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(54) HEAT PUMP AND ASSOCIATED METHOD OF CONTROLLING A HEAT PUMP

(57) A heat pump (1) comprising a circuit (2) for circulating a refrigerant fluid, a first heat exchanger (3) placed in the circuit (2) and forming an evaporator (4), a compressor (5) placed in the circuit (2) downstream of the first heat exchanger (3), a second heat exchanger (6) placed in the circuit (2) downstream of the compressor (5) and forming a condenser (7), a transit duct (10) connecting the second heat exchanger (6) to the first heat exchanger (3) downstream of the second heat exchanger (6), an expansion device (8) connected in the transit duct (10) and having a first expansion valve unit (8') and a second expansion valve unit (8") arranged in series in the transit duct (10).

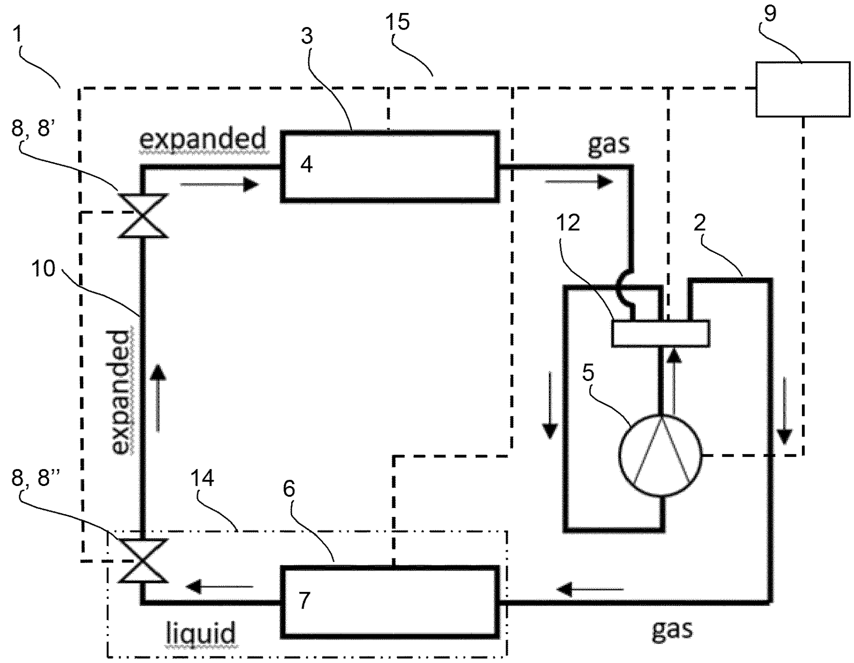


FIG. 3

Description

[0001] The invention relates to a heat pump, for example for heating and/or cooling air and/or water, e.g., in a system for heating and/or cooling spaces and/or water.

[0002] A heat pump comprises a circuit for the circulation of a refrigerant fluid, an evaporator (consisting of a first heat exchanger) placed in the circuit, a compressor placed in the circuit downstream of the evaporator, a condenser (embodied by a second heat exchanger) placed in the circuit downstream of the compressor, and an expansion valve placed in the circuit downstream of the condenser and upstream of the evaporator. The indications "downstream" and "upstream" refer to the circulation direction of the refrigerant fluid in at least one operating mode. The compressor is operable to suck the refrigerant fluid in the gaseous phase and at low pressure from the evaporator, compress the refrigerant fluid, and push it into the condenser. Inside the condenser, the compressed refrigerant fluid releases heat and condensation at high pressure. After leaving the condenser, the refrigerant fluid passes through the expansion valve which decompresses it, bringing the refrigerant fluid to a depressurized two-phase state with a possibly lower amount of gaseous phase. Still due to the suction effect of the compressor, the depressurized two-phase refrigerant fluid is conveyed into the evaporator where the refrigerant fluid absorbs heat and evaporates at low pressure, before being sucked and compressed again by the compressor.

[0003] The refrigerant fluid changes state inside the evaporator, changing from two-phase to gaseous by absorbing heat, and inside the condenser, changing from gaseous to liquid by releasing heat. The air or fluid in contact with the evaporator (or, in other words: the space where it is located) is thus cooled, whereas the air or fluid in contact with the condenser (or, in other words: the space where it is located) is heated.

[0004] It is further known to connect the compressor in the circuit by the interposition of a (four-way) switching valve which allows inverting the compression and circulation direction of the refrigerant fluid and thus switching the first heat exchanger from evaporator to condenser and the second heat exchanger from condenser to evaporator, allowing both cooling and heating the air or fluid in contact with the first and second heat exchangers (or the spaces in which they are located).

[0005] Known heat pumps, described above, can be used in a heating mode, e.g., in winter months, taking heat from the external air and bringing heat into a building.

[0006] In this case, the refrigerant fluid crosses the expansion valve and becomes a liquid-vapor mixture at low pressure, then enters into the evaporator, placed outside, where it absorbs heat until it becomes vapor at low temperature, which vapor is then sucked and compressed by the compressor resulting in a temperature increase, and the hot and compressed vapor is pushed from the compressor outlet into the condenser, which can be a fan coil unit, for example, placed inside the building (close to the boiler, for example), and changes phase again from gas to liquid releasing the liquefaction heat. The liquid refrigerant fluid returns to the expansion valve, and the cycle is repeated.

[0007] By inverting the cooling cycle, e.g., through the (four-way) switching valve, the same heat pump can be used in a cooling mode, e.g., in the summer months, where the refrigerant fluid evaporates in the indoor fan coil unit and condenses in the outdoor heat exchange battery.

[0008] Heat pumps use greenhouse gas as a refrigerant fluid. The F-gas regulation introduced by the European Union, and similar legislation or initiatives in other countries, aim to reduce the emission of greenhouse gases and are pushing manufacturers of heat pumps to reduce the global warming potential (GWP) of their products. The reduction in global warming potential can be carried out using refrigerant fluids with low greenhouse effect properties, or by adopting technical solutions that reduce the mass of fluid required for the individual heat pump, with the thermal performance levels being the same.

