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Description

The invention relates to an air-conditioning system for a rail vehicle according to the preamble of Claim 1.

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According to this, an air-conditioning system, by way of example for a rail vehicle, is known which has a refrigeration circuit which is able to be switched between a cooling mode and a heating mode and which has a first heat exchanger, which interacts with ambient air and works as a condenser in the cooling mode and as an evaporator in the heating mode, a second heat exchanger, which conditions supply air for a passenger interior compartment, an expansion valve, a compressor and a valve arrangement for switching between the cooling mode and the heating mode. An air-conditioning system of this kind is known from EP 2 811 241 A1.

Apparatuses of this kind, often provided as a compact air-conditioning system, are used not only in rail vehicles but also in vehicles of all kinds and also in buildings.

When air conditioning rail vehicles, the main functions of the air-conditioning system are to condition mixed air, consisting of fresh air and ambient air into a specific supply air so that the desired air-conditioned comfort is maintained in a passenger interior compartment. Since the air-conditioning system in rail vehicles is often the second largest energy consumer after the traction components of the rail vehicle, reducing the power consumption of the air-conditioning system is important. One of the measures for this is to provide an air-conditioning system, in particular a compact air-conditioning system, with an integrated heat pump function.

A primary working range for the heat pump function is typically with outside temperatures between -5°C and $+15^{\circ}\text{C}$. The operation

of the air-conditioning system must moreover comply with the relevant standards DIN EN14750 and DIN EN13129.

5 The heat pump function of the air-conditioning system is enabled through a valve arrangement, wherein the refrigeration circuit operates in cooling mode like a conventional air-conditioning system, i.e. the evaporator cools the mixed air to the required supply air temperature, wherein, at the same time, the mixed air is also evaporated through falling below a thaw point
10 temperature. The evaporator conditions the mixed air of fresh air and ambient air by acting on the temperature and/or the moisture content of the mixed air.

Compared to this, the condenser dissipates waste heat from the operating process of the evaporator and compressor to the ambient
15 surroundings.

During the heating mode of the air-conditioning system, the valve arrangement is set so that the evaporator is arranged for
20 technical reasons on an outer side and cools down the ambient air. Water then condenses since the thaw point of the ambient air is not reached. At lower temperatures below 0°C, the heat transfer surface of the evaporator becomes frosted.

25 The mixed air is heated up by the heat pump since the condenser in practice supplies the heat of the compressor and the heat of the condenser to the mixed air.

However, it has to be taken into account that the function during
30 operation of the heat pump is as a rule limited to below -5°C since otherwise the evaporator severely ices up on the outer side. In the transition region between -5°C and about +5°C, the refrigeration circuit is either halted for a certain time until the ice on the heat transfer surface of the evaporator has melted
35 again, or the process is reversed. If the process is reversed, it is switched over to the cooling mode. This is however

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generally avoided since the interior would then be cooled instead of heated.

Both measures lead to a break in the heat pump function of the refrigeration circuit so that it is necessary to switch on an electric heating device arranged downstream of the second heat exchanger in order to bring the mixed air up to a suitable temperature so that it can be supplied as supply air to the passenger interior compartment. Switching on the electric heating device leads to a fluctuation in the supply air temperature since the electric heating device itself has to be heated up first, which is determined by a heat capacity of the electric heating device. Thus, the same supply temperature cannot be immediately set exactly.

Finally, the break in the heat pump function and switching on the electric heating device causes a fluctuation in the supply air temperature for the passenger interior compartment, which severely impedes observing the aforementioned relevant standards.

In addition, the use of the electric heating device requires providing different safety devices since very high surface temperatures of by way of example more than 300°C can occur on the heating elements of the electric heating device.

Based on this, the object of the invention is to further develop the air-conditioning system described at the beginning so that fluctuations in the supply air temperature for the passenger interior compartment/building interior due to a break in the heat pump operation are reduced.

This is achieved by an air-conditioning system according to Claim 1.

