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(54) HIGH EFFICIENCY INTEGRATED AIR CONDITIONING SYSTEM

INTEGRIERTES KLIMAAANLAGE-SYSTEM MIT ERHÖHTEM WIRKUNGSGRAD

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EP 3 361 171 B1

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Description

[0001] The present invention relates to a high efficiency integrated air conditioning system and an air-conditioning method.

[0002] More specifically, the present invention relates to an integrated high efficiency energy air conditioning system, which uses 3F-CMC three-fluid membrane contactors. The system according to the invention is presented as a hybrid system, which combines a steam compression cycle with a cycle operating with liquid desiccants. The system is equipped with a refrigerant flow switching valve to enable with a more energy efficiency also the winter heating as well as the air conditioning in the intermediate and summer seasons.

Field of the invention

[0003] The invention concerns the broad sector of air treatment (conditioning of civil and industrial environments, air conditioning of transport means, hygrometric control of confined spaces, air dehumidification, the refrigeration sector, development of compact evaporative membrane condensers for improving the efficiency of refrigeration cycles, passive cooling of confined spaces, etc.) and it is particularly promising in the field of air conditioning on electric vehicles.

State of the art

[0004] In the field of (industrial and civil) dehumidification and the air conditioning air treatments, in addition to the traditional vapor compression refrigeration cycles, there is also more and more space for the use of hygroscopic solutions (liquid desiccants) such as, for example, aqueous solutions of LiCl, CaCl₂, etc.. In particular, today, mixed systems (hybrids) that use liquid desiccants to cope with the latent part of the thermal load (air dehumidification) and vapor compressor cooling cycles to cope with the sensitive part (air cooling), are particularly interesting for their great energy efficiency.

[0005] With these approaches, in the summer and in the intermediate seasons, energy consumption can be reduced up to 35-40% compared with traditional technology, which has to be cooled under the dew temperature to dehumidify the air. The adoption of three-fluid contactors (air, drying liquid and refrigerant fluid) with a hydrophobic membrane separating the air and the desiccant allows the creation of compact hybrid systems and it is suitable also for the use on transport means as already illustrated, for example, in WO 2012/042553 and WO 2015/132809.

[0006] Figure 1 shows an embodiment of an integrated system according to the prior art, where there are two CMC, the dehumidifier CMC1 and the prior art regenerator CMC2, are respectively arranged in series and in parallel with conventional exchange thermal batteries B1 and B2. The evaporation/condensation temperature of

the refrigerant in the batteries B1 and B2 is the same of CMC1 and CMC2 respectively. Via the 3-way valves V1, V2, V3 and V4 it is possible to divide the refrigerant flow between CMC1 and B1 as well as between CMC2 and B2, until one or the other of the two mentioned components can be completely excluded.

[0007] As can be seen, the membrane contactor CMC1 (dehumidifier) is placed in series with the heat exchanger B1 to treat the entire flow of the air entering the environment.

[0008] The two components CMC1 and B1, with reference to the circuit part of the low-pressure refrigerant (downstream of the lamination valve up to the compressor suction), are arranged in parallel so that the evaporation temperature of the refrigerating fluid in B1 and in CMC1 will be the same. With 3-way valves, the refrigerant flow can be appropriately distributed between CMC1 and B1 until either of the two components can be completely excluded. With reference to the high-pressure refrigerant circuit part (output from the compressor to the entrance of the lamination valve L), the two components CMC2 and B2 are still arranged in parallel with the same condensing temperature of the refrigerant. Through the other 3-way valves it is possible to adequately distribute the refrigerant flow between CMC2 and B2 up to completely exclude one or the other of the two components. The CMC2 and B2 components are crossed in parallel by external air.

[0009] As observed in the same prior art documents, this system architecture is of great interest for the air conditioning of electric vehicles in order to increase their autonomy by reducing the costly energy demands of the air conditioning system. This system, moreover, was the basis of the European XERIC funding application presented in the Horizon 2020, which was then funded with the title "Innovative Climate-control system to extend range of electric vehicles and improve comfort". In fact, the system allows achieving significant energy savings and being able to treat the air in the passenger compartment in different ways: in particular, it is possible to cool and to dehumidify it in the summer, only to dehumidify it in the intermediate seasons, while it can be heated in winter season operating as a heat pump in winter mode by the 4-way switching valve, which allows the direction of refrigerant flow to be reversed. In fact, it must be remembered that winter heating, if carried out with the direct use of electricity, greatly penalizes the autonomy (in this case the thermal energy is not available from the engine as in traditional vehicles). In case of the air conditioning of a car, hot air can be sent into the passenger compartment by inverting, through the 4-way switching valve (V), the circulation direction of the refrigerant fluid between the batteries B1 and B2 and closing by the 3-way valves the supply of refrigerant to CMC1 and CMC2. The inversion can be done automatically when required by the climatic conditions. In case of complete exclusion of the CMC, the system would work with the battery B2 operating as an evaporator and B1 as a condenser and

namely as a heat pump to supply hot air into the passenger compartment.

[0010] The problems encountered with this prior art system include three main limitations.

[0011] Firstly, the dehumidifying membrane contactor must be sized to handle the internal air flow to be introduced into the passenger compartment and can not be excluded from the air path during the winter season when only B1 must be operated (pressure drops on the CMC1 air side).

[0012] Secondly, in the summer regime it is necessary, both on the low pressure circuit part and on the high pressure part, to ensure the correct distribution of the refrigerant fluid between said supply parallel circuits between B1 and CMC1 and between B2 and CMC2 respectively, by partially and appropriately operating the 3-way valves assigned to this function. This output flow rates adjusting action requires the use of appropriate automatic activation devices for the 3-way valves controlled by suitable sensors: therefore this approach shows aspects of a certain complexity and cumbersome nature.

[0013] Thirdly, the air dehumidification action alone in the intermediate seasons does not provide for the possibility of carrying out a subsequent process of heating the air to be introduced into the passenger compartment.

Purpose and object of the invention

[0014] The object of the present invention is to provide an integrated high-efficiency air-conditioning system and an air-conditioning method, which at least partially solve the problems and overcomes the disadvantages of the prior art.