[0009] Many refrigerant fluids with low global warming potential (GWP) are classified as flammable (e.g., R32, propane). For safety reasons, allowable amount limits for these flammable refrigerant fluids are set or recommended in a heat pump present (or at least even extending) inside a house. In particular, heat pumps known as splits (with units inside the house) which use flammable refrigerant fluids must thus operate with low charges of refrigerant fluid as compared, for example, to single-block heat pumps completely located outdoors.

[0010] However, heat pumps have to operate in a wide range of outdoor temperatures and water (or indoor) temperatures and it is known that a refrigerant fluid charge reduction in the same heat pump also reduces the operating temperature range.

[0011] A further reason for having to charge split heat pumps with undesirably high amounts of refrigerant fluid is the size itself of the heat pump system, understood as the overall length of the ducts filled with this refrigerant fluid, which can amount to tens of meters.

[0012] In known split heat pump systems, the expansion valve is positioned in a transit pipe connecting the heat exchangers of the external unit and internal unit. This implies that, both in heating and cooling modes, the connecting duct must be filled with refrigerant fluid. The refrigerant fluid upstream of the expansion valve is in the liquid state (high density), while downstream of the expansion valve the refrigerant fluid is typically in the two-phase liquid-gas state, with much lower density.

[0013] The expansion valve could be located in the internal unit or external unit of the heat pump. However, since the heat pump must operate in both heating and cooling modes (cycle invertibility), regardless of the position of the expansion valve on the internal unit side or the external unit side, an operating mode always exists, in which the transit duct that connects the external unit to the internal unit (and which can be up to 30m long) is filled with high density liquid refrigerant fluid.

[0014] This implies that the amount of refrigerant fluid contained in this transit duct can be significant, thus making it impossible to use propane as refrigerant gas for split heat pumps, for example.

[0015] Therefore, it is the object of the invention to provide an improved heat pump and a method of operating the heat pump which allow reducing the mass of refrigerant fluid used (as compared to a known split heat pump with optimized refrigerant fluid charge), with the size of the system being the same, and possibly, with performance in terms of COP (coefficient of performance) and thermal capacity being the same, and the operating interval/range being the same.

[0016] At least some of the objects are achieved by a heat pump according to claim 1. The dependent claims relate to advantageous and preferred embodiments.

[0017] According to an aspect of the invention, a heat pump comprises:

- a circuit for circulating a refrigerant fluid,
- a first heat exchanger placed in the circuit and forming an evaporator,
- a compressor placed in the circuit downstream of the first heat exchanger,
- a second heat exchanger placed in the circuit downstream of the compressor and forming a condenser,
- a transit duct connecting the second heat exchanger to the first heat exchanger downstream of the second heat exchanger,
- an expansion device connected in the transit duct between the second heat exchanger and the first heat exchanger,
- an electronic control system controlling the compressor and the expansion device,
  where:
    - the compressor is operable to suck the refrigerant fluid in the gaseous phase and at low pressure from the evaporator, compress the refrigerant fluid, and push it into the condenser,
    - in the condenser, the compressed refrigerant fluid releases heat and condenses at high pressure,
    - after leaving the condenser, the refrigerant fluid passes through the transit duct and the expansion device which depressurizes it,
    - the refrigerant fluid depressurized by the expansion device enters from the transit duct into the evaporator where it absorbs heat and evaporates at low pressure, before being sucked and compressed again by the compressor,
      where:
        - the expansion device comprises a first expansion valve unit and a second expansion valve unit arranged in series in the transit duct,
        - the first expansion valve unit is arranged (in a first end portion of the transit duct) at the first heat exchanger and the second expansion valve unit is arranged (in a second end portion of the transit duct) at the second heat exchanger,
        - the control system and the expansion device are configured so that:

          an expansion valve unit on the evaporator side of said first and second expansion valve units is completely open to allow an unthrottled passage of the refrigerant fluid from the transit duct into the evaporator, whereas
          an expansion valve unit on the condenser side of said first and second expansion valve units is adjusted to act as a single expansion valve in order to expand the refrigerant fluid when entering from the condenser into the transit duct.

[0018] Placing two expansion valves, one on the evaporator side and the other on the condenser side, or in other words, one in the internal unit and one in the external unit, and using the valve as an expansion point at inlet of the transit duct, respectively, allows the refrigerant fluid in the transit duct to always be expanded, with a considerably lower density than that of the liquid refrigerant fluid. This allows reducing the amount (total mass) of refrigerant fluid in the transit duct and, therefore, in the entire heat pump, so as to reduce the environmental footprint of the product and comply with the most stringent regulations.

Brief description of the drawings

[0019] These and other aspects and advantages of the invention will become apparent from the following description of exemplary and non-limiting embodiments thereof, with reference to the drawings, in which:

figure 1 shows a heat pump of the prior art in a winter heating mode,
figure 2 shows the heat pump of the prior art in figure 1 in a summer cooling mode,
figure 3 shows a heat pump according to an embodiment of the invention in the winter heating mode,
figure 4 shows the heat pump in figure 3 in the summer cooling mode,
figure 5 shows a heat pump according to a further embodiment of the invention,
figure 6 shows a heat pump according to a further embodiment of the invention,

figure 7 shows an expansion valve device of the heat pump in figure 7 according to a further embodiment.

Description of embodiments

[0020] With reference to the figures, a heat pump 1 comprises:

- a circuit 2 for circulating a refrigerant fluid,
- a first heat exchanger 3 placed in the circuit 2 and embodying an evaporator 4) in a heating mode of operation and/or a condenser 7 in a cooling mode of operation,
- a compressor 5 placed in the circuit 2 downstream of the first heat exchanger 3,
- a second heat exchanger 6 placed in the circuit 2 downstream of the compressor 5 and embodying a condenser 7 in a heating mode of operation and/or an evaporator 4 in a cooling mode of operation,
- a transit duct 10 connecting the second heat exchanger 6 to the first heat exchanger 3 downstream of the second heat exchanger 6,
- an expansion device 8 connected in the transit duct 10 between the second heat exchanger 6 and the first heat exchanger 3,
- an electronic control system 9 which controls the compressor 5 and the expansion device 8,
  where:
  - the compressor 5 is operable to suck the refrigerant fluid in the gaseous phase and at low pressure from the evaporator 4, compress the refrigerant fluid, and push it into the condenser 7,
  - in the condenser 7, the compressed refrigerant fluid releases heat and condensates at high pressure,
  - after leaving the condenser 7, the refrigerant fluid passes through the transit duct 10 and the expansion device 8 which depressurizes it,
  - the refrigerant fluid depressurized by the expansion device 8 enters from the transit duct 10 into the evaporator 4 where it absorbs heat and evaporates at low pressure, before being sucked and compressed again by the compressor 5.

