, and a heat storage means.

[0009] The prior art suffers two specific and interrelated problems associated with two-stage ASHP systems designed for operation in low-ambient temperature environments: (1) the requirement to provide heat for defrosting of the evaporator, which in RCD systems can result in compromised comfort conditions by cooling the indoor space, and (2) the requirement to remove heat from the superheated refrigerant vapour exiting the first compression stage, which conventionally is either rejected to an external fluid stream (limiting the COP of the cycle) or recovered elsewhere within the cycle (increasing cost and complexity of the system).

[0010] Based on the above, it has been an object of the present invention to provide a vapour-compression heat pump system and a method for operating a vapour-compression heat pump system which do not suffer the disadvantages of the prior art.

[0011] The object is solved by the vapour-compression heat pump system according to claim 1 and the method according to claim 14. The dependent claims illustrate advantageous embodiments of the invention.

[0012] According to the invention, a vapour-compression heat pump system is provided, comprising

a) a first heat exchange device,
b) a second heat exchange device;
c) a first compressor configured to perform a low compression stage and a second compressor configured to perform a high compression stage;
d) a first expansion device configured to perform a low expansion stage and a second expansion device configured to perform a high expansion stage;
e) a receiver vessel which is configured to receive refrigerant from the second expansion device;
f) a fluid line establishing a refrigerant circuit;
g) a thermal energy storage device which comprises a phase change material and is located, in a flow direction of refrigerant in the refrigerant circuit, up-

stream of the second compressor; and
h) a controller;

characterized in that the controller is configured to,
in a heating operation mode of the heat pump system, establish a thermal connection between the phase change material of the thermal energy storage device and a part of the fluid line which is located between the first compressor and the second compressor, and
in a defrosting operation mode of the heat pump system, establish a thermal connection between the phase change material of the thermal energy storage device and the first heat exchange device.

[0013] The inventive system makes use of a thermal energy storage device which comprises a phase change material (PCM) to receive and store heat from a superheated refrigerant vapour stream leaving the first compression stage, thereby also cooling the refrigerant close to its saturated vapour temperature, as desired. Heat is accumulated in the PCM at constant temperature until such a time that evaporator defrosting is required, whereupon it is released to provide heat for the defrosting process. This negates the requirement to extract heat from the internal space heating circuit for the defrosting process, thereby reducing the risk of compromised indoor comfort conditions. The constant phase-change temperature of the PCM assists in providing a stable operating condition of the heat pump, and the thermal energy storage device can be sized and selected with the optimal phase-change temperature for the required heat pump application and operating conditions.

[0014] The inventive system can be characterized in that, in the heating operation mode, the controller is configured to establish a fluid connection between the thermal energy storage device and the part of the fluid line which is located between the first compressor and the second compressor, wherein the thermal energy storage device preferably comprises a heat exchanger which is configured to receive refrigerant on one side of the heat exchanger.

[0015] Furthermore, the system can be characterized in that, in the defrosting operation mode, the controller is configured to establish a fluid connection between the thermal energy storage device and the first heat exchange device, preferably a fluid connection in which the refrigerant of the heat pump system is suitable to flow.

[0016] Moreover, the system can comprise a first valve, preferably a three-port-valve, which is located, in a flow direction of refrigerant in the refrigerant circuit, upstream of the thermal energy storage device. In the heating operation mode, the controller can be configured to switch the first valve to allow refrigerant to flow from the first compressor to the thermal energy storage device. In the defrosting operation mode, the controller can be configured to switch the first valve to allow refrigerant to flow from the receiver vessel to the thermal energy storage device.

[0017] Besides, the system can comprise a second valve, preferably a three-port-valve, which is located, in a flow direction of refrigerant in the refrigerant circuit, downstream of the second compressor. In the heating operation mode, the controller can be configured to switch the second valve to allow refrigerant to flow from the second compressor to the first heat exchange device via at least the second heat exchange device, the second expansion device, the receiver vessel and the first expansion device. In the defrosting operation mode, the controller can be configured to switch the second valve to allow refrigerant to flow from the second compressor to the first heat exchange device.

[0018] What is more, the system can comprise a first bypass fluid line which comprises a non-return valve. In the heating operation mode, the first bypass fluid line, especially the non-return valve, can prevent refrigerant from flowing in the first bypass fluid line. In the defrosting operation mode, the first bypass fluid line, especially the non-return valve, can allow refrigerant to flow in the first bypass fluid line in a direction from the first heat exchange device to the second expansion device.

[0019] Apart from the above, the system can comprise a second bypass fluid line. In the heating operation mode, the second bypass fluid line, especially a switching status of the second valve, can prevent refrigerant from flowing in the second bypass fluid line. In the defrosting operation mode, the second bypass fluid line, especially a switching status of the second valve, can allow refrigerant to flow in the second bypass fluid line from the second compressor to the first heat exchange device.

[0020] Furthermore, the controller of the system can be configured to, when the heat load is reduced in the heating operation mode, charge the phase change material of the thermal energy storage device, switch the first valve to allow refrigerant to flow from the first compressor to the thermal energy storage device (PCM). Moreover, the controller of the system can be configured to, when the heat load is reduced in the heating operation mode, discharge the phase change material of the thermal energy storage device, switch the first valve to allow refrigerant to flow from the receiver vessel to the thermal energy storage device.

[0021] The phase change material of the thermal energy storage device can have a phase change temperature which is suitable for under floor heating, hot water heating and/or space heating, preferably a phase change temperature in the range of 30 °C to 100 °C.