[0015] It is object of the present invention a system according to claim 1 and a method according to claim 2.

Detailed description of the embodiments of the invention

List of figures

[0016] The invention will now be described for illustrative but not limitative purposes, with particular reference to the drawings of the attached figures, in which:

- Figure 1 shows an integrated system according to the prior art for air conditioning with CMC1 (dehumidifier) and CMC2 (regenerator) in series and two traditional heat exchange batteries (B1 and B2) in parallel; the heat recovery HE is arranged between the CMC1 and the CMC2. VC represents the 4-way switching valve on the circuit of the batteries;
- Figure 2 shows a system scheme according to the new system architecture of the invention;
- Figure 3 shows the diagram of Figure 2 in a cooling and dehumidification configuration;
- Figure 4 shows the diagram of Figure 2 in a dehumidification only configuration;

- Figure 5 shows the diagram of Figure 2 in a heating and dehumidification configuration; and
- Figure 6 shows the diagram of Figure 2 in a heating only configuration.

[0017] It is here specified that elements of different embodiments may be combined together to provide further embodiments without limits with respect to the technical concept of the invention, as the person skilled in the art intends without problems with respect to what has been described.

[0018] The present description also refers to the prior art for its implementation, with regard to the detail characteristics not described, such as less important elements usually used in the prior art in solutions of the same type.

[0019] When an element is introduced, it always means that it can be "at least one" or "one or more".

[0020] When listing a list of elements or features in this description it is meant that the invention according to the invention "comprises" or alternatively "is composed of" such elements.

Embodiments

[0021] Referring to the diagram of Figure 2, according to the invention, the integrated system according to the invention is shown in its structure in order to show the possible paths, without specifying the possible paths of the cooling fluid. The possible paths of the cooling fluid are represented with a simple dashed line. The white dotted is used to represent the air paths, the dotted line the hot concentrated desiccant, and finally the dash-dot line the cold diluted desiccant.

[0022] Furthermore, the following references will be used in all the figures:

HE	Heat exchanger
3V	Three-way valve
ET	Expansion tank
ECEV	Electronic-Controlled Expansion Valve
RDO	Recycle Door
OA	Outside Air
3F-CMC	Three-Fluids Combined Membrane Contactor
4V	Four-way valve
COMP	Compressor
DO	Door
DEF	Defrost
VE	Vent
IA	Inside Air

[0023] The low pressure part (evaporation section) includes two refrigerant supply circuits to the evaporator HE1 and to the dehumidification contactor 3F-CMC1 still arranged in parallel. However, in this architecture, the refrigerant flow rate in the two parallel circuits is perfectly independently distributed, due to the presence of two

electronically controlled expansion valves ECEV₁ and ECEV₂, which ensure the output of both the first heat exchanger HE1 and the dehumidification contactor 3F-CMC1 the same thermodynamic condition (equal temperature of steam overheating).

[0024] When the regeneration contactor 3F-CMC2 and the second heat exchanger HE2/HE1 operate simultaneously in the high-pressure part (condensation section), they will operate in series, i.e. they will be traversed by the entire refrigerant flow rate exiting the compressor; this arrangement solves the problem of an adequate distribution of the refrigerant flow between the two high-pressure circuits which instead characterized the previous architecture.

[0025] In the figures from 3 to 6, the arrows indicating the flow directions of the fluids will be inserted, and with the simple dashed line that in Figure 2 indicates the possible paths of the thermal convector will indicate all those paths (regardless of the fluid) that are not used in the specific configuration. Furthermore, with the thicker solid line, the low pressure heat transfer fluid will be indicated and with the thinner solid line the high pressure heat transfer fluid.

[0026] The architecture schematized in the following figures may allow, by suitably actuating both the 4-way reversing valve (4V) and the other 3-way valve (3V), various control actions on the air to be introduced into the cabin. In particular, it is now possible associating the dehumidification action with a subsequent heating action for the intermediate seasons.

[0027] Electronic control means are provided for selectively opening and closing one or more ways of said first 3V₁, second 3V₂, third 3V₃ and fourth 3V₄ three-way valve, as well as of said 4-way valve 4V as well as opening and closing selectively said first ECEV1 and second ECEV2 electronically controlled expansion valve.

[0028] It can be observed that in the system architecture according to the invention the 3-way valves operate only in order to achieve a complete deviation of the entire flow rate along two alternative paths. There is no longer the need of a fine control of the partialization with the aim of correctly distributing the refrigerant flow rates on the two high pressure circuits.

[0029] The configuration of Figure 3 is a special configuration of the 3 and 4-way valves to achieve a combined cooling and dehumidification action (two parallel paths) by the system 1000.

[0030] In fact, both the heat exchangers HE1 and HE2 act, at the top in the figure to cool the cold air stream (since the cooling fluid evaporates at low temperature and pressure) and at the bottom always in the figure, to transfer to the external air the desuperheating and condensation heat (because the cooling fluid is desuperheat and condenses at higher temperatures and high pressure). The first contactor 3F-CMC1 dehumidifies the external air and cools the heat-carrying fluid, while the second contactor 3F-CMC2 regenerates the desiccant solution, transferring the water absorbed in the 3FR-CMC1

in the form of water vapor. The valves ECEV regulate the expansion of the cooling fluid, so as to be able to send the cooling fluid to the compressor in a slightly overheated steam condition.

[0031] In detail, the following configuration steps of the system according to the invention are performed to obtain cooling and dehumidification of the process air:

- A1. closing only one way of said first 3-way valve 3V₁ so that the passage of cooling fluid between said evaporator HE1 and said condenser HE2 is prevented;
- B1. closing only one way of said second 3-way valve 3V₂ so that the passage of cooling fluid directly between said four-way valve 4V to said third three-way valve 3V₃ is prevented;
- C1. closing only one way of said third three-way valve 3V₃ so that the passage of cooling fluid between said evaporator HE1 and said condenser HE2 is prevented;
- D1. closing only one way of said fourth 3-way valve 3V₄ so that the passage of cooling fluid between said evaporator HE1 and said condenser HE2 is prevented;
- E1. Opening said 4-way valve 4V so that as to allow the flow of the cooling fluid on one hand between said first 3-way valve 3V₁ and the inlet of said compressor COMP, and on the other hand between the outlet of said compressor COMP and said second three-way valve 3V₂; and
- F1. opening said first ECEV1 and said second expansion valve with electronic control ECEV₂;

[0032] The configuration of Figure 4 is a special configuration of the 3 and 4-way valves to obtain only a dehumidification action by the system 1000.