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According to this, the air-conditioning system mentioned at the beginning is further developed so that the refrigeration circuit has a primary refrigeration circuit which comprises the first heat exchanger, the expansion valve, the compressor, the valve arrangement for switching between the cooling mode and the heating mode as well as a primary side of a third heat exchanger, which works as an evaporator in the cooling mode and as a condenser in the heating mode, and also has a secondary refrigeration circuit which comprises the secondary side of the third heat exchanger and the second heat exchanger, wherein an activatable electric heating device for heating a coolant inflow for the second heat exchanger is arranged between a refrigerating fluid outlet on the secondary side of the third heat exchanger and a refrigerating fluid inlet of the second heat exchanger.

By dividing up the refrigeration circuit into a primary refrigeration circuit and a secondary refrigeration circuit, which are connected to one another by the third heat exchanger, it is possible to reduce temperature fluctuations in the supply air for the passenger interior compartment. For the secondary refrigeration circuit operates in the manner of a thermal store and the electric heating device does not act on the supply air temperature, as known from the prior art, but on the temperature of the coolant inflow for the second heat exchanger which causes the conditioning of the air which is to be directed into the passenger interior compartment.

The electric heating device can be configured as an immersion heater. This provides a simple way of forming the electric heating device.

The heat storage capacity of the secondary refrigeration circuit is designed so that short breaks in the heat pump operation do not have a negative effect on the supply air temperature.

The heat storage capacity of the secondary refrigeration circuit can be further increased if the secondary refrigeration circuit is equipped with a reservoir. The immersion heater is in this case integrated into a reservoir for the refrigerant of the secondary refrigerant circuit. The provision of a reservoir in the secondary refrigeration circuit enables the heat pump operation of the air-conditioning system to be carried out at intervals with maximum efficiency. Breaks in the heat pump operation are compensated in particular by the reservoir.

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The heat pump operation can furthermore be carried out substantially without any icing since thawing of water at the evaporator can take place during the operating pauses without having to take into account negative effects on observing the desired supply air temperature.

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It is thus preferred that, during its heating mode, the air-conditioning system works at intervals such that thawing is made possible at the first heat exchanger, which acts alternately with the outside air.

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The valve arrangement can be formed by a four-way valve. In this case, the four-way valve is fitted with a first port which is connected to a refrigerating fluid inlet of the first heat exchanger in the cooling mode, a second port which is connected to a refrigerating fluid outlet on the primary side of the third heat exchanger in the cooling mode, a third port which is connected to an entry side of the compressor, and a fourth port which is connected to an exit side of the compressor.

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A cooling mode of the air-conditioning system can be implemented in that the four-way valve is switched such that its second port is connected in terms of flow to the third port and its fourth port is connected in terms of flow to the first port. Conversely, in the heating mode, the first port is connected in terms of

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flow to the third port and the fourth port is connected in terms of flow to the second port of the four-way valve.

5 The third heat exchanger is preferably designed as a plate-type heat exchanger. This ensures an effective heat exchange between the primary and the secondary refrigeration circuit.

10 The secondary refrigeration circuit can work with a brine/water mixture as refrigerant. Common refrigerants can be used for the primary refrigeration circuit.

15 The ambient air can be guided past the first heat exchanger by means of a first fan, whilst a fan can likewise be used for drawing in supply air at the second heat exchanger which produces the conditioned supply air for the passenger interior compartment.

20 Exemplary embodiments of the invention will now be explained in further detail below with reference to the drawings. In the drawings:

25 Fig. 1 shows a diagrammatic illustration of a refrigeration circuit with heat pump function in a cooling mode in a first embodiment;

Fig. 2 shows a diagrammatic illustration of the refrigerant circuit of Fig. 1 in a heating mode;

30 Fig. 3 shows a diagrammatic illustration of a refrigeration circuit with heat pump function in a cooling mode in a second embodiment and

35 Fig. 4 shows a diagrammatic illustration of the refrigeration circuit of Fig. 3 in a heating mode.

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The refrigeration circuits depicted in Figs. 1 to 4 are implemented by way of example in a compact air-conditioning system, as used in a rail vehicle. The refrigeration circuits can however likewise be used in the region of other vehicles and
5 in building constructions.

It should be emphasized that connections in terms of flow shown in the drawings by solid lines are those in which the refrigerating fluid has a formerly low temperature, whilst the
10 connections in terms of flow shown in dotted lines relate to a refrigerating fluid with an increased temperature.