[0021] The expansion device 8 comprises a first expansion valve unit 8' and a second expansion valve unit 8" arranged in series in the transit duct 10.

[0022] The first expansion valve unit 8' is arranged (in a first end portion of the transit duct 10) at the first heat exchanger 3 and the second expansion valve unit 8" is arranged (in a second end portion of the transit duct 10) at the second heat exchanger 6. In an advantageous embodiment:

- said first end portion of the transit duct 10 in which the first expansion valve unit 8' is arranged has a first end length less than 10%, preferably less than 5%, more preferably less than 2%, of a total length of the transit duct 10, and
- said second end portion of the transit duct 10 in which the second expansion valve unit 8" is arranged has a second end length less than 10%, preferably less than 5%, more preferably less than 2%, of the total length of the transit duct 10.

Moreover, the transit duct 10 is preferably continuous without any intervening valves, preferably continuous without any intervening duct branch-offs or duct junctions (as shown in figures 3, 4, 5), and preferably continuous with a constant transit duct cross-section, between the first and second expansion valve units 8', 8".
The first expansion valve unit 8' embodies an evaporator side expansion valve unit in the heating mode of operation and/or a condenser side expansion valve unit in the cooling mode of operation. The second expansion valve unit 8" embodies a condenser side expansion valve unit in the heating mode of operation and/or an evaporator side expansion valve unit in the cooling mode of operation.

[0023] The control system 9 and the expansion device 8 are configured so that:

an (the) evaporator side expansion valve unit 8'; 8" of said first 8' and second 8" expansion valve units is completely open to allow an unthrottled passage of the refrigerant fluid from the transit duct 10 into the evaporator 4, whereas
a (the) condenser side expansion valve unit 8'; 8" of said first 8' and second 8" expansion valve units is adjusted to act as a single expansion valve to expand the refrigerant fluid when entering from the condenser 7 into the transit duct 10.

[0024] According to an embodiment, the compressor 5 is connected in the circuit 2 by the interposition of a (four-way) switching/inverting valve 12 controlled by the control system 9 and which allows inverting the compression and circulation direction of the refrigerant fluid and thus switching the first heat exchanger 3 from evaporator 4 (in the heating mode of operation) to condenser 7 (in the cooling mode of operation) and switching the second heat exchanger 6 from condenser 7 (in the heating mode of operation) to evaporator 4 (in the cooling mode of operation), allowing both cooling and heating of the air or fluid in contact with the first heat exchanger 3 and the second heat exchanger 6 (or the environments in which they are located). As described above and illustrated in figures 3 and 4, also when inverting the compression and circulation direction of the refrigerant fluid, i.e. in both the heating mode of operation and the cooling mode of operation, the evaporator side expansion valve unit 8'; 8" of said first 8' and second 8" expansion valve units is completely open to allow an unthrottled passage of the refrigerant fluid from the transit duct 10 into the evaporator

4, whereas the condenser side expansion valve unit 8'; 8" of said first 8' and second 8" expansion valve units is adjusted to act as a single expansion valve to expand the refrigerant fluid when entering from the condenser 7 into the transit duct 10.

[0025] According to an embodiment, the heat pump 1 comprises an external unit 14 intended to be positioned outdoors, (outside a building), an internal unit 15 intended to be positioned inside a building and connected to a use (device) 35, such as a heating/cooling system with a primary water circuit 16, for example. The external unit 14 houses in a housing thereof (or through a support structure thereof) at least the first heat exchanger 3, and the internal unit 15 houses in a housing thereof (or through a support structure thereof) at least the second heat exchanger 6, where the transit duct 10 extends between the external unit 14 and the internal unit 15 and the first expansion valve unit 8' is arranged in or at the (housing of) the external unit 14 and the second expansion valve unit 8" is arranged in or at the (housing of) the internal unit 15.

[0026] According to an embodiment, the first expansion valve unit 8' comprises a first expansion valve 11' controlled by the control system 9 and adapted to carry out an expansion or lamination of the refrigerant fluid, as well as a first bypass valve 11a', placed in a first bypass duct 37' which bypasses the first expansion valve 11', and configured or controlled to completely open and close the first bypass duct 37' depending on the flow direction of the refrigerant fluid through the first expansion valve unit 8'.

[0027] In particular, the first bypass valve 11a' closes the first bypass duct 37' when the refrigerant fluid flows through the transit duct 10 from the first heat exchanger 3 towards the second heat exchanger 6, and opens the first bypass duct 37' when the refrigerant fluid flows through the transit duct 10 from the second heat exchanger 6 towards the first heat exchanger 3.

[0028] The first bypass valve 11a' can be an electric valve actively controlled by the electronic control system 9 or, advantageously, a self-regulating one-way valve (non-return valve) without any control signal connection with the control system 9.

[0029] Similarly, according to an embodiment, the second expansion valve unit 8" comprises a second expansion valve 11" controlled by the control system 9 and adapted to carry out an expansion or lamination of the refrigerant fluid, as well as a second bypass valve 11a", placed in a second bypass duct 37" which bypasses the second expansion valve 11", and configured or controlled to completely open and close the second bypass duct 37" depending on the flow direction of the refrigerant fluid through the second expansion valve unit 8".

[0030] In particular, the second bypass valve 11a" closes the second bypass duct 37" when the refrigerant fluid flows through the transit duct 10 from the second heat exchanger 6 towards the first heat exchanger 3, and opens the second bypass duct 37" when the refrigerant fluid flows through the transit duct 10 from the first heat exchanger 3 towards the second heat exchanger 6.

[0031] The second bypass valve 11a" can be an electric valve actively controlled by the electronic control system 9 or, advantageously, a self-regulating one-way valve (non-return valve) without any control signal connection with the control system 9. This considerably simplifies the control, the hydraulic structure and the cost of the expansion device 8.