[0022] The system can further comprise
an additional third heat exchange device which is in thermal connection with a cooling fluid; and
a temperature sensor which is located, in a flow direction of refrigerant in the refrigerant circuit, downstream the third heat exchange device (HEX3) and upstream of the second compressor;
wherein the controller is configured to
receive temperature information from the temperature sensor, and
when, during the heating operation,

i) the received temperature is higher than a predetermined temperature and a defrosting operation is not necessary; and/or

ii) a manual input from a system user is received, preferably based on a decision about how best to use the recovered heat; and/or

iii) an automatic detection of flow in the cooling device circuit indicates that demand exists for heating of the additional cooling device;

establish a thermal connection between the additional cooling device and a part of the fluid line located between the first compressor and the second compressor, preferably by switching at least one further valve which is located, in a flow direction of refrigerant in the refrigerant circuit, upstream of the additional cooling device.

[0023] The controller of the system can be configured to, in the heating operation, make refrigerant flow in a direction from the first heat exchange device via at least the first compressor, the thermal energy storage device and/or an additional cooling device, the second compressor, the second heat exchange device, the second expansion device, the receiver vessel, the first expansion device and then back to the first heat exchange device, optionally also from the receiver vessel directly to the second compressor.

[0024] Moreover, the controller of the system can be configured to, in a defrosting operation, make refrigerant flow from the first heat exchange device via at least the second expansion device, the receiver vessel, the thermal energy storage device and the second compressor back to the first heat exchange device, optionally also from the receiver vessel directly to the second compressor.

[0025] Furthermore, the controller of the system can be configured to, in a reduced load heating operation and during charging of the phase change material, make refrigerant flow in a direction from the first heat exchange device via at least the first compressor, the thermal energy storage device, the second compressor, the second heat exchange device, the second expansion device, the receiver vessel, the first expansion device and then back to the first heat exchange device, optionally also from the receiver vessel directly to the second compressor.

[0026] Besides, the controller of the system can be configured to, in a reduced load heating operation and during discharging of the phase change material, make refrigerant flow from the receiver vessel via at least the thermal energy storage device, the second compressor, the second heat exchange device, the second expansion device and then back to the receiver vessel, optionally also from the receiver vessel directly to the second compressor.

[0027] The first compressor of the system can be configured to compress refrigerant from a low pressure to an intermediate pressure and/or the second compressor of the system can be configured to compress refrigerant from an intermediate pressure to a high pressure.

[0028] The first expansion device and/or second expansion device can be an expansion valve, preferably a linear expansion valve or a turboexpander. The first expansion valve can be configured to expand refrigerant from an intermediate pressure to a low pressure. The second expansion valve can be configured to expand refrigerant from a high pressure to an intermediate pressure.

[0029] According to the invention, a method for operating a vapour-compression heat pump system is provided, comprising the steps

a) in a heating operation mode of the heat pump system, establish a thermal connection between a phase change material of a thermal energy storage device and a part of a fluid line which is located between a first compressor and a second compressor; and

b) in a defrosting operation mode of the heat pump system, establish a thermal connection between the phase change material of a thermal energy storage device and the first heat exchanger.

[0030] The method can be characterized in that a system according to the invention operated.

[0031] The inventive system and inventive method can relate to air-source heat pump (ASHP) systems, but can also relate to water-source heat pump (WSHP) systems and ground-source heat pump (GSHP) systems, or any heat pump application that has: (1) a high enough temperature lift to require two compression stages; (2) operating conditions in which ice formation may occur at the evaporator, such that periodic defrosting is a requirement.

[0032] With reference to the following Figures, the subject according to the invention is explained in more detail without wishing to restrict said subject to the specific embodiments shown here.

[0033] Figure 1 shows a schematic drawing of a system according to the invention in a normal heating operation mode. In normal operation, heat is pumped from the outdoor environment at low temperature to the heating circuit at an elevated temperature. The system operates with three pressure levels, a low pressure, a high pressure and an intermediate pressure. Refrigerant working fluid at State A enters HEX 1 where it is evaporated, receiving heat from the ambient air. The vaporised refrigerant exiting HEX 1 at State B is then compressed to the intermediate pressure by COMP 1. Superheated vapour exiting COMP 1 at State C is directed by valve V1 through the PCM vessel where it is cooled, transferring heat to the PCM. The cooled vapour exiting the PCM vessel at State D mixes with saturated vapour exiting the RECEIVER vessel at State H before being compressed to the high pressure by COMP 2. Superheated vapour exiting COMP 2 at State E is directed by valve V2 through HEX 2, where it is cooled and condensed, transferring heat to the heating circuit. Subcooled liquid refrigerant exiting HEX 2 at State F is expanded to the intermediate pressure by LEV 2. The refrigerant exits LEV 2 in a two-phase state at State G and is received in the RECEIVER vessel. Saturated liquid exits the receiver at State I, and enters LEV 1 where it is expanded to the low pressure and exits at State A.

[0034] Figure 2 shows a schematic drawing of a system according to the invention in a defrost operation mode. In the defrost mode, stored heat is pumped from the PCM to melt the build-up of ice on HEX 1. Due to the smaller temperature lift required between the heat source and heat load in this operating mode, the first compression stage is bypassed. The position of valves V1 and V2 change so that COMP 1, LEV 1 and HEX 2 are bypassed. Refrigerant working fluid at State A is directed to the PCM vessel by valve V1 where it is evaporated, receiving heat from the PCM. The vaporised refrigerant exiting the PCM vessel at State B mixes with saturated vapour exiting the RECEIVER vessel at State F before being compressed to the high pressure by COMP 2. Superheated vapour exiting COMP 2 at State C is directed by valve V2 to HEX 1, where it is cooled and condensed, transferring heat to the ice layer on the fins which proceeds to melt. Liquid refrigerant exiting HEX 1 at State D flows in the permitted direction through the NRV before being expanded to the low pressure by LEV 2. The refrigerant exits LEV 2 in a two-phase state at State E and is received in the RECEIVER vessel. Saturated liquid exits the receiver at State A.