Fig. 1 shows a cooling mode for a refrigeration circuit with heat pump function. The refrigeration circuit comprises a
15 primary refrigeration circuit 1 and a secondary refrigeration circuit 2. The primary refrigeration circuit 1 has a first heat exchanger 3 which interacts with ambient air and works in the cooling mode as an evaporator. The ambient air is guided past the first heat exchanger 3 by means of a fan 4. In the cooling
20 mode shown in Fig. 1 for the refrigeration circuit, the first heat exchanger 3 works as an evaporator. A four-way valve 5 is attached to the inlet side of the first heat exchanger 3 during cooling mode and is fitted with four ports 6, 7, 8, 9. A first port 6 of the four-way valve is connected to the entry side of
25 the first heat exchanger 3 in cooling mode. Since the first port 6 of the four-way valve 5 in cooling mode is connected to the fourth port 9 of the four-way valve 5 through suitable adjustment of the latter, which is connected in terms of flow to an exit side of a compressor 10, heated refrigerating fluid of
30 the primary refrigeration circuit 1 flows into the first heat exchanger 3. An entry side of the compressor 10 is connected to the secondary refrigeration circuit 2 via the four-way valve 5, in particular via its second port 7 and third port 8.

35 Refrigerating fluid, which leaves the first heat exchanger 3 on its exit side, passes to an expansion valve 11, is cooled down

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there and passes from there in the direction of the secondary refrigeration circuit 2.

5 The secondary refrigeration circuit 2 comprises a second heat exchanger 12 for conditioning supply air Z for a passenger interior compartment, by way of example of a rail vehicle. A fan 13 draws in the mixed air M of outside air and ambient air supplied to the compact air-conditioning unit, and guides this past the second heat exchanger 12. In the cooling mode
10 illustrated here, the mixed air is cooled down at the heat exchanger 9 and then conveyed towards the passenger interior compartment by means of the fan 13.

The secondary refrigeration circuit 2 moreover comprises an immersion heater 14 which can be switched on when required. The refrigerating fluid in the secondary refrigeration circuit 2, which can be a water/brine mixture, is conveyed by means of a circulating pump 15.

20 The primary refrigeration circuit 1 and the secondary refrigeration circuit 2 are connected to one another via a third heat exchanger 16 which, in cooling mode, works as a condenser but, during heating mode, works as an evaporator and is designed as a plate-type heat exchanger. Its primary side is connected
25 on one side to the expansion valve 11 and on the other side to the second exit 7 of the four-way valve 5. In cooling mode, cooled refrigerating fluid of the primary refrigeration circuit 1 coming from the expansion valve 11 flows into the third heat exchanger 12, interacts with the refrigerating fluid of the
30 secondary refrigeration circuit 2 and leaves the third heat exchanger 12 in the direction of the second port 7 of the four-way valve 5.

In the heating mode illustrated in Fig. 2, the refrigeration circuit executes a heat pump function. The arrangement in terms
35 of flow of the primary refrigeration circuit 1 differs from that

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shown in Fig. 1 through the inclusion of the fan 10. Its entry side is now, in terms of flow, connected via the first 6 and the third ports 8 of the four-way valve 5 to an exit side for refrigerating fluid of the first heat exchanger 3 in the heating mode (this corresponds to the inlet side in the cooling mode). The flow through the first heat exchanger 3 is now in the reverse direction compared with cooling mode.

In the cooling mode shown in Fig. 1 of the refrigeration circuit, the third heat exchanger 16, which works here as condenser, transfers the temperature of the refrigerant of the primary refrigeration circuit 1, as present on the exit side of the expansion valve 8. The immersion heater 14 has no function during the cooling mode.

In the heating mode according to Fig. 2, the refrigeration circuit, in particular at outside temperatures between -5°C and $+5^{\circ}\text{C}$, is operated at intervals, i.e. the heat pump function is interrupted in intervals, wherein an actual process reverse is dispensed with as far as possible from the energy efficiency point of view so that, in the rest intervals, a de-icing/thawing of condensed water from the outside air A is possible at the first heat exchanger 3. A (temporary) lowering of the heat transfer at the third heat exchanger 16 requires the use of the immersion heater 14. This is arranged between the secondary side of the third heat exchanger 16 and a refrigerating fluid inlet side of the second heat exchanger 12 and heats up the refrigerating fluid of the secondary refrigeration circuit 2 when necessary so that the temperature of the supply air Z for the passenger interior compartment remains unaffected as far as possible by the switching over or switching off of the refrigeration circuit.