[0032] The heat pump 1 further comprises, in a known manner, a refrigerant fluid storage vessel/reservoir 13, connected to the circuit 2, e.g., between the first heat exchanger 3 (e.g., external unit) and the compressor 5, or directly upstream of the compressor 5.

[0033] Figure 6 shows a further embodiment of the heat pump 1, with an external unit 14 intended to be positioned outdoors, an internal unit 15 intended to be positioned inside a building, and with a use (device) 35, such as a heating/cooling system with a primary water circuit 16, for example.

[0034] The external unit 14 comprises (inside a housing):

- the first heat exchanger 3, possibly provided with an air fan 17, an external air temperature sensor 18, possibly a thermal probe 19' for measuring the temperature of the refrigerant at an intermediate point in the first heat exchanger 3, and a temperature sensor 19 for the refrigerant fluid between the first heat exchanger 3 and the expansion device 8,
- the compressor 5 with a temperature sensor 20 for the refrigerant fluid on the suction side of the compressor 5, and with a temperature sensor 21 for the refrigerant fluid on the delivery side of the compressor 5
- the refrigerant fluid storage vessel 13 arranged on the suction side of the compressor 5,
- a pressure switch 22 arranged on the delivery side of the compressor 5,
- the switching/inverting valve 12,
- (connection attachments of) tubes 23 of the circuit 2,
- the expansion device 8 with the first electric expansion valve 11' and the second electric expansion valve 11",
- a refrigerant temperature sensor 24 placed in the circuit 2 between the expansion device 8 and the second heat exchanger 6.

[0035] The internal unit 15 comprises (inside a housing):

- the second heat exchanger 6 which exchanges heat between the refrigerant fluid circuit 2 and the primary water circuit 16,
- a water pump 25 in the primary water circuit 16 upstream of the second heat exchanger 6,
- a flow rate sensor (flowmeter) 26, e.g., on the inlet

side of the water pump 25,

- a water return temperature sensor 27, e.g., on the inlet side of the water pump 25,
- an expansion vessel 28 of the water connected to the primary water circuit 16, e.g., on the inlet side of the water pump 25,
- a water filter 29 connected to the primary water circuit 16, e.g., upstream of the water pump 25 and/or upstream of the water expansion vessel 28,
- a water delivery temperature sensor 30 (LWT = Leaving Water Temperature) at the outlet of the second heat exchanger 6,
- an electric backup heater 31 connected in the primary water circuit 16, preferably downstream of the second heat exchanger 6, to an associated temperature sensor 32, for the water at the outlet of the electric backup heater 31, and
- (connection attachments of) tubes 33 of the circuit 2, and
- (connection attachments of) tubes 34 of the primary water circuit.

[0036] The use (device) 35 comprises a part of the primary water circuit 16 and a water vessel 36 and/or a plurality of heaters or radiators 36 for heating and cooling.

[0037] The invention is also directed to a method of controlling a heat pump, such as the heat pump 1, comprising the steps of:

A) operating the compressor 5 to suck the refrigerant fluid in the gaseous phase and at low pressure from the evaporator 4, compress the refrigerant fluid, and push it into the condenser 7, so that:

- in the condenser 7, the compressed refrigerant fluid releases heat and condensates at high pressure,
- after leaving the condenser 7, the refrigerant fluid passes through the transit duct 10 and the expansion device 8 which depressurizes it,
- the refrigerant fluid depressurized by the expansion device 8 enters from the transit duct 10 into the evaporator 4 where it absorbs heat and evaporates at low pressure, before being sucked and compressed again by the compressor 5,

B) using a switching/inverting valve 12 to invert a compression and circulation direction of the refrigerant fluid and therefore a switching of the first heat exchanger 3 from evaporator 4 to condenser 7 and of the second heat exchanger 6 from condenser 7 to evaporator 4,

C) arranging a first expansion valve unit 8' and a second expansion valve unit 8" in series in the transit duct 10, where the first expansion valve unit 8' is arranged (in an end portion of the transit duct 10) at the first heat exchanger 3 and the second expansion valve unit 8" is arranged (in a second end portion of the transit duct 10) at the second heat exchanger 6,

D) controlling the first expansion valve unit 8' and the second expansion valve unit 8" so that:

- an expansion valve unit 8'; 8" on the evaporator side of said first 8' and second 8" expansion valve units is completely open to allow an unthrottled passage of the refrigerant fluid from the transit duct 10 into the evaporator 4, whereas
- an expansion valve unit 8'; 8" on the condenser side of said first 8' and second 8" expansion valve units is adjusted to expand the refrigerant fluid when entering from the condenser 7 into the transit duct 10.

[0038] The further steps and features of the method correspond to the functions and measures of provision, positioning, structuring and control of the components of the heat pump 1 (understood herein as method steps) already described with reference to the heat pump 1 and not repeated here for conciseness.

List of reference numerals in the figures

[0039]

heat pump 1
circuit 2
first heat exchanger 3
evaporator 4
compressor 5
second heat exchanger 6
condenser 7
expansion device 8
first expansion valve unit 8'
second expansion valve unit 8"
electronic control system 9
transit duct 10
first expansion valve 11'
second expansion valve 11"
first bypass valve 11a'
second bypass valve 11a"
switching/inverting valve 12
storage vessel 13
external unit 14
internal unit 15
primary water circuit 16
air fan 17
outdoor air temperature sensor 18
thermal probe 19' for the refrigerant fluid in the first heat exchanger
temperature sensor 19 for the refrigerant fluid at the first heat exchanger,
temperature sensor 20 for the refrigerant fluid on the suction side of compressor 5
temperature sensor 21 for the refrigerant fluid on the delivery side of compressor 5

high pressure switch (pressure switch) 22
(connection attachments of) tubes 23 of the refrigerant circuit 2
refrigerant temperature sensor 24
water pump 25
water flow rate sensor 26
water temperature sensor 27
water expansion vessel 28
water filter 29
water delivery temperature sensor 30
electric backup heater 31
temperature sensor 32 for the water at the outlet of the electric heater
(connection attachments of the) tubes 33 of the refrigerant circuit 2
(connection attachments of the) tubes 34 of the primary water circuit
use (device) 35
radiators/water vessels/fan coil units 36
first bypass duct 37'
second bypass duct 37"