[0033] In fact, the first heat exchanger HE1 is not passed through by the refrigerant. The first contactor 3F-CMC1 dehumidifies and cools the process air, while the second contactor 3F-CMC2 regenerates the desiccant solution due to the previously mentioned mass exchange with the external air.

[0034] In detail, the following configuration steps of the system of the invention are performed to obtain only dehumidification of the process air:

- A2. closing all the ways of the first 3-ways valve 3V₁;
- B2. closing only one way of said second 3-way valve 3V₂ so that the direct passage of cooling fluid between said four-way valve 4V to said third three-way valve 3V₃ is prevented;
- C2. closing only one way of said third three-way valve 3V₃ so that the passage of cooling fluid between said evaporator HE1 and said condenser HE2 is prevented;
- D2. closing only one way of said fourth 3-way valve 3V₄ so that the passage of cooling fluid between said evaporator HE1 and said condenser HE2 is prevented;

ed;

E2. closing only two ways of said four-way valve 4V so that the passage of cooling fluid between said first 3-way valve 3V₁ and said compressor COMP is prevented, and opening the other two ways to allow the passage of cooling fluid between the outlet of said compressor COMP and said second contactor 3F-CMC2; and

F2. Closing said first ECEV1 and opening said second expansion valve with electronic control ECEV2;

[0035] The configuration of Figure 5 is a particular configuration of the 3 and 4-way valves for obtaining a heating and dehumidification action of the process air by the system 1000.

[0036] In fact, the first heat exchanger HE1 is now crossed by the cooling fluid which, by condensing, releases heat to the process air while the second exchanger HE2 is excluded. The first contactor 3F-CMC1 dehumidifies the external carrier air, while the second contactor 3F-CMC2 is always used to regenerate the desiccant solution.

[0037] In detail, the following configuration steps of the system according to the invention are carried out to obtain the heating and the dehumidification of the process air:

A3. closing only one way of said first 3-way valve 3V₁ so as to interrupt the flow of cooling fluid between said evaporator HE1 and the inlet of said compressor COMP;

B3. closing only one way of said second 3-way valve 3V₂ so that the passage of cooling fluid directly between said four-way valve 4V and said third three-way valve 3V₃ is prevented;

C3. closing only one way of said third three-way valve 3V₃ so that the passage of cooling fluid between said evaporator HE1 and said condenser HE2 is prevented;

D3. closing only one way of said fourth 3-way valve 3V₄ so that the passage of cooling fluid between said evaporator HE1 and said condenser HE2 is prevented;

E3. Closing two ways of said four-way valve 4V so that the passage of cooling fluid between said first 3-way valve 3V₁ and said compressor COMP is prevented and opening the other two ways to allow the passage of cooling fluid between the outlet of said compressor (COMP) and said second contactor (3F-CMC2); and

F3. Closing said first ECEV1 and opening said second expansion valve ECEV2 with electronic control; and alternatively in that the following fourth steps to obtain only process air heating are executed:

The configuration of Figure 6 is a special configuration of the 3 and 4-way valves to obtain a heating only action (traditional heat pump) by the system 1000.

[0038] In fact, the first heat exchanger HE1 is activated (with cooling fluid which is desuperheated and condensed inside). The two contactors 3F-CMC1 and 3F-CMC2 are excluded.

[0039] In detail, the following configuration steps of the system of the invention are performed to obtain only the process air heating:

A4. closing only one way of said first 3-way valve 3V₁ so that the flow of cooling fluid between said evaporator HE1 and said condenser HE2 is prevented;

B4. closing only one way of said second 3-way valve 3V₂ so that the passage of cooling fluid between the inlet of said compressor and said second contactor 3F-CMC2 is prevented;

C4. closing only one way of said third three-way valve 3V₃ so that the passage of cooling fluid between said evaporator HE1 and said condenser HE2 is prevented;

D4. closing only one way of said fourth 3-way valve 3V₄ so that the passage of cooling fluid between said evaporator HE1 and said condenser HE2 is prevented;

E4. Opening two ways of said four-way valve 4V so as to allow the passage of said cooling fluid between the outlet of said compressor COMP and said first three-way valve 3V₁ and the two other ways so as to allow the flow of the cooling fluid between the inlet of said compressor COMP and said second three-way valve 3V₂; and

F4. Opening said first ECEV₁ and closing said second ECEV2 expansion valve with electronic control.

Novelties with respect the prior art

[0040] The new integrated system architecture is of great interest for the air conditioning of electric vehicles. In fact it can operate as a hybrid in the summer/intermediate seasons regime and as a heat pump in the winter regime using the 4-way switching valve. In fact, it must be remembered that winter heating, if carried out with the direct use of electricity, penalizes considerably the autonomy (in this case thermal energy is not available from the engine as in traditional vehicles).

[0041] The difference with the prior art includes the fact of having two parallel circuits in the system. Due to this and to the valves, all the operating modes suitable for each season and condition can be realized with just one system.

[0042] The regulation action no longer requires any control device to guarantee the correct partialization of the refrigerant flow rates on the two parallel circuits, in fact now it will be sufficient only to open/close the appropriate three-way valves to achieve the complete deviation of the entire flow rate on two alternative paths.

[0043] Furthermore, the action of air dehumidification alone in the intermediate seasons can also be associated

with the heating process of the air to be introduced into the passenger compartment.