[0035] Figures 3 and 4 show a schematic drawing of a system according to the invention in a heating operation mode under reduced load and PCM charging (Figure 3) and discharging (Figure 4). Figure 3 shows the principle operation in a reduced-load case where outdoor ambient temperature is high enough that there is no build-up of ice on the evaporator and thus periodic defrosting not required. Under this condition, the system primarily operates in its normal configuration, as shown in Figure 3 (identical to Figure 1). Heat is stored in the PCM despite there being no requirement for defrosting of HEX 1. To make use of the stored heat in the PCM, the system periodically switches configuration to the alternative heating operation mode shown in Figure 4. The PCM vessel now serves as the heat source and the system operates using only one compression stage until the PCM is fully discharged (frozen). The position of valve V1 changes so that HEX 1, COMP 1 and LEV 1 are bypassed. During this mode, outdoor air is not used as the heat source and thus energy is not required for fan operation associated with HEX 1. Instead, saturated liquid working fluid at State A is directed to the PCM vessel by valve V1 where it is evaporated, receiving heat from the PCM. The vaporised refrigerant exiting the PCM vessel at State B mixes with saturated vapour exiting the RECEIVER vessel at State F before being compressed to the high pressure by COMP 2. Superheated vapour exiting COMP 2 at State C is directed by valve V2 to HEX 2 where it is cooled and condensed, transferring heat to the heating circuit. Liquid refrigerant exiting HEX 2 is expanded to the low pressure by LEV 2. The refrigerant exits LEV 2 in a two-phase state at State E and is received in the RECEIVER vessel. Saturated liquid exits the receiver at State A.

[0036] Figure 5 shows a schematic drawing of a system according to the invention comprising a third heat exchange device for inter-stage cooling from an external fluid stream. In this system, cooling of the superheated refrigerant vapour prior to the second compression stage can be provided by an external fluid stream, via an additional heat exchanger installed in parallel with the PCM vessel. For example, when there is no requirement to store heat in the PCM for defrosting, the surplus heat could be recovered to the external fluid stream to preheat a domestic hot water supply. Compared to the configuration in Figure 1, this arrangement has an additional heat exchanger, HEX 3, and additional valves V3 and V4. By closing V3 and opening V4, the refrigerant vapour exiting COMP 1 at State C is directed through HEX 3 rather than the PCM vessel, where it is cooled by the available fluid stream. The cooled vapour at State D then proceeds to COMP 2 after mixing with saturated vapour at State H.

List of reference signs

[0037]

HEX 1:	first heat exchanger (e.g. evaporator heat exchanger);
HEX2:	second heat exchanger (e.g. condenser heat exchanger);
HEX3:	third heat exchanger;
COMP 1	first compressor (low-stage compressor);
COMP 2	second compressor (high-stage compressor);
PCM:	thermal energy storage device which comprises a phase change material;
LEV 1:	first expansion valve (low-stage expansion valve);
LEV2:	second expansion valve (high-stage expansion valve);
RECEIVER:	receiver vessel;
V1:	first valve (e.g. three-port valve);
V2:	second valve (e.g. three-port valve);
V3:	third valve (e.g. two-port valve);
V4:	fourth valve (e.g. two-port valve);
NRV:	non-return valve.
A to H:	states

Claims

1. A vapour-compression heat pump system, comprising

a) a first heat exchange device (HEX1),

b) a second heat exchange device (HEX2);
c) a first compressor (COMP1) configured to perform a low compression stage and a second compressor (COMP2) configured to perform a high compression stage;
d) a first expansion device (LEV1) configured to perform a low expansion stage and a second expansion device (LEV2) configured to perform a high expansion stage;
e) a receiver vessel (RECEIVER) which is configured to receive refrigerant from the second expansion device (LEV2);
f) a fluid line establishing a refrigerant circuit;
g) a thermal energy storage device (PCM) which comprises a phase change material and is located, in a flow direction of refrigerant in the refrigerant circuit, upstream of the second compressor (COMP2); and
h) a controller;
characterized in that the controller is configured to,
in a heating operation mode of the heat pump system, establish a thermal connection between the phase change material of the thermal energy storage device (PCM) and a part of the fluid line which is located between the first compressor (COMP1) and the second compressor (COMP2), and
in a defrosting operation mode of the heat pump system, establish a thermal connection between the phase change material of the thermal energy storage device (PCM) and the first heat exchange device (HEX1).

2. System according to the preceding claim, **characterized in that**, in the heating operation mode, the controller is configured to establish a fluid connection between the thermal energy storage device (PCM) and the part of the fluid line which is located between the first compressor (COMP1) and the second compressor (COMP2), wherein the thermal energy storage device (PCM) preferably comprises a heat exchanger which is configured to receive refrigerant on one side of the heat exchanger.

3. System according to any one of the preceding claims, **characterized in that**, in the defrosting operation mode, the controller is configured to establish a fluid connection between the thermal energy storage device (PCM) and the first heat exchange device (HEX1), preferably a fluid connection in which the refrigerant of the heat pump system is suitable to flow.