Claims

1. A heat pump (1) comprising:

- a circuit (2) for circulating a refrigerant fluid,
- a first heat exchanger (3) placed in the circuit (2) and embodying an evaporator (4) in a heating mode of operation and/or a condenser (7) in a cooling mode of operation,
- a compressor (5) placed in the circuit (2) downstream of the first heat exchanger (3),
- a second heat exchanger (6) placed in the circuit (2) downstream of the compressor (5) and embodying a condenser (7) in a heating mode of operation and/or an evaporator (4) in a cooling mode of operation,
- a transit duct (10) connecting the second heat exchanger (6) to the first heat exchanger (3) downstream of the second heat exchanger (6),
- an expansion device (8) connected in the transit duct (10) between the second heat exchanger (6) and the first heat exchanger (3),
- an electronic control system (9) which controls the compressor (5) and the expansion device (8),

wherein:

- the compressor (5) is operable to suck the refrigerant fluid in the gaseous phase and at low pressure from the evaporator (4), compress the refrigerant fluid, and push it into the condenser (7),
- in the condenser (7), the compressed refrigerant fluid releases heat and condensates at high pressure,
- after leaving the condenser (7), the refrigerant fluid passes through the transit duct (10) and the expansion device (8) which depressurizes the refrigerant fluid,
- the refrigerant fluid depressurized by the expansion device (8) enters from the transit duct (10) into the evaporator (4) where it absorbs heat and evaporates at low pressure, before being sucked and compressed again by the compressor (5),

wherein:

- the expansion device (8) comprises a first expansion valve unit (8') and a second expansion valve unit (8") arranged in series in the transit duct (10),
- the first expansion valve unit (8') is arranged at the first heat exchanger (3) and the second expansion valve unit (8") is arranged at the second heat exchanger (6),

the control system (9) and the expansion device (8) are configured so that:

- an expansion valve unit (8'; 8") on the evaporator side (4) of said first (8') and second (8") expansion valve units is completely open to allow an unthrottled passage of the refrigerant fluid from the transit duct (10) into the evaporator (4), while
- an expansion valve unit (8'; 8") on the condenser side (7) of said first (8') and second (8") expansion valve units is adjusted to expand the refrigerant fluid when entering from the condenser (7) into the transit duct (10).

2. A heat pump (1) according to claim 1, wherein the compressor (5) is connected in the circuit (2) by the interposition of a switching valve (12) controlled by the control system (9) and allowing an inversion of the compression and circulation direction of the refrigerant fluid and therefore a switching of the first heat exchanger (3) from evaporator (4) to condenser (7) and a switching of the second heat exchanger (6) from condenser (7) to evaporator (4).

3. A heat pump (1) according to claim 1 or 2, comprising an external unit (14) intended to be positioned in the external environment, an internal unit (15) intended to be positioned inside a building and connected to a use device (35), wherein the external unit (14) accommodates in a housing thereof the first heat exchanger (3) and the internal unit (15) accommodates in a housing thereof the second heat exchanger (6), wherein the transit duct (10) extends between the external unit (14) and the internal unit (15) and the first expansion valve unit (8’) is arranged at the external unit (14) and the second expansion valve unit (8") is arranged at the internal unit (15).

4. A heat pump (1) according to any one of the preceding claims, wherein the first expansion valve unit (8’) comprises:

- a first expansion valve (11’) controlled by the control system (9) and adapted to perform an expansion of the refrigerant fluid, and
- a first bypass valve (11a’) positioned in a first bypass duct (37’) which bypasses the first expansion valve (11’), and configured or controlled to completely open and close the first bypass duct (37’) as a function of the flow direction of the refrigerant fluid through the first expansion valve unit (8’).

5. A heat pump (1) according to claim 4, wherein the first bypass valve (11a’) closes the first bypass duct (37’) when the refrigerant fluid flows through the transit duct (10) from the first heat exchanger (3) towards the second heat exchanger (6), and opens the first bypass duct (37’) when the refrigerant fluid flows through the transit duct (10) from the second heat exchanger (6) towards the first heat exchanger (3).

6. A heat pump (1) according to claim 4 or 5, wherein the first bypass valve (11a’) is an electric valve actively controlled by the electronic control system (9).

7. A heat pump (1) according to one of claims 4 to 6, wherein the first bypass valve (11a’) is a one-directional self-regulated valve without command signal connection with the control system (9).

8. A heat pump (1) according to any one of the preceding claims, wherein the second expansion valve unit (8") comprises:

- a second expansion valve (11") controlled by the control system (9) and adapted to perform an expansion of the refrigerant fluid, and
- a second bypass valve (11a") positioned in a second bypass duct (37") which bypasses the second expansion valve (11"), and configured or controlled to completely open and close the second bypass duct (37") as a function of the flow direction of the refrigerant fluid through the second expansion valve unit (8").

9. A heat pump (1) according to claim 8, wherein the second bypass valve (11a") closes the second bypass duct (37’) when the refrigerant fluid flows through the transit duct (10) from the second heat exchanger (6) towards the first heat exchanger (3), and opens the second bypass duct (37") when the refrigerant fluid flows through the transit duct (10) from the first heat exchanger (3) towards the second heat exchanger (6).

10. A heat pump (1) according to claim 7 or 8, wherein the second bypass valve (11a") is an electric valve actively controlled by the electronic control system (9).

11. A heat pump (1) according to one of claims 8 to 10, wherein the second bypass valve (11a") is a one-directional self-regulated valve without a command signal connection with the control system (9).