Advantages of the invention

[0044] The advantages of the invention are:

- a) in the air conditioning and dehumidification: energy saving;
- b) in the air conditioning sector of traditional vehicles: energy saving and the possibility to carry out air dehumidification only in the intermediate seasons (impossible with a traditional system);
- c) in case of electric vehicles: the energy saving referred to in point b) involves the added value related to a remarkable increase in vehicle autonomy, with the same passenger comfort;
- d) in the refrigeration sector: the energy saving of the system (with the reduction of ice formation on the air cooling coils) and the improvement of the quality of the foodstuffs (reduction/elimination of the defrosting cycles).

[0045] The system according to the invention in fact allows significant energy savings both during dehumidification and cooling typical of the summer and intermediate seasons and in the winter, when it can operate as a simple heat pump to introduce hot air into the environment.

[0046] Particularly interesting is its application for the air conditioning of electric vehicles in order to obtain significant increases in autonomy, with the same passenger comfort. In fact, in fully electric vehicles, it is not possible to exploit the thermal waste energy of the heat engine to supply hot air into the passenger compartment as in traditional vehicles.

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[0047]

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[0048] In the foregoing the preferred embodiments have been described and variants of the present invention have been suggested, but it is to be understood that those skilled in the art will be able to make modifications and changes without thereby falling out of the relative scope of protection, as defined by the claims attached.

Claims

1. Integrated air-conditioning system (1000), comprising:

- a first three-fluids membrane contactor (3F-CMC1) operating with air, cooling fluid and liquid desiccant fluid, as air conditioning and/or dehumidifying unit;
- a second three-fluids membrane contactor (3F-CMC2) operating with air, cooling fluid and liquid desiccant fluid, as regeneration unit for regeneration of said liquid desiccant fluid, connected to said first contactor (3F-CMC1);
- a compressor (COMP), connected to said first contactor (3F-CMC1), said compressor having a compressor inlet and outlet;
- a first heat exchanger (HE1) operable as an evaporator with two channels each being alternately evaporator inlet or outlet;
- a second heat exchanger (HE2) operable as a condenser having two channels each being alternately evaporator inlet or outlet;
- a 4-way switching valve (4V);
- four three-way valve (3V₁-3V₄);
- a first electronically controlled expansion valve (ECEV₁);

characterized in that:

- said compressor (COMP) is adapted to receive cooling fluid only from said air-conditioning and/or dehumidifying unit (3F-CMC1) through said compressor inlet;
 - said 4-way switching valve (4V) is configured to connect alternately and exclusively:

- the outlet and the inlet of said compressor (COMP) with each other;
- the inlet of said compressor (COMP) with said first three-way valve (3V₁) and the outlet of said compressor (COMP) with said second three-way valve (3V₂);
- the inlet of said compressor (COMP) with said second three-way valve (3V₂) and the outlet of said compressor (COMP) with said first three-way valve (3V₁);

- said second three-way valve (3V₂) is placed along one of said two first heat exchanger channels (HE1);
 - said first three-way valve (3V₁) is placed along one of said two first heat exchanger channels (HE1) and is configured to connect alternately:

- said first heat exchanger (HE1) with said four-way valve (4V);
- said first heat exchanger (HE1) with said third three-way valve (3V₃);

- said third three-way valve (3V₃) is configured to connect in an exclusive way:

- said second three-fluids membrane contactor (3F-CMC2) with said second heat exchanger (HE2); and/or
- said second three-fluids membrane contactor (3F-CMC2) with said 4-way valve (4V); or
- said second heat exchanger (HE2) with said 4-way valve (4V);

wherein said system (1000) further comprises

- said first (ECEV₁) and a second expansion valve with electronic control (ECEV₂) connectable in cascade between said first heat exchanger (HE1) and said first three-fluids membrane contactor (3F-CMC1);

- said fourth three-way valve (3V₄) configured to connect alternately and exclusively:

- said second heat exchanger (HE2) to a node between said first (ECEV₁) and said second (ECEV₂) expansion valve with electronic control;
- said first heat exchanger (HE1) to said node between said first (ECEV₁) and said

second (ECEV₂) expansion valve with electronic control;

- an electronic control means to open and close selectively one or more ways of said first (3V₁), second (3V₂), third (3V₃) and fourth (3V₄) three-way valve, said 4-way valve (4V) as well as to open and close selectively said first (ECEV₁) and second (ECEV₂) expansion valve with electronic control.

2. Method for air conditioning **characterized**

in that the system (1000) according to claim 1 is provided and

in that the following first steps to obtain process air cooling and dehumidification are performed:

A1. closing only one way of said first 3-way valve (3V₁) so that the passage of cooling fluid between said evaporator (HE1) and said condenser (HE2) is prevented;

B1. closing only one way of said second 3-way valve (3V₂) so that the passage of cooling fluid directly between said four-way valve (4V) to said third three-way valve (3V₃) is prevented;

C1. closing only one way of said third three-way valve (3V₃) so that the passage of cooling fluid between said evaporator (HE1) and said condenser (HE2) is prevented;

D1. closing only one way of said fourth 3-way valve (3V₄) so that the passage of cooling fluid between said evaporator (HE1) and said condenser (HE2) is prevented;

E1. Opening said 4-way valve (4V) so that as to allow the flow of the cooling fluid on one hand between said first 3-way valve (3V₁) and the inlet of said compressor (COMP), and on the other hand between the outlet of said compressor (COMP) and said second three-way valve (3V₂); and

F1. opening said first (ECEV₁) and said second expansion valve with electronic control (ECEV₂);

and alternatively in that the following second steps to obtain only process air dehumidification are executed:

A2. closing all the ways of the first 3-ways valve (3V₁);

B2. closing only one way of said second 3-way valve (3V₂) so that the direct passage of cooling fluid between said four-way valve (4V) to said third three-way valve (3V₃) is prevented;

C2. closing only one way of said third three-way valve (3V₃) so that the passage of cooling fluid between said evaporator (HE1) and said condenser (HE2) is prevented;

D2. closing only one way of said fourth 3-way valve (3V₄) so that the passage of cooling fluid between said evaporator (HE1) and said condenser (HE2) is prevented;