Figs. 3 and 4 show a second embodiment of a refrigeration circuit with heat pump function. Compared to the first embodiment previously explained, the secondary refrigeration circuit 2 is

- 10 -

expanded by a reservoir 17 for the refrigerating fluid of the secondary refrigeration circuit 2. The immersion heater 14 is integrated into this reservoir 17 so that, in the event of a break in the heat pump function of the refrigeration circuit, sufficient refrigerating fluid of a desired temperature is available so that, as far as possible, the temperature of the supply air Z, which is conditioned at the second heat exchanger 12, does not undergo any fluctuation.

Patentkrav

1. Klimaanlæg til et skinnekøretøj, med et kølekredsløb, som kan omskiftes mellem en køledrift og en varmedrift, og

5 - en første varmeveksler (3), der vekselvirker med en omgivelsesluft (A) og arbejder som kondensator under køledriften og som fordamper under varmedriften,

- en anden varmeveksler (12), som konditionerer tilførselsluft (Z) til et indvendigt passagerum,

10 - en ekspansionsventil (11), en kompressor (10) og en ventilanordning til omskiftning mellem køledriften og varmedriften,

kendetegnet ved, at

at kølekredsløbet

15 - har et primærkølekredsløb (1), som omfatter den første varmeveksler (3), ekspansionsventilen (11), kompressoren (10), ventilanordningen til omskiftning mellem køledriften og varmedriften samt en primærside af en tredje varmeveksler (16), der arbejder som fordamper under køledriften og som kondensator under varmedriften, og

20 - har et sekundærkølekredsløb (2), som omfatter sekundærsiden af den tredje varmeveksler (16) og den anden varmeveksler (12),

- hvor der mellem et kølefluidudløb på sekundærsiden af den tredje varmeveksler (16) og et kølefluidindløb af den anden varmeveksler (12) er anbragt en tilkøbbelbar elektrisk varmeindretning til opvarmning af en kølemiddeltilstrømning for den anden varmeveksler (12).

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30 2. Klimaanlæg ifølge krav 1,

kendetegnet ved, at

den elektriske varmeindretning er udformet som dyppekoger (14).

3. Klimaanlæg ifølge krav 2,

kendetegnet ved, at

dyppekogeren (14) er integreret i et reservoir (17) for sekundærkølekredsløbets (2) kølemiddel.

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4. Klimaanlæg ifølge et af kravene 1 til 3,

kendetegnet ved, at

det under sin varmedrift arbejder intervallignende på en sådan måde, at en optøning bliver mulig på den første varmeveksler (3).

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5. Klimaanlæg ifølge et af kravene 1 til 4,

kendetegnet ved, at

ventilanordningen er dannet af en firvejsventil (5), med en første tilslutning (6), som under køledriften er forbundet med et kølefluidindløb af den første varmeveksler (3), en anden tilslutning (7), som under køledriften er forbundet med et kølefluidudløb på primærsiden af den tredje varmeveksler (12), en tredje tilslutning (8), der er forbundet med en indgangsside af kompressoren, og en fjerde tilslutning (9), der er forbundet med en udgangsside af kompressoren (7).

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6. Klimaanlæg ifølge krav 5,

kendetegnet ved, at

under køledriften er firvejsventilen (5) tilkoblet på en sådan måde, at dens anden tilslutning (7) er strømningsteknisk forbundet med den tredje tilslutning (8), og dens fjerde tilslutning (9) er strømningsteknisk forbundet med den første tilslutning (6), mens under varmedriften den første tilslutning (6) er strømningsteknisk forbundet med den tredje tilslutning (8), og den fjerde tilslutning (9) er strømningsteknisk forbundet med den første tilslutning (6).

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7. Klimaanlæg ifølge et af kravene 1 til 6,

kendetegnet ved, at

den tredje varmeveksler (16) er udført som pladevarmeoverføringsanordning.