12. A method for controlling a heat pump (1) comprising:

- a circuit (2) for circulating a refrigerant fluid,
- a first heat exchanger (3) placed in the circuit (2) and forming an evaporator (4) in a heating mode of operation and/or a condenser (7) in a cooling mode of operation,
- a compressor (5) placed in the circuit (2) downstream of the first heat exchanger (3),
- a second heat exchanger (6) placed in the circuit (2) downstream of the compressor (5) and forming a condenser (7) in a heating mode of operation and/or an evaporator (4) in a cooling mode of operation,
- a transit duct (10) connecting the second heat exchanger (6) to the first heat exchanger (3) downstream of the second heat exchanger (6),
- an expansion device (8) connected in the transit duct (10) between the second heat exchanger (6) and the first heat exchanger (3),

<u>the method comprising the steps of:</u>

A) operating the compressor (5) to suck the refrigerant fluid in the gaseous phase and at low pressure from the evaporator (4), compress the refrigerant fluid, and push it into the condenser (7), so that:

- in the condenser (7), the compressed refrigerant fluid releases heat and condensates at high pressure,
- after leaving the condenser (7), the refrigerant fluid passes through the transit duct (10) and the expansion device (8) which depressurizes the refrigerant fluid,
- the refrigerant fluid depressurized by the expansion device (8) enters from the transit duct (10) into the evaporator (4) where it absorbs heat and evaporates at low pressure, before being sucked and compressed again by the compressor (5).

B) inverting a compression and circulation direction of the refrigerant fluid and, thereby, switching of the first heat exchanger (3) from evaporator (4) to condenser (7) and switching of the second heat exchanger (6) from condenser (7) to evaporator (4),

C) arranging a first expansion valve unit (8') and a second expansion valve unit (8") in series in the transit duct (10), wherein the first expansion valve unit (8') is arranged at the first heat exchanger (3) and the second expansion valve unit (8") is arranged at the second heat exchanger (6),

D) controlling the first expansion valve unit (8') and the second expansion valve unit (8") so that:

- an expansion valve unit (8'; 8") on the evaporator side (4) of said first (8') and second (8") expansion valve units is completely open to allow an unthrottled passage of the refrigerant fluid from the transit duct (10) into the evaporator (4), while
- an expansion valve unit (8'; 8") on the condenser side (7) of said first (8') and second (8") expansion valve units is adjusted to expand the refrigerant fluid when entering from the condenser (7) into the transit duct (10).

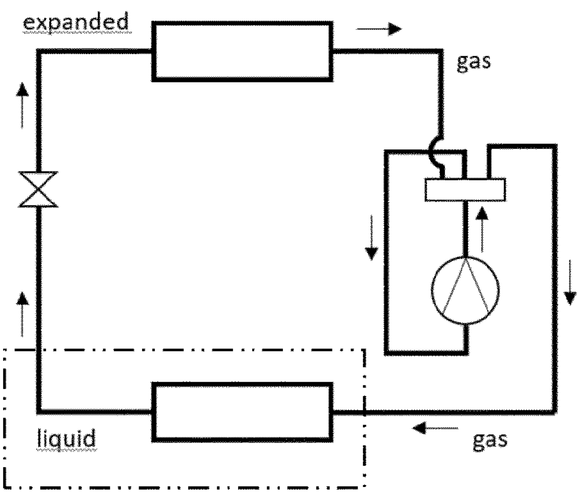


FIG. 1 (PRIOR ART)

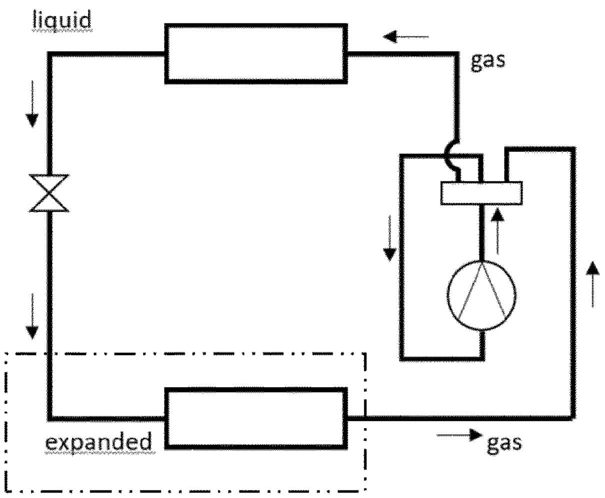


FIG. 2 (PRIOR ART)