E2. closing only two ways of said four-way valve (4V) so that the passage of cooling fluid between said first 3-way valve (3V₁) and said compressor (COMP) is prevented, and opening the other two ways to allow the passage of cooling fluid between the outlet of said compressor (COMP) and said second contactor (3F-CMC2); and
F2. Closing said first (ECEV1) and opening said second expansion valve with electronic control (ECEV2);

and alternatively in that the following third steps to achieve process air heating and dehumidification are executed:

A3. closing only one way of said first 3-way valve (3V₁) so as to interrupt the flow of cooling fluid between said evaporator (HE1) and the inlet of said compressor (COMP);

B3. closing only one way of said second 3-way valve (3V₂) so that the passage of cooling fluid directly between said four-way valve (4V) and said third three-way valve (3V₃) is prevented;

C3. closing only one way of said third three-way valve (3V₃) so that the passage of cooling fluid between said evaporator (HE1) and said condenser (HE2) is prevented;

D3. closing only one way of said fourth 3-way valve (3V₄) so that the passage of cooling fluid between said evaporator (HE1) and said condenser (HE2) is prevented;

E3. Closing two ways of said four-way valve (4V) so that the passage of cooling fluid between said first 3-way valve (3V₁) and said compressor (COMP) is prevented and opening the other two ways to allow the passage of cooling fluid between the outlet of said compressor (COMP) and said second contactor (3F-CMC2); and

F3. Closing said first (ECEV1) and opening said second expansion valve (ECEV2) with electronic control; and alternatively in that the following fourth steps to obtain only process air heating are executed:

A4. closing only one way of said first 3-way valve (3V₁) so that the flow of cooling fluid between said evaporator (HE1) and said condenser (HE2) is prevented;

B4. closing only one way of said second 3-way valve (3V₂) so that the passage of cooling fluid between the inlet of said compressor and said second contactor (3F-CMC2) is prevented;

C4. closing only one way of said third three-

way valve (3V₃) so that the passage of cooling fluid between said evaporator (HE1) and said condenser (HE2) is prevented;

D4. closing only one way of said fourth 3-way valve (3V₄) so that the passage of cooling fluid between said evaporator (HE1) and said condenser (HE2) is prevented;

E4. Opening two ways of said four-way valve (4V) so as to allow the passage of said cooling fluid between the outlet of said compressor (COMP) and said first three-way valve (3V₁) and the two other ways so as to allow the flow of the cooling fluid between the inlet of said compressor (COMP) and said second three-way valve (3V₂); and

F4. Opening said first (ECEV1) and closing said second (ECEV2) expansion valve with electronic control.

Patentansprüche

1. Integriertes Klimatisierungssystem (1000), umfassend:

- einen ersten Drei-Fluid-Membrankontaktor (3F-CMC1), der mit Luft, Kühlfluid und flüssigem Trockenmittelfluid als Klimatisierungs- und/oder Entfeuchtungseinheit arbeitet;
- einen zweiten Drei-Fluid-Membrankontaktor (3F-CMC2), der mit Luft, Kühlfluid und flüssigem Trockenmittelfluid als Regenerationseinheit zur Regeneration des flüssigen Trockenmittelfluids arbeitet, der mit dem ersten Kontaktor (3F-CMC1) verbunden ist;
- einen Kompressor (COMP), der mit dem ersten Kontaktor (3F-CMC1) verbunden ist, wobei der Kompressor einen Kompressoreinlass und -auslass aufweist;
- einen ersten Wärmetauscher (HE1), der als Verdampfer betreibbar ist, mit zwei Kanälen, die jeweils abwechselnd ein Verdampfereinlass oder -auslass sind;
- einen zweiten Wärmetauscher (HE2), der als Kondensator betreibbar ist und zwei Kanäle aufweist, die jeweils abwechselnd ein Verdampfereinlass oder -auslass sind;
- ein 4-Wege-Umschaltventil (4V);
- vier Dreiwegeventile (3V₁-3V₄);
- ein erstes elektronisch gesteuertes Expansionsventil (ECEV₁);

dadurch gekennzeichnet, dass:

- der Kompressor (COMP) angepasst ist, um Kühlfluid nur von der Klimatisierungs- und/oder Entfeuchtungseinheit (3F-CMC1) durch den Kompressoreinlass aufzunehmen;

- das 4-Wege-Umschaltventil (4V) konfiguriert ist, um abwechselnd und ausschließlich Folgendes zu verbinden:

- den Auslass und den Einlass des Kompressors (COMP) miteinander; 5
- den Einlass des Kompressors (COMP) mit dem ersten Dreiwegeventil (3V₁) und den Auslass des Kompressors (COMP) mit dem zweiten Dreiwegeventil (3V₂); 10
- den Einlass des Kompressors (COMP) mit dem zweiten Dreiwegeventil (3V₂) und den Auslass des Kompressors (COMP) mit dem ersten Dreiwegeventil (3V₁);

- wobei das zweite Dreiwegeventil (3V₂) entlang eines der beiden ersten Wärmetauscherkanäle (HE1) angeordnet ist;

- wobei das erste Dreiwegeventil (3V₁) entlang eines der beiden ersten Wärmetauscherkanäle (HE1) angeordnet und konfiguriert ist, um abwechselnd Folgendes zu verbinden:

- den ersten Wärmetauscher (HE1) mit dem Vierwegeventil (4V); 25
- den ersten Wärmetauscher (HE1) mit dem dritten Dreiwegeventil (3V₃);

- wobei das dritte Dreiwegeventil (3V₃) konfiguriert ist, um auf ausschließliche Weise Folgendes zu verbinden: 30

- den zweiten Drei-Fluid-Membrankontaktor (3F-CMC2) mit dem zweiten Wärmetauscher (HE2); und/oder 35
- den zweiten Drei-Fluid-Membrankontaktor (3F-CMC2) mit dem 4-Wegeventil (4V); oder
- den zweiten Wärmetauscher (HE2) mit dem 4-Wegeventil (4V); 40

wobei das System (1000) weiter umfasst:

- das erste (ECEV₁) und ein zweites Expansionsventil mit elektronischer Steuerung (ECEV₂), die in Kaskadenschaltung zwischen dem ersten Wärmetauscher (HE1) und dem ersten Drei-Fluid-Membrankontaktor (3F-CMC1) verbindbar sind; 45