8. Klimaanlæg ifølge et af kravene 1 til 7,

kendetegnet ved, at

sekundærkølekredsløbet (1) arbejder med en brine-vand-blanding som kølemiddel.

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9. Klimaanlæg ifølge et af kravene 1 til 8,

kendetegnet ved, at

omgivelsesluften er ført forbi den første varmeveksler (3) ved hjælp af en første ventilator (4).

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10. Klimaanlæg ifølge et af kravene 1 til 9,

kendetegnet ved, at

tilførselsluft (Z), der skal konditioneres, til det indvendige passagerrum er ført forbi den anden varmeveksler (12) ved hjælp af en anden ventilator (10).

15

FIG 1

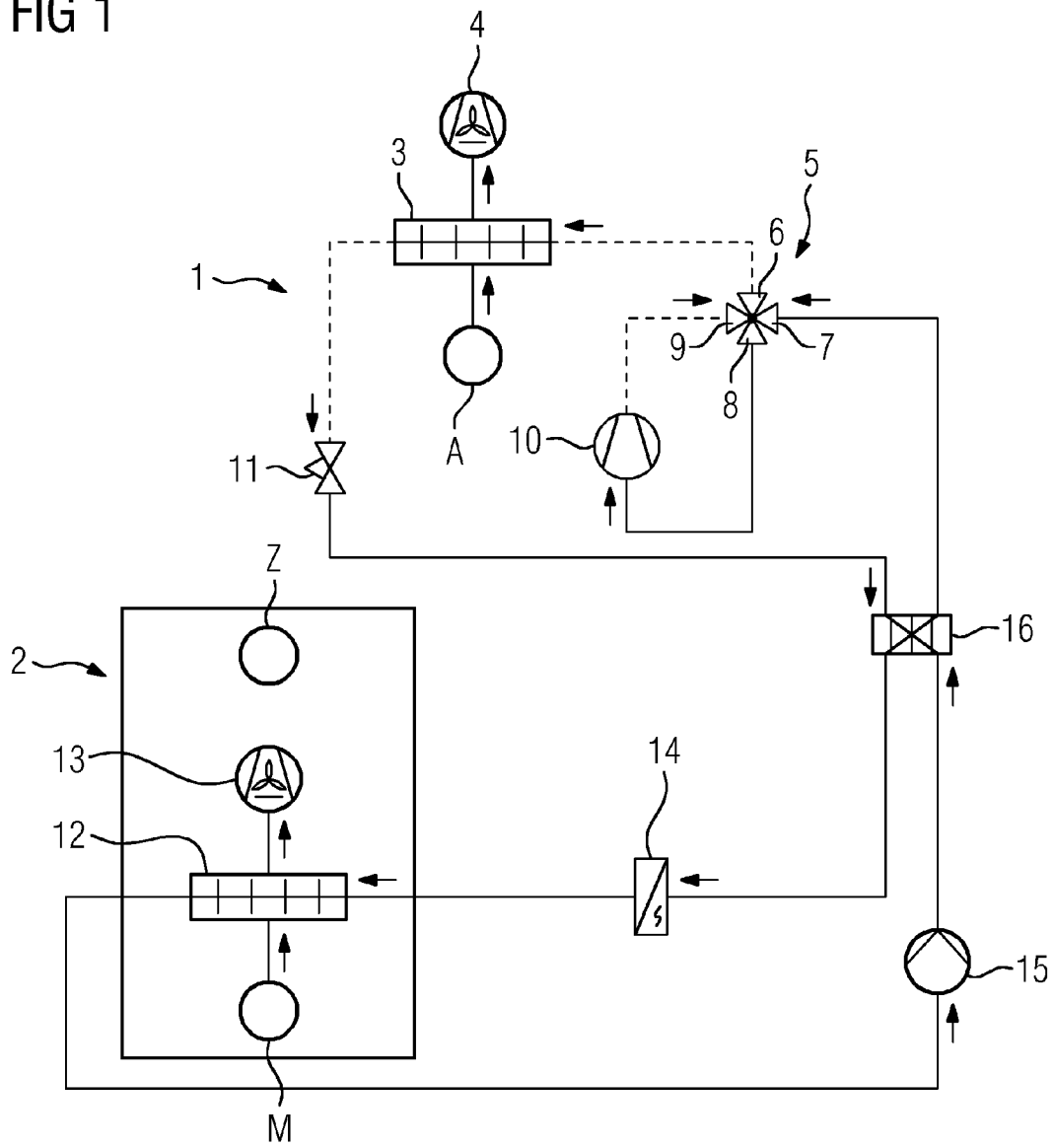


FIG 2

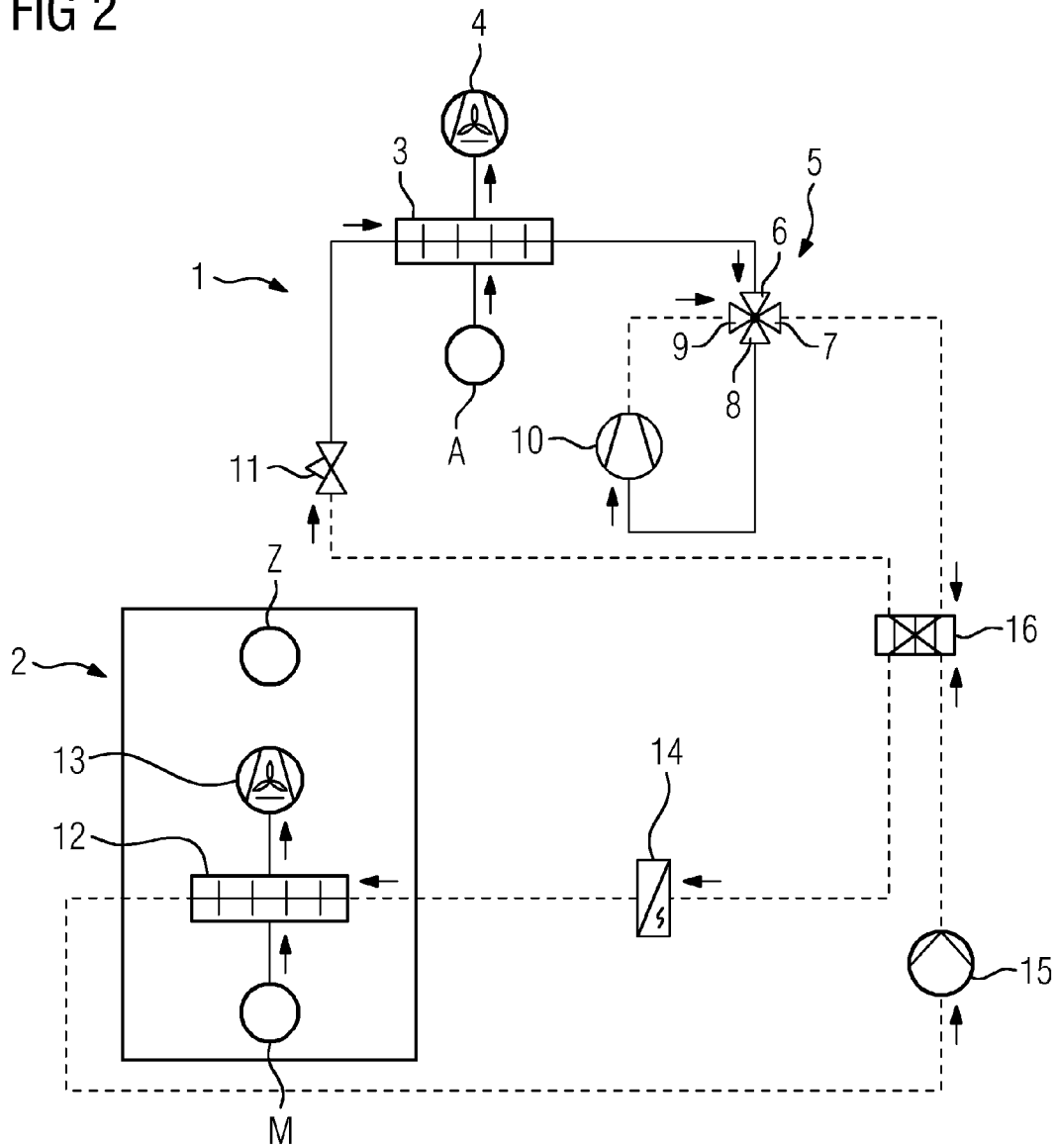


FIG 3

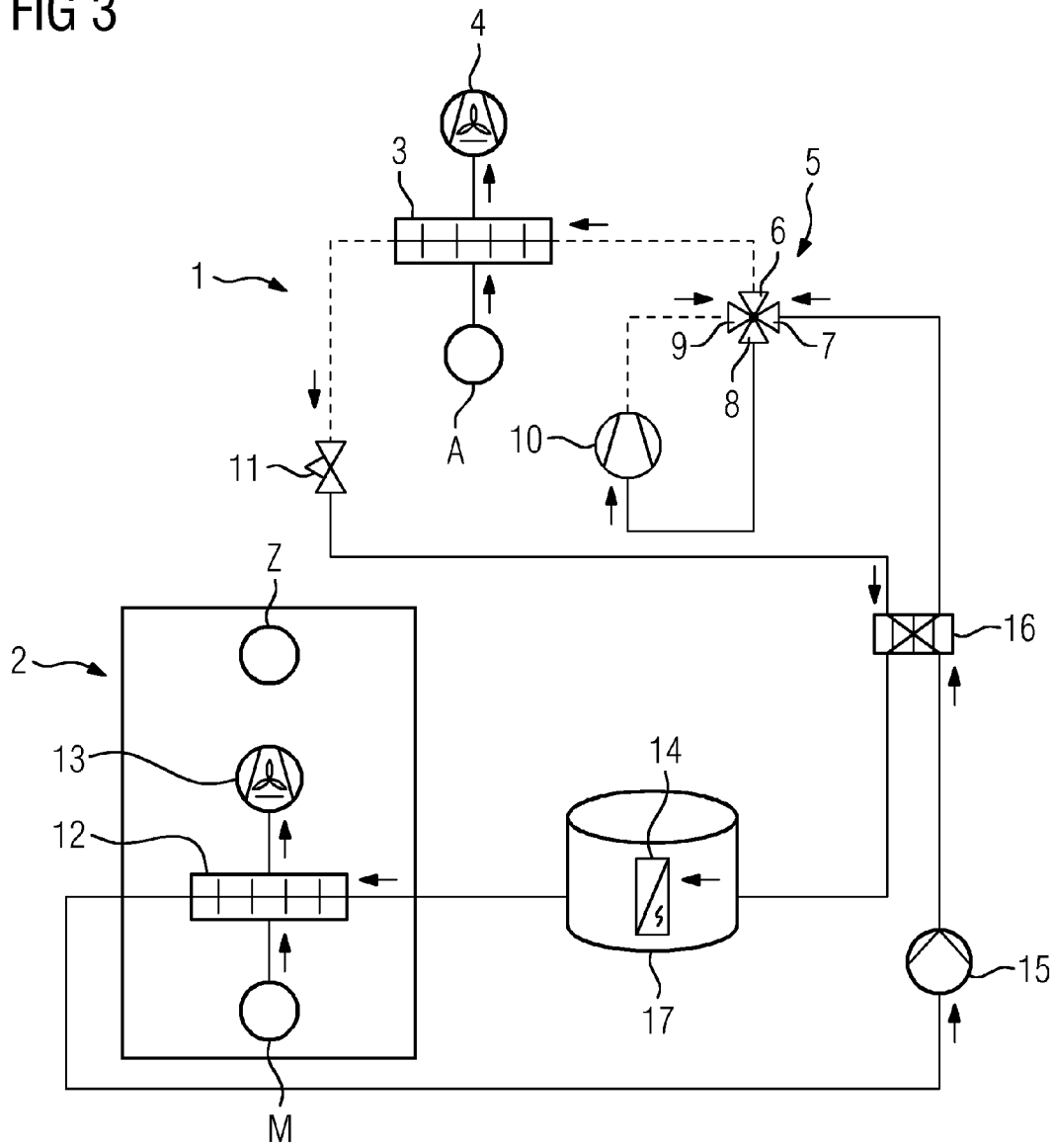


FIG 4