4. System according to any one of the preceding claims, **characterized in that** the system comprises a first valve (V1), preferably a three-port-valve, which is located, in a flow direction of refrigerant in the refrigerant circuit, upstream of the thermal energy storage device (PCM), wherein

i) in the heating operation mode, the controller is configured to switch the first valve (V1) to allow refrigerant to flow from the first compressor (COMP1) to the thermal energy storage device (PCM); and/or
ii) in the defrosting operation mode, the controller is configured to switch the first valve (V1) to allow refrigerant to flow from the receiver vessel (RECEIVER) to the thermal energy storage device (PCM).

5. System according to any one of the preceding claims, **characterized in that** the system comprises a second valve (V2), preferably a three-port-valve, which is located, in a flow direction of refrigerant in the refrigerant circuit, downstream of the second compressor (COMP2), wherein

i) in the heating operation mode, the controller is configured to switch the second valve (V2) to allow refrigerant to flow from the second compressor (COMP2) to the first heat exchange device (HEX1) via at least the second heat exchange device (HEX2), the second expansion device (LEV2), the receiver vessel (RECEIVER) and the first expansion device (LEV1); and/or
ii) in the defrosting operation mode, the controller is configured to switch the second valve (V2) to allow refrigerant to flow from the second compressor (COMP2) to the first heat exchange device (HEX1).

6. System according to any one of the preceding claims, **characterized in that** the system comprises a first bypass fluid line which comprises a non-return valve (NRV), wherein,

i) in the heating operation mode, the first bypass fluid line, especially the non-return valve (NRV), prevents refrigerant from flowing in the first bypass fluid line; and/or
ii) in the defrosting operation mode, the first bypass fluid line, especially the non-return valve (NRV), allows refrigerant to flow in the first bypass fluid line in a direction from the first heat exchange device (HEX1) to the second expansion device (LEV2).

7. System according to any one of the preceding claims, **characterized in that** the system comprises a second bypass fluid line, wherein

i) in the heating operation mode, the second bypass fluid line, especially a switching status of the second valve (V2), prevents refrigerant from

flowing in the second bypass fluid line; and/or
ii) in the defrosting operation mode, the second bypass fluid line, especially a switching status of the second valve (V2), allows refrigerant to flow in the second bypass fluid line from the second compressor (COMP2) to the first heat exchange device (HEX1).

8. System according to any one of the preceding claims, **characterized in that** the controller is configured to, when the heat load is reduced in the heating operation mode,

i) charge the phase change material of the thermal energy storage device (PCM), switch the first valve (V1) to allow refrigerant to flow from the first compressor (COMP1) to the thermal energy storage device (PCM); and/or
ii) discharge the phase change material of the thermal energy storage device (PCM), switch the first valve (V1) to allow refrigerant to flow from the receiver vessel (RECEIVER) to the thermal energy storage device (PCM).

9. System according to any one of the preceding claims, **characterized in that** the phase change material has a phase change temperature which is suitable for under floor heating, hot water heating and/or space heating, preferably a phase change temperature in the range of 30 °C to 100 °C.

10. System according to any one of the preceding claims, **characterized in that** the system further comprises
an additional third heat exchange device (HEX3) which is in thermal connection with a cooling fluid; and
a temperature sensor which is located, in a flow direction of refrigerant in the refrigerant circuit, downstream the third heat exchange device (HEX3) and upstream of the second compressor;
wherein the controller is configured to
receive temperature information from the temperature sensor, and
when, during the heating operation,

i) the received temperature is higher than a predetermined temperature and a defrosting operation is not necessary; and/or
ii) a manual input from a system user is received, preferably based on a decision about how best to use the recovered heat; and/or
iii) an automatic detection of flow in the cooling device circuit indicates that demand exists for heating of the additional cooling device;

establish a thermal connection between the additional cooling device and a part of the fluid line located between the first compressor and the second compressor, preferably by switching at least one further valve which is located, in a flow direction of refrigerant in the refrigerant circuit, upstream of the additional cooling device.

11. System according to any one of the preceding claims, **characterized in that** the controller is configured to

i) in the heating operation, make refrigerant flow in a direction from the first heat exchange device (HEX1) via at least the first compressor (COMP1), the thermal energy storage device (PCM) and/or an additional cooling device (HEX3), the second compressor (COMP2), the second heat exchange device (HEX2), the second expansion device (LEV2), the receiver vessel (RECEIVER), the first expansion device (LEV1) and then back to the first heat exchange device (HEX1), optionally also from the receiver vessel (RECEIVER) directly to the second compressor (COMP2); and/or
i) in a defrosting operation, make refrigerant flow from the first heat exchange device (HEX1) via at least the second expansion device (LEV2), the receiver vessel (RECEIVER), the thermal energy storage device (PCM) and the second compressor (COMP2) back to the first heat exchange device (HEX1), optionally also from the receiver vessel (RECEIVER) directly to the second compressor (COMP2); and/or
ii) in a reduced load heating operation and during charging of the phase change material, make refrigerant flow in a direction from the first heat exchange device (HEX1) via at least the first compressor (COMP1), the thermal energy storage device (PCM), the second compressor (COMP2), the second heat exchange device (HEX2), the second expansion device (LEV2), the receiver vessel (RECEIVER), the first expansion device (LEV1) and then back to the first heat exchange device (HEX1), optionally also from the receiver vessel (RECEIVER) directly to the second compressor (COMP2); and/or
iii) in a reduced load heating operation and during discharging of the phase change material, make refrigerant flow from the receiver vessel (RECEIVER) via at least the thermal energy storage device (PCM), the second compressor (COMP2), the second heat exchange device (HEX2), the second expansion device (LEV2) and then back to the receiver vessel (RECEIVER), optionally also from the receiver vessel (RECEIVER) directly to the second compressor (COMP2).