- wobei das vierte Dreiwegeventil (3V₄) konfiguriert ist, um abwechselnd und ausschließlich Folgendes zu verbinden: 50

- den zweiten Wärmetauscher (HE2) mit einem Knoten zwischen dem ersten (ECEV₁) und dem zweiten (ECEV₂) Expansionsventil mit elektronischer Steuerung; 55
- den ersten Wärmetauscher (HE1) mit ei-

nem Knoten zwischen dem ersten (ECEV₁) und dem zweiten (ECEV₂) Expansionsventil mit elektronischer Steuerung;

- ein elektronisches Steuermittel zum selektiven Öffnen und Schließen einer oder mehrerer Wege des ersten (3V₁), zweiten (3V₂), dritten (3V₃) und vierten (3V₄) Dreiwegeventils, des 4-Wegeventils (4V), sowie zum selektiven Öffnen und Schließen des ersten (ECEV₁) und zweiten (ECEV₂) Expansionsventils mit elektronischer Steuerung.

2. Verfahren zur Klimatisierung, **dadurch gekennzeichnet,**

dass das System (1000) nach Anspruch 1 bereitgestellt ist und

dass die folgenden ersten Schritte zum Erhalten der Prozessluftkühlung und -entfeuchtung durchgeführt werden:

A1. Schließen nur eines Weges des ersten 3-Wegeventils (3V₁), so dass der Durchgang von Kühlfluid zwischen dem Verdampfer (HE1) und dem Kondensator (HE2) verhindert wird;

B1. Schließen nur eines Weges des zweiten 3-Wegeventils (3V₂), so dass der Durchgang von Kühlfluid direkt zwischen dem Vierwegeventil (4V) und dem dritten Dreiwegeventil (3V₃) verhindert wird;

C1. Schließen nur eines Weges des dritten Dreiwegeventils (3V₃), so dass der Durchgang von Kühlfluid zwischen dem Verdampfer (HE1) und dem Kondensator (HE2) verhindert wird;

D1. Schließen nur eines Weges des vierten 3-Wegeventils (3V₄), so dass der Durchgang von Kühlfluid zwischen dem Verdampfer (HE1) und dem Kondensator (HE2) verhindert wird;

E1. Öffnen des 4-Wege-Ventils (4V), um den Strom des Kühlfluids einerseits zwischen dem ersten 3-Wege-Ventil (3V₁) und dem Einlass des Kompressors (COMP) und andererseits zwischen dem Auslass des Kompressors (COMP) und dem zweiten Dreiwegeventil (3V₂) zu ermöglichen; und

F1. Öffnen des ersten (ECEV₁) und des zweiten Expansionsventils mit elektronischer Steuerung (ECEV₂);

und alternativ dadurch, dass die folgenden zweiten Schritte durchgeführt werden, um nur die Prozessluftentfeuchtung zu erhalten:

A2. Schließen aller Wege des ersten 3-Wegeventils (3V₁);

B2. Schließen nur eines Weges des zweiten 3-Wegeventils (3V₂), so dass der direkte Durchgang von Kühlfluid zwischen dem Vierwegeven-

til (4V) und dem dritten Dreiwegeventil (3V₃) verhindert wird;

C2. Schließen nur eines Weges des dritten Dreiwegeventils (3V₃), so dass der Durchgang von Kühlfluid zwischen dem Verdampfer (HE1) und dem Kondensator (HE2) verhindert wird;

D2. Schließen nur eines Weges des vierten 3-Wegeventils (3V₄), so dass der Durchgang von Kühlfluid zwischen dem Verdampfer (HE1) und dem Kondensator (HE2) verhindert wird;

E2. Schließen nur zweier Wege des Vierwegeventils (4V), so dass der Durchgang von Kühlfluid zwischen dem ersten Dreiwegeventil (3V₁) und dem Kompressor (COMP) verhindert wird, und Öffnen der beiden anderen Wege, um den Durchgang von Kühlfluid zwischen dem Ausgang des Kompressors (COMP) und dem zweiten Kontaktor (3F-CMC2) zu ermöglichen; und F2. Schließen des ersten (ECEV1) und Öffnen des zweiten Expansionsventils mit elektronischer Steuerung (ECEV2);

und alternativ dadurch, dass die folgenden dritten Schritte zum Erreichen der Prozesslufteerwärmung und -entfeuchtung durchgeführt werden:

A3. Schließen nur eines Weges des ersten 3-Wege-Ventils (3V₁), um den Strom von Kühlfluid zwischen dem Verdampfer (HE1) und dem Einlass des Kompressors (COMP) zu unterbrechen;

B3. Schließen nur eines Weges des zweiten 3-Wegeventils (3V₂), so dass der Durchgang von Kühlfluid direkt zwischen dem Vierwegeventil (4V) und dem dritten Dreiwegeventil (3V₃) verhindert wird;

C3. Schließen nur eines Weges des dritten Dreiwegeventils (3V₃), so dass der Durchgang von Kühlfluid zwischen dem Verdampfer (HE1) und dem Kondensator (HE2) verhindert wird;

D3. Schließen nur eines Weges des vierten 3-Wegeventils (3V₄), so dass der Durchgang von Kühlfluid zwischen dem Verdampfer (HE1) und dem Kondensator (HE2) verhindert wird;

E3. Schließen nur zweier Wege des Vierwegeventils (4V), so dass der Durchgang von Kühlfluid zwischen dem ersten 3-Wegeventil (3V₁) und dem Kompressor (COMP) verhindert wird, und Öffnen der beiden anderen Wege, um den Durchgang von Kühlfluid zwischen dem Ausgang des Kompressors (COMP) und dem zweiten Kontaktor (3F-CMC2) zu ermöglichen; und F3. Schließen des ersten (ECEV1) und Öffnen des zweiten Expansionsventils (ECEV2) mit elektronischer Steuerung; und alternativ dadurch, dass die folgenden vierten Schritte durchgeführt werden, um nur die Prozesslufteerwärmung zu erhalten:

A4. Schließen nur eines Weges des ersten 3-Wegeventils (3V₁), so dass der Strom von Kühlfluid zwischen dem Verdampfer (HE1) und dem Kondensator (HE2) verhindert wird;

B4. Schließen nur eines Weges des zweiten 3-Wegeventils (3V₂), so dass der Durchgang von Kühlfluid zwischen dem Einlass des Kompressors und dem zweiten Kontaktor (3F-CMC2) verhindert wird;

C4. Schließen nur eines Weges des dritten Dreiwegeventils (3V₃), so dass der Durchgang von Kühlfluid zwischen dem Verdampfer (HE1) und dem Kondensator (HE2) verhindert wird;

D4. Schließen nur eines Weges des vierten 3-Wegeventils (3V₄), so dass der Durchgang von Kühlfluid zwischen dem Verdampfer (HE1) und dem Kondensator (HE2) verhindert wird;

E4. Öffnen von zwei Wegen des Vierwegeventils (4V), um den Durchgang des Kühlfluids zwischen dem Ausgang des Kompressors (COMP) und dem ersten Dreiwegeventil (3V₁) und den beiden anderen Wegen zu ermöglichen, um den Strom des Kühlfluids zwischen dem Einlass des Kompressors (COMP) und dem zweiten Dreiwegeventil (3V₂) zu ermöglichen; und F4. Öffnen des ersten (ECEV1) und Schließen des zweiten (ECEV2) Expansionsventils mit elektronischer Steuerung.

Revendications

1. Système de climatisation intégré (1000) comprenant :

- un premier contacteur de membrane à trois fluides (3F-CMC1) fonctionnant avec de l'air, du fluide de refroidissement et du fluide dessiccateur liquide, comme une unité de climatisation et/ou de déshumidification ;
- un second contacteur de membrane à trois fluides (3F-CMC2) fonctionnant avec de l'air, du fluide de refroidissement et du fluide dessiccateur liquide, comme une unité de régénération pour la régénération dudit fluide dessiccateur liquide, raccordé audit premier contacteur (3F-CMC1) ;
- un compresseur (COMP) raccordé audit premier contacteur (3F-CMC1), ledit compresseur présentant une entrée et sortie de compresseur ;
- un premier échangeur de chaleur (HE1) actionnable comme un évaporateur avec deux canaux qui sont chacun en alternance une entrée

ou sortie d'évaporateur ;
 - un second échangeur de chaleur (HE2) actionnable comme un condensateur présentant deux canaux qui sont chacun en alternance une entrée ou sortie d'évaporateur ; 5
 - une soupape de commutation à quatre voies (4V) ;
 - quatre soupapes à trois voies ($3V_1$ - $3V_4$) ;
 - une première soupape de détente à commande électronique (ECEV₁) ; 10

caractérisé en ce que :

- ledit compresseur (COMP) est adapté pour recevoir du fluide de refroidissement seulement de ladite unité de climatisation et/ou de déshumidification (3F-CMC1) au travers de ladite entrée de compresseur ; 15
 - ladite soupape de commutation à quatre voies (4V) est configurée pour raccorder en alternance et exclusivement : 20

la sortie et l'entrée dudit compresseur (COMP) l'une à l'autre ;
 l'entrée dudit compresseur (COMP) avec ladite première soupape à trois voies ($3V_1$) et la sortie dudit compresseur (COMP) avec ladite deuxième soupape à trois voies ($3V_2$) ; 25
 l'entrée dudit compresseur (COMP) avec ladite deuxième soupape à trois voies ($3V_2$) et la sortie dudit compresseur (COMP) avec ladite première soupape à trois voies ($3V_1$) ; 30

- ladite deuxième soupape à trois soupapes ($3V_2$) est placée le long d'un des dits deux premiers canaux d'échangeur de chaleur (HE1) ; 35
 - ladite première soupape à trois voies ($3V_1$) est placée le long d'un desdits deux premiers canaux d'échangeur de chaleur (HE1) et est configurée pour raccorder en alternance : 40

ledit premier échangeur de chaleur (HE1) avec ladite soupape à quatre voies (4V) ;
 ledit premier échangeur de chaleur (HE1) avec ladite troisième soupapes à trois voies ($3V_3$) ; 45

- ladite troisième soupape à trois voies ($3V_3$) est configurée pour raccorder de manière exclusive : 50

ledit second contacteur de membrane à trois fluides (3F-CMC2) avec ledit second échangeur de chaleur (HE2) ; et/ou 55
 ledit second contacteur de membrane à trois fluides (3F-CMC2) avec ladite soupape à quatre voies (4V) ; ou

ledit second échangeur de chaleur (HE2) avec ladite soupape à quatre voies (4V) ; dans lequel ledit système (1000) comprend en outre

- ladite première (ECEV₁) et une seconde soupape de détente avec une commande électronique (ECEV2) raccordables en cascade entre ledit premier échangeur de chaleur (HE1) et ledit premier contact de membrane à trois fluides (3F-CMC1) ;
 - ladite quatrième soupape à trois voies ($3V_4$) configurée pour raccorder en alternance et exclusivement :

ledit second échangeur de chaleur (HE2) avec un noeud entre ladite première (ECEV₁) et ladite seconde (ECEV2) soupape de détente avec commande électronique ;
 ledit premier échangeur de chaleur (HE1) avec ledit noeud entre ladite première (ECEV₁) et ladite seconde (ECEV2) soupape de détente avec commande électronique ;

- un moyen de commande électronique pour ouvrir et fermer sélectivement une ou plusieurs voies desdites première ($3V_1$), deuxième ($3V_1$), troisième ($3V_3$) et quatrième ($3V_4$) soupapes à trois voies, ladite soupape à quatre voies (4V) ainsi que pour ouvrir et fermer sélectivement lesdites première (ECEV₁) et seconde (ECEV2) soupape de détente avec commande électronique.