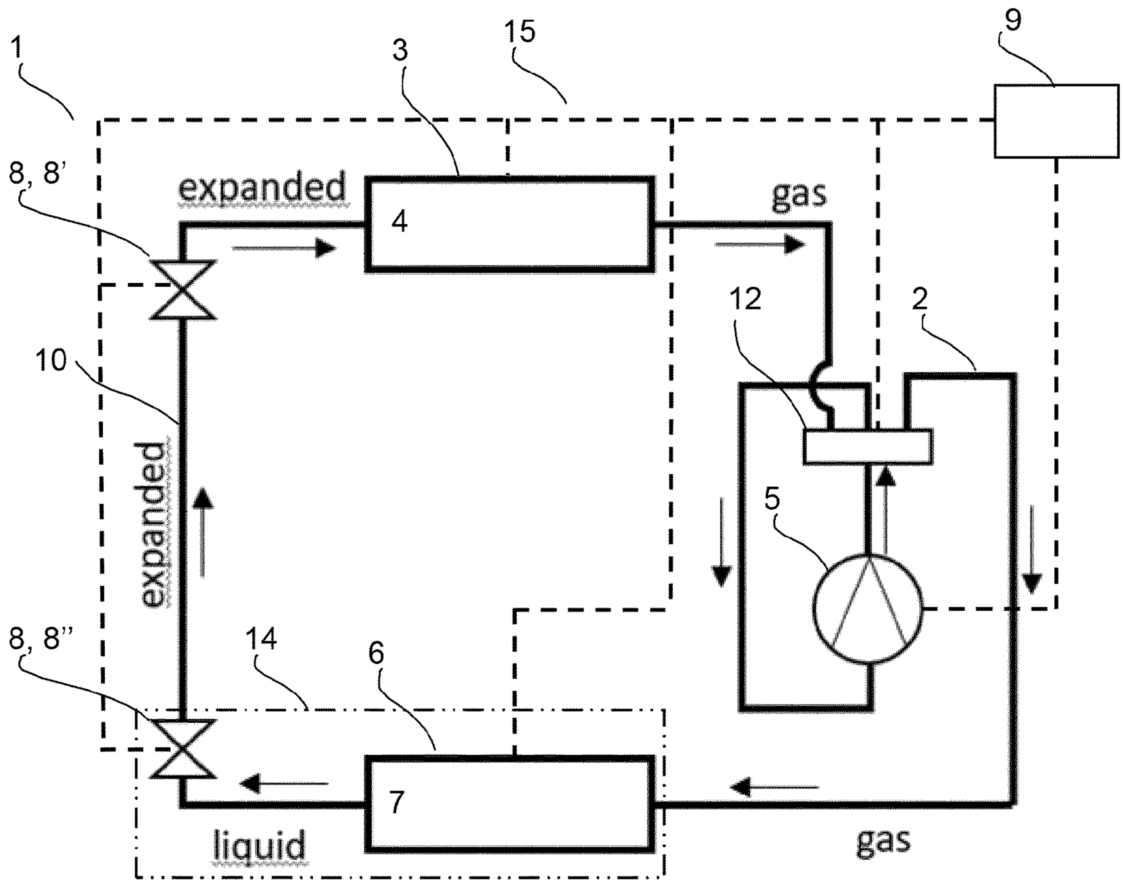
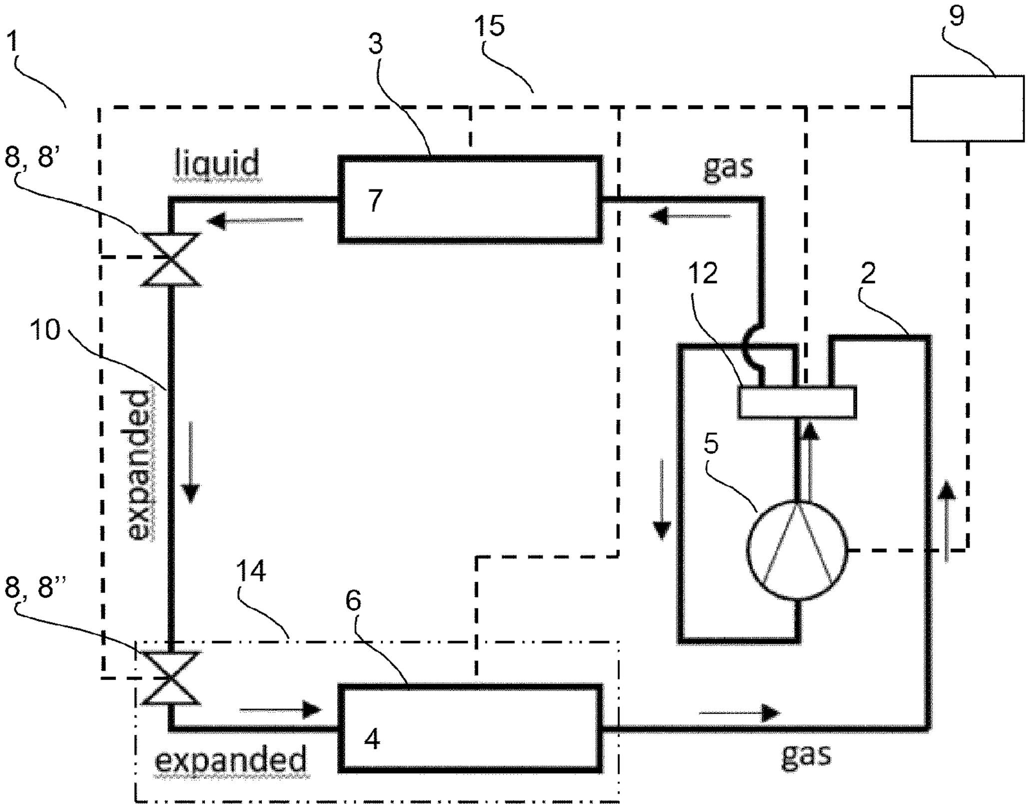
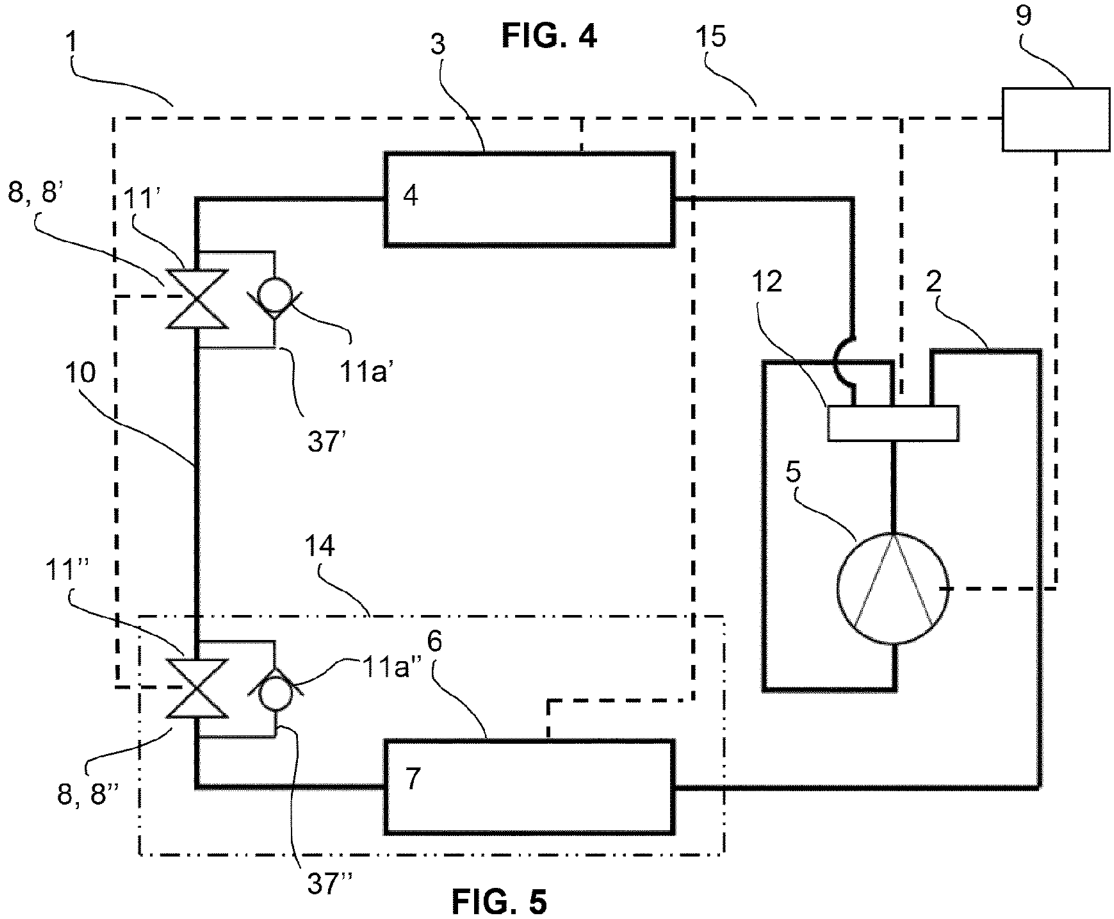