12. System according to any one of the preceding claims, **characterized in that** the first compressor (COMP1) is configured to compress refrigerant from a low pressure to an intermediate pressure and/or the second compressor (COMP2) is configured to compress refrigerant from an intermediate pressure to a high pressure.

13. System according to any one of the preceding claims, **characterized in that** the first expansion device (LEV1) and/or second expansion device (LEV2) is/are an expansion valve, preferably a linear expansion valve or a turboexpander, wherein the

i) first expansion valve (LEV1) is configured to expand refrigerant from an intermediate pressure to a low pressure; and/or
ii) the second expansion valve (LEV2) is configured to expand refrigerant from a high pressure to an intermediate pressure.

14. Method for operating a vapour-compression heat pump system, comprising the steps

a) in a heating operation mode of the heat pump system, establish a thermal connection between a phase change material of a thermal energy storage device (PCM) and a part of a fluid line which is located between a first compressor (COMP1) and a second compressor (COMP2); and
b) in a defrosting operation mode of the heat pump system, establish a thermal connection between the phase change material of a thermal energy storage device (PCM) and the first heat exchanger (HEX1).

15. Method according to claim 14, **characterized in that** a system according to one of claims 1 to 13 is operated.

Figure 1

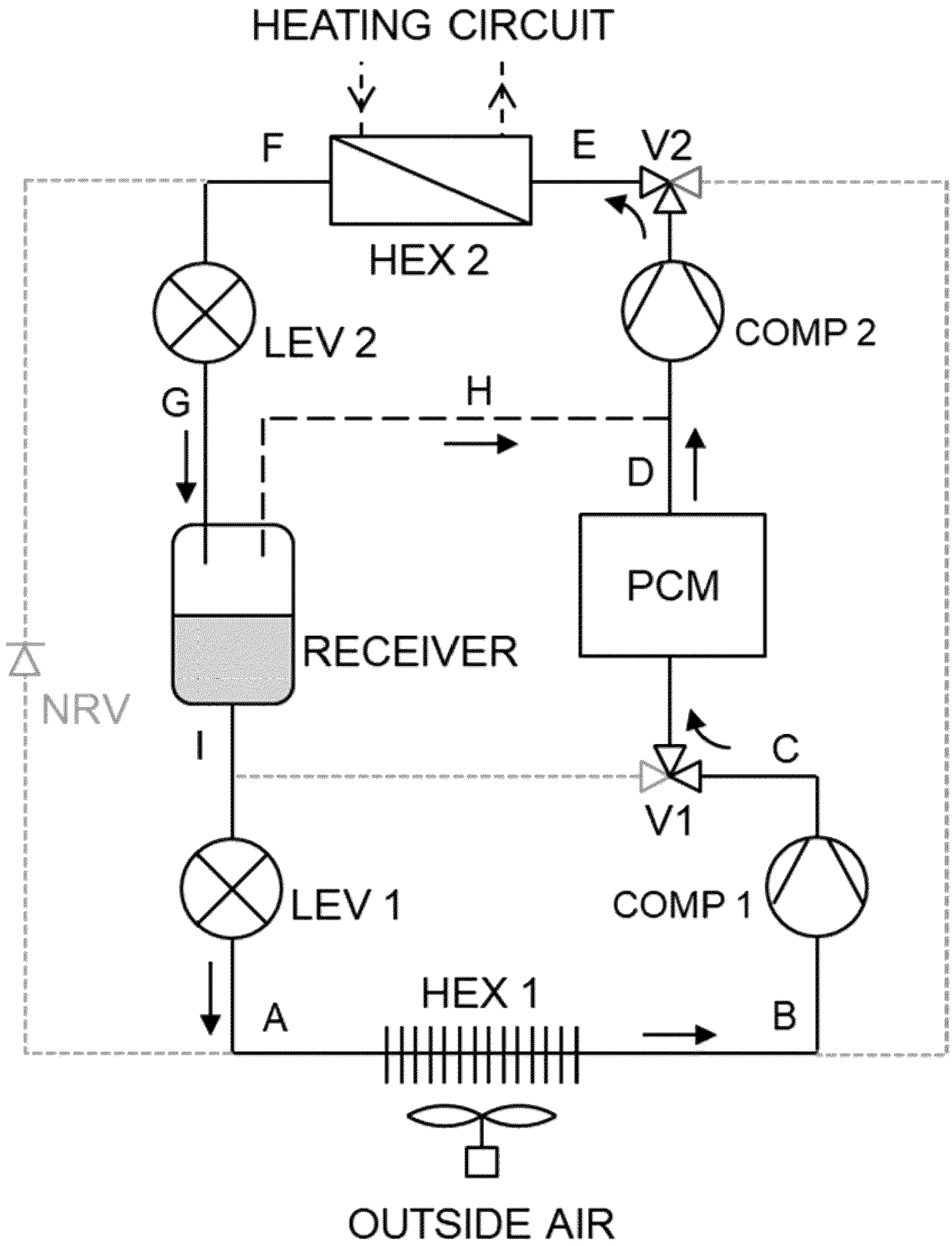

HEATING CIRCUIT
F
E
V2
HEX 2
LEV 2
COMP 2
G
H
D
PCM
RECEIVER
NRV
I
C
V1
LEV 1
COMP 1
HEX 1
A
B
OUTSIDE AIR

Figure 2

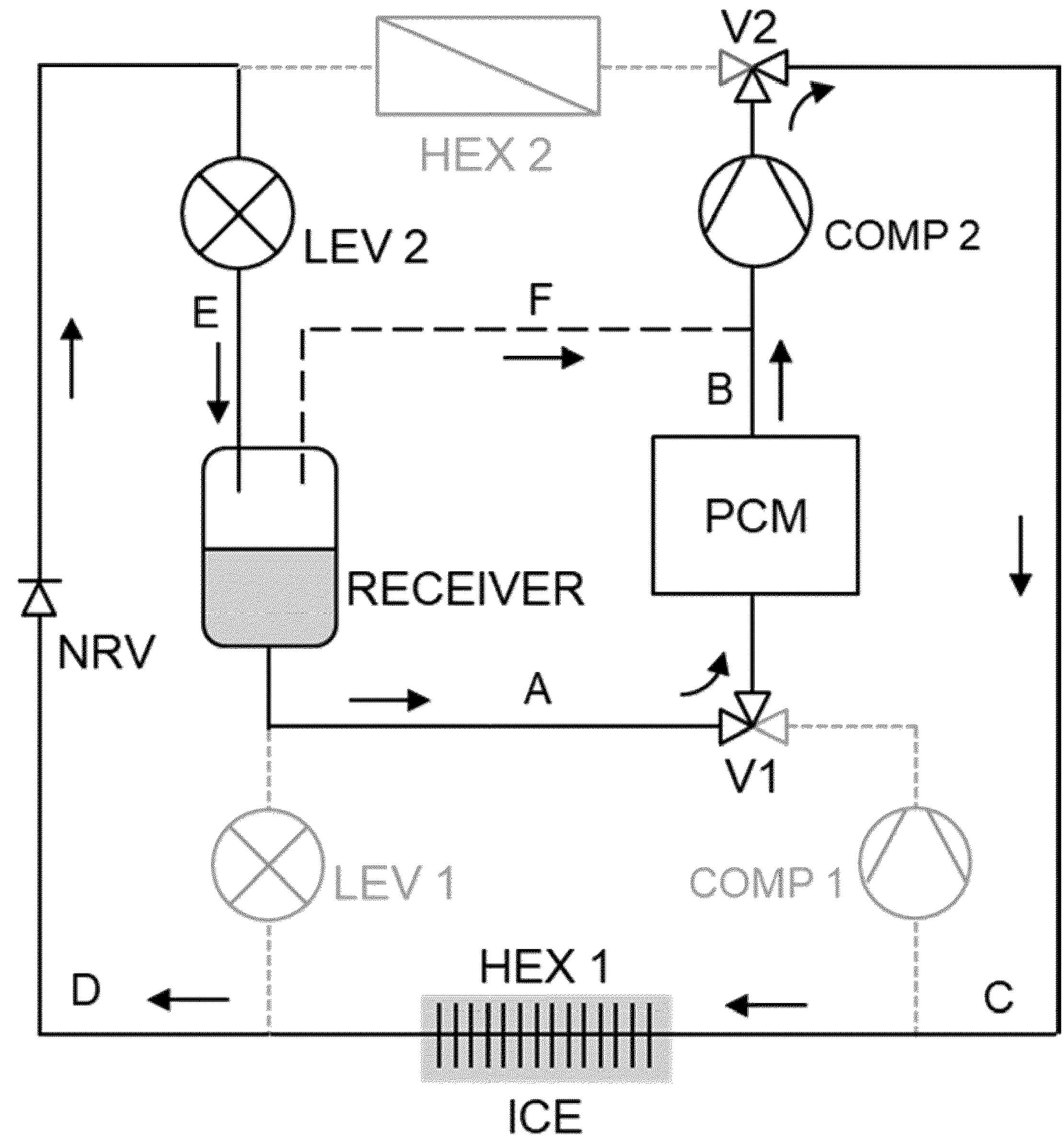

HEX 2
V2
LEV 2
COMP 2
E
F
B
PCM
RECEIVER
NRV
A
V1
LEV 1
COMP 1
HEX 1
D
C
ICE

Figure 3

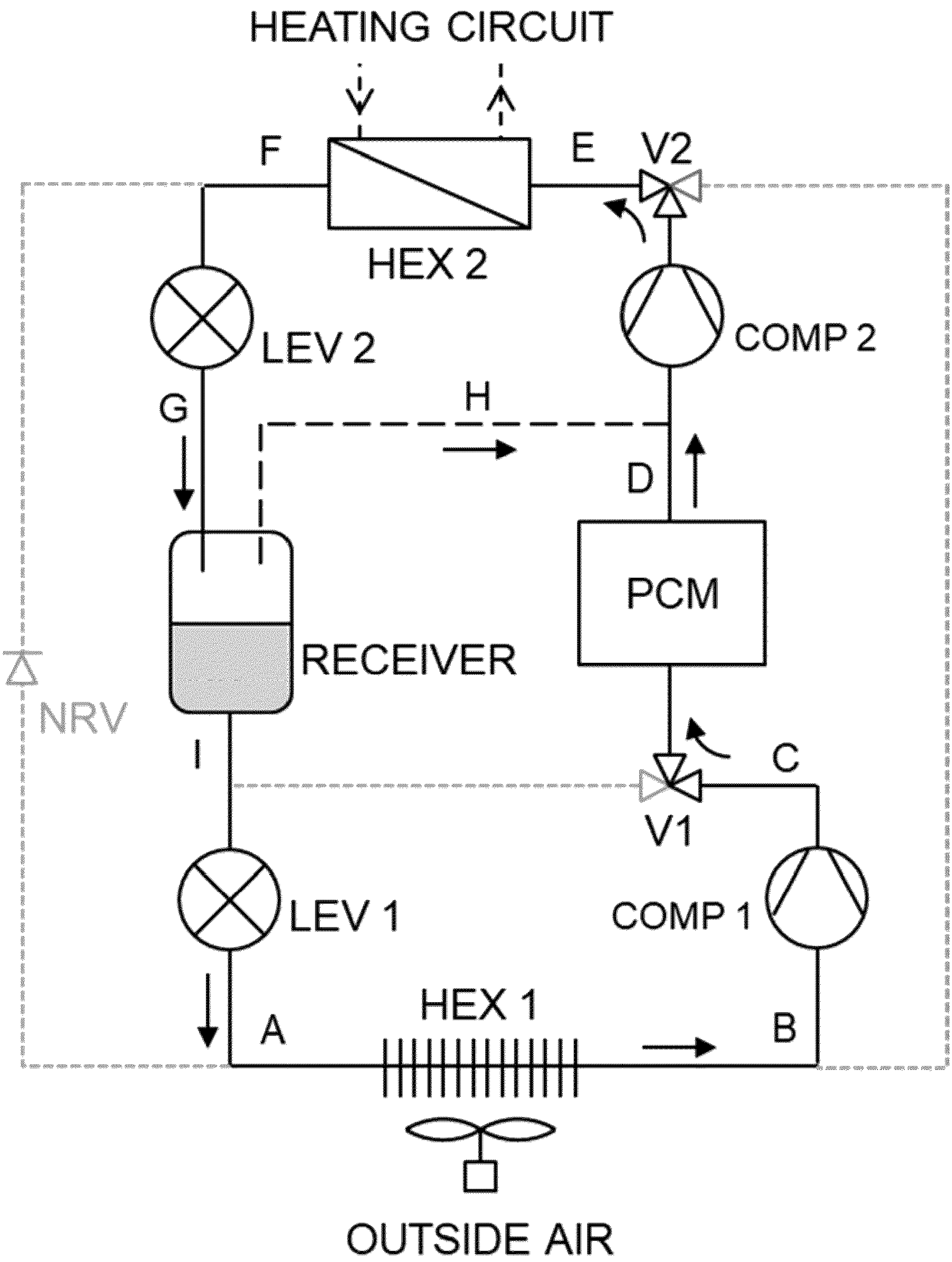

HEATING CIRCUIT
F
E
V2
HEX 2
LEV 2
COMP 2
G
H
D
PCM
RECEIVER
NRV
I
C
V1
LEV 1
COMP 1
HEX 1
A
B
OUTSIDE AIR

Figure 4

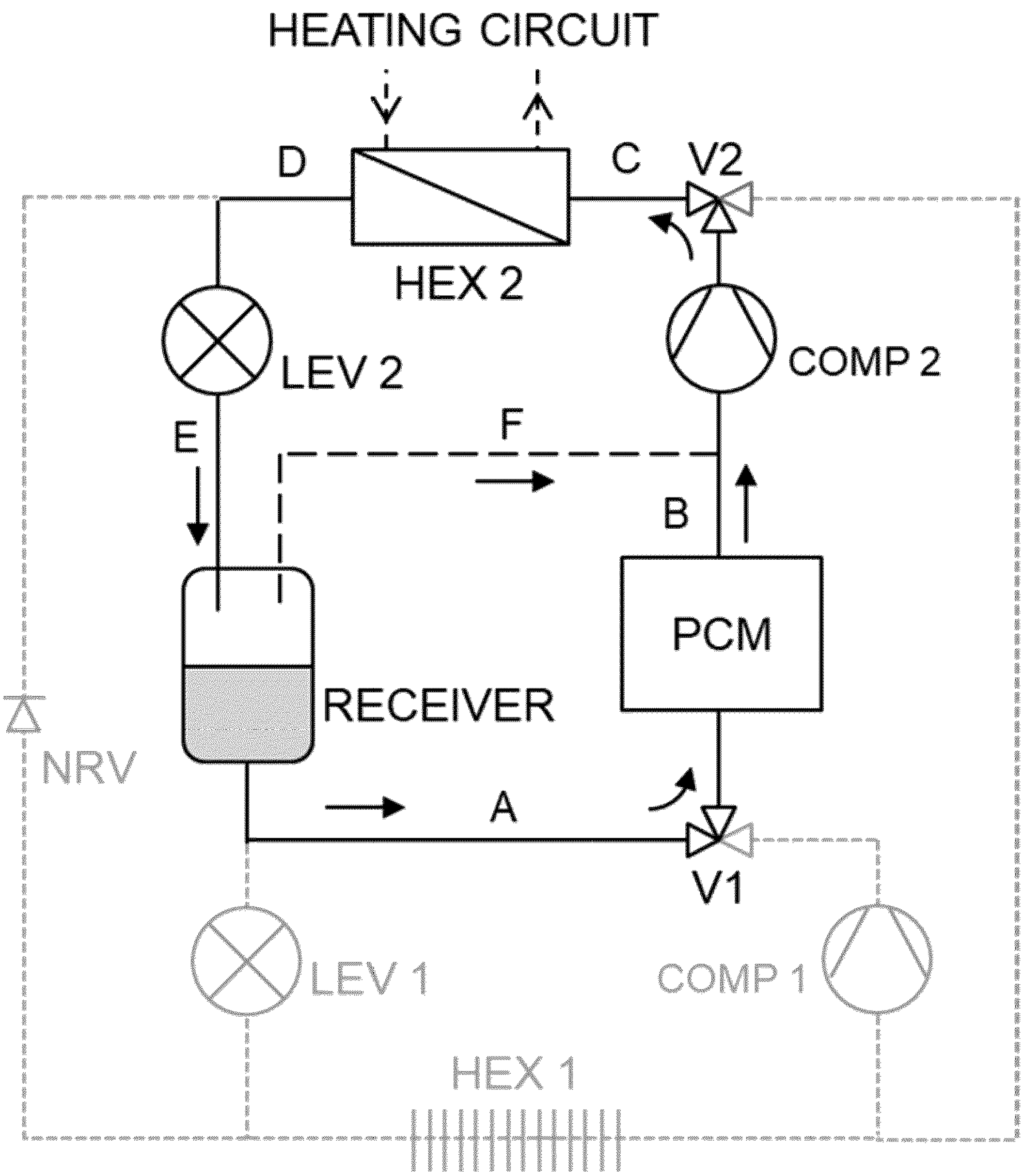
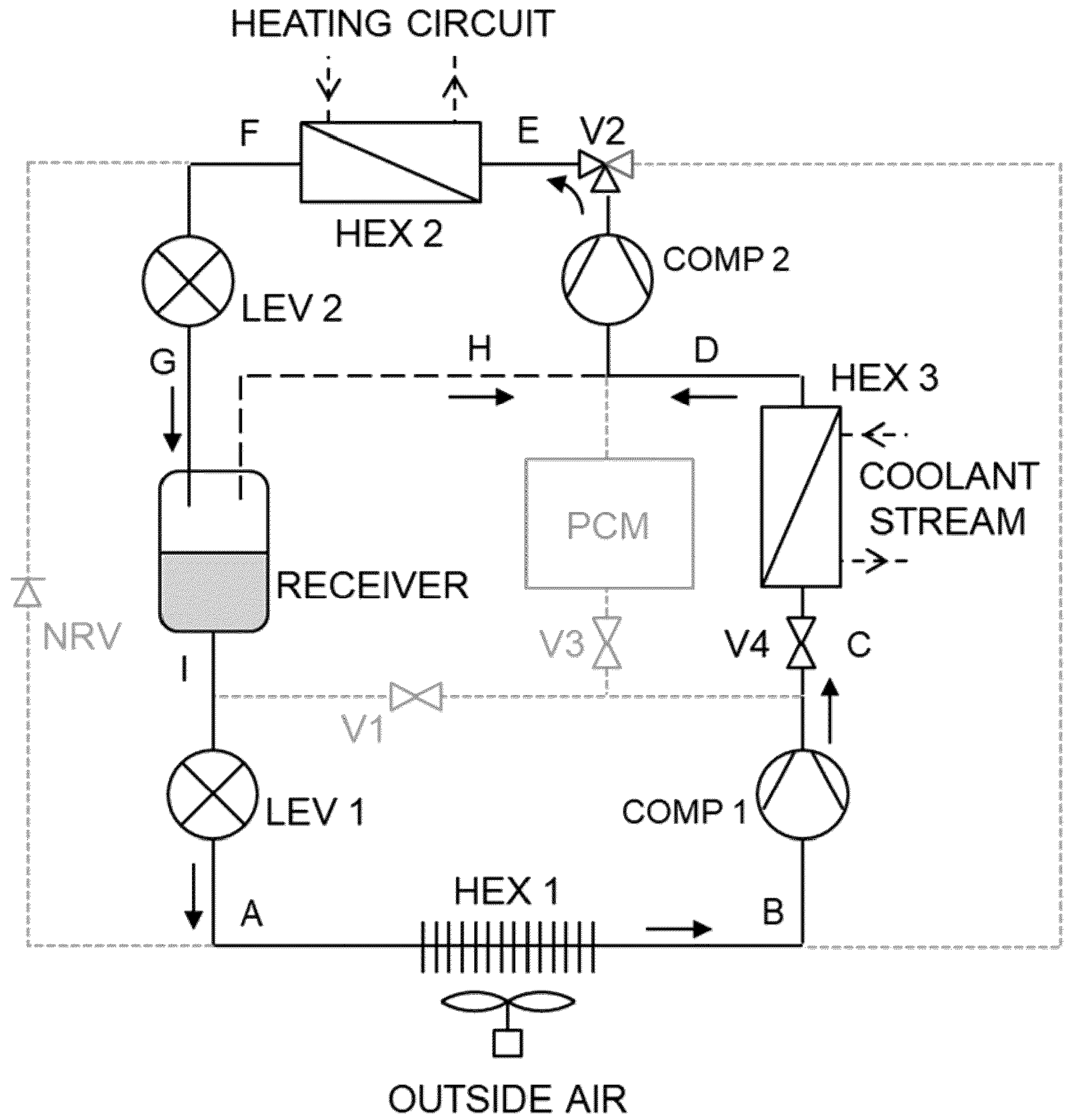

HEATING CIRCUIT
D
C
V2
HEX 2
LEV 2
COMP 2
E
F
B
PCM
RECEIVER
NRV
A
V1
LEV 1
COMP 1
HEX 1

Figure 5


HEATING CIRCUIT
F
E
V2
HEX 2
COMP 2
LEV 2
G
H
D
HEX 3
COOLANT
STREAM
PCM
RECEIVER
NRV
V3
V4
C
I
V1
LEV 1
COMP 1
A
HEX 1
B
OUTSIDE AIR

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EUROPEAN SEARCH REPORT

Application Number
EP 20 19 3703

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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F25B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	15 February 2021	Schopfer, Georg

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