FIG. 3



1
3
15
9
8, 8'
liquid
7
gas
12
2
10
expanded
5
8, 8''
14
6
4
expanded
gas

FIG. 4



1
3
15
9
8, 8'
11'
4
12
2
11a'
10
37'
5
14
11''
6
11a''
7
8, 8''
37''

FIG. 5

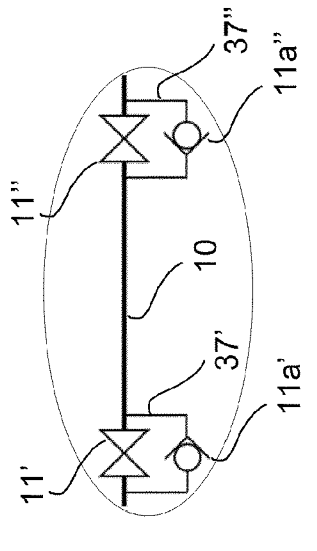
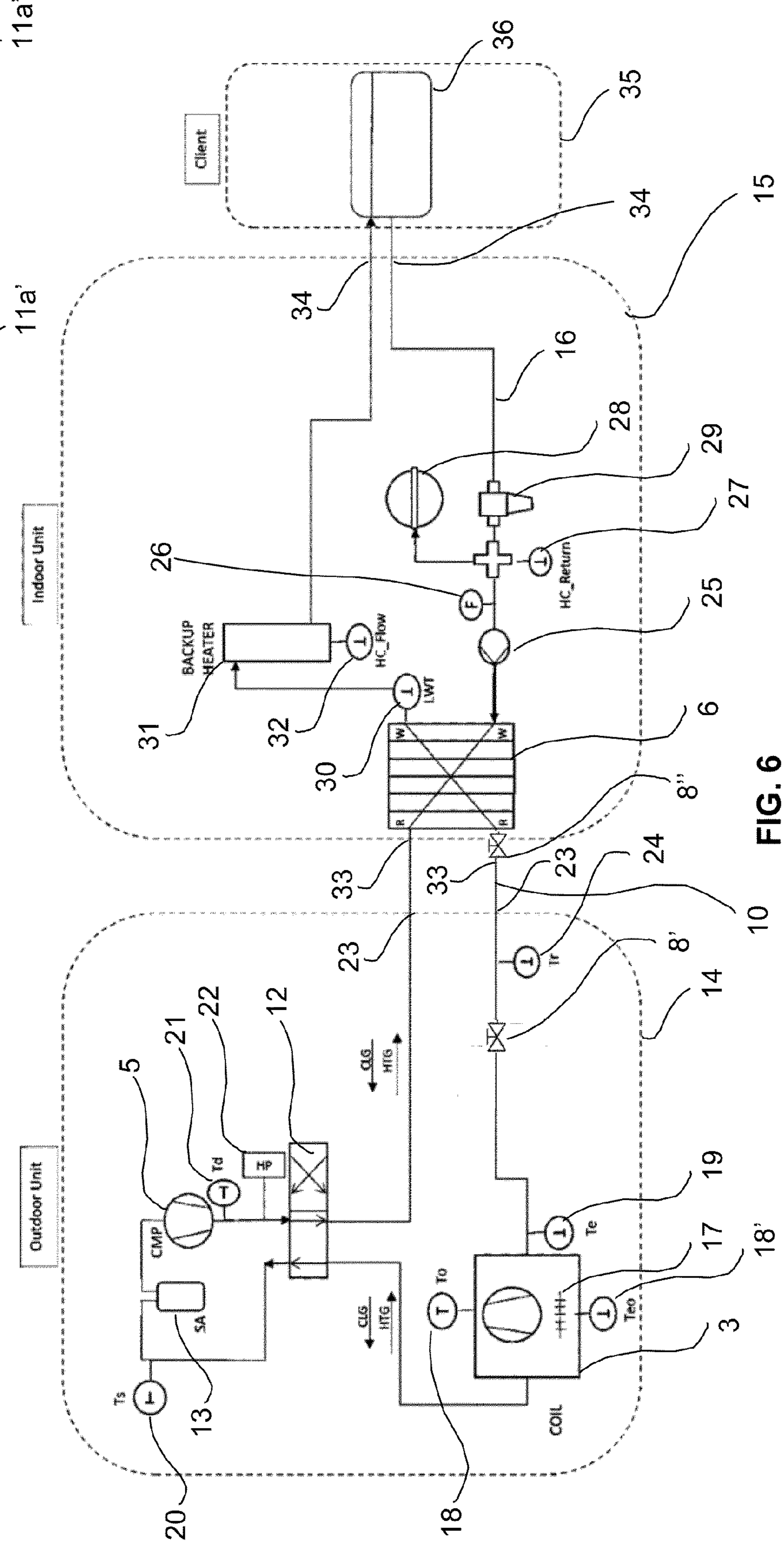

11'
11a'
37'
10
11''
11a''
37''

FIG. 7


Outdoor Unit
Indoor Unit
Client
BACKUP HEATER
HC_Flow
LWT
HC_Return
CMP
SA
HP
COIL
CLG
HTG
Ts
Td
To
Te
Teo
Tr
5
21
22
12
13
20
18
3
18'
17
19
14
8'
24
23
10
33
8''
6
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31
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36

FIG. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 23 20 6956

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	21 December 2023	Lepers, Joachim

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