2. Procédé de climatisation, caractérisé

en ce que le système (1000) selon la revendication 1 est prévu et

en ce que les premières étapes suivantes pour obtenir le refroidissement et la déshumidification d'air de processus sont réalisées :

A1. la fermeture d'une seule voie de ladite première soupape à trois voies ($3V_1$) de sorte que le passage du fluide de refroidissement entre ledit évaporateur (HE1) et ledit condensateur (HE2) soit empêché ;

B1. la fermeture d'une seule voie de ladite deuxième soupape à trois voies ($3V_2$) de sorte que le passage du fluide de refroidissement directement entre ladite soupape à quatre voies (4V) à ladite troisième soupape à trois voies ($3V_3$) soit empêché ;

C1. la fermeture d'une seule voie de ladite troisième soupape à trois voies ($3V_3$) de sorte que le passage du fluide de refroidissement entre ledit évaporateur (HE1) et ledit condensateur

(HE2) soit empêché ;

D1. la fermeture d'une seule voie de ladite quatrième soupape à trois voies (3V₄) de sorte que le passage du fluide de refroidissement entre ledit évaporateur (HE1) et ledit condensateur (HE2) soit empêché ; 5

E1. l'ouverture de ladite soupape à quatre voies (4V) de sorte à permettre le flux du fluide de refroidissement d'une part entre ladite première soupape à trois voies (3V₁) et l'entrée dudit compresseur (COMP), et d'autre part entre la sortie dudit compresseur (COMP) et ladite deuxième soupape à trois voies (3V₂) ; et 10

F1. l'ouverture de ladite première (ECEV1) et de ladite seconde soupape de détente avec commande électronique (ECEV2) ; 15

et en alternance en ce que les secondes étapes suivantes pour obtenir seulement la déshumidification d'air de processus sont exécutées : 20

A2. la fermeture de toutes les voies de la première soupape à trois voies (3V₁) ;

B2. la fermeture d'une seule voie de ladite deuxième soupape à trois voies (3V₂) de sorte que le passage direct du fluide de refroidissement entre ladite soupape à quatre voies (4V) à ladite troisième soupape à trois voies (3V₃) soit empêché ; 25

C2. la fermeture d'une seule voie de ladite troisième soupape à trois voies (3V₃) de sorte que le passage du fluide de refroidissement entre ledit évaporateur (HE1) et ledit condensateur (HE2) soit empêché ; 30

D2. la fermeture d'une seule voie de ladite quatrième soupape à trois voies (3V₄) de sorte que le passage du fluide de refroidissement entre ledit évaporateur (HE1) et ledit condensateur (HE2) soit empêché ; 35

E2. la fermeture seulement de deux voies de ladite soupape à quatre voies (4V) de sorte que le passage du fluide de refroidissement entre ladite première soupape à trois voies (3V₁) et ledit compresseur (COMP) soit empêché, et l'ouverture des deux autres voies pour permettre le passage du fluide de refroidissement entre la sortie dudit compresseur (COMP) et ledit second contacteur (3F-CMC2) ; et 40

F2. la fermeture de ladite première (ECEV1) et l'ouverture de ladite seconde soupape de détente avec commande électronique (ECEV2) ; 45

et en alternance en ce que les troisièmes étapes suivantes pour atteindre le chauffage et la déshumidification d'air de processus sont exécutées : 50

A3. la fermeture d'une seule voie de ladite première soupape à trois voies (3V₁) de sorte à

interrompre le flux du fluide de refroidissement entre ledit évaporateur (HE1) et l'entrée dudit compresseur (COMP) ;

B3. la fermeture d'une seule voie de ladite deuxième soupape à trois voies (3V₂) de sorte que le passage du fluide de refroidissement directement entre ladite soupape à quatre voies (4V) et ladite troisième soupape à trois voies (3V₃) soit empêché ;

C3. la fermeture d'une seule voie de ladite troisième soupape à trois voies (3V₃) de sorte que le passage du fluide de refroidissement entre ledit évaporateur (HE1) et ledit condensateur (HE2) soit empêché ;

D3. la fermeture d'une seule voie de ladite quatrième soupape à trois voies (3V₄) de sorte que le passage du fluide de refroidissement entre ledit évaporateur (HE1) et ledit condensateur (HE2) soit empêché ;

E3. la fermeture de deux voies de ladite soupape à quatre voies (4V) de sorte que le passage du fluide de refroidissement entre ladite première soupape à trois voies (3V₁) et ledit compresseur (COMP) soit empêché et l'ouverture des autres deux voies pour permettre le passage du fluide de refroidissement entre la sortie dudit compresseur (COMP) et ledit second contacteur (3F-CMC2) ; et

F3. la fermeture de ladite première (ECEV1) et l'ouverture de ladite seconde soupape de détente (ECEV2) avec commande électronique ; et en alternance en ce que les quatre étapes suivantes pour obtenir le chauffage de l'air de processus sont exécutées :

A4. la fermeture d'une seule voie de ladite première soupape à trois voies (3V₁) de sorte que le flux du fluide de refroidissement entre ledit évaporateur (HE1) et ledit condensateur (HE2) soit empêché ;

B4. la fermeture d'une seule voie de ladite deuxième soupape à trois voies (3V₂) de sorte que le passage du fluide de refroidissement entre l'entrée dudit compresseur et ledit second contacteur (3F-CMC2) soit empêché ;

C4. la fermeture d'une seule voie de ladite troisième soupape à trois voies (3V₃) de sorte que le passage du fluide de refroidissement entre ledit évaporateur (HE1) et ledit condensateur (HE2) soit empêché ;

D4. la fermeture d'une seule voie de ladite quatrième soupape à trois voies (3V₄) de sorte que le passage du fluide de refroidissement entre ledit évaporateur (HE1) et ledit condensateur (HE2) soit empêché ;

E4. l'ouverture de deux voies de ladite soupape à quatre voies (4V) de sorte à permet-

tre le passage dudit fluide de refroidissement d'une part entre la sortie dudit compresseur (COMP) et ladite première soupape à trois voies ($3V_1$) et les deux autres voies de sorte à permettre le flux du fluide de refroidissement entre l'entrée dudit compresseur (COMP) et ladite deuxième soupape à trois voies ($3V_2$) ; et

F4. l'ouverture de ladite première (ECEV1) et la fermeture de ladite seconde (ECEV2) soupape de détente avec commande électronique.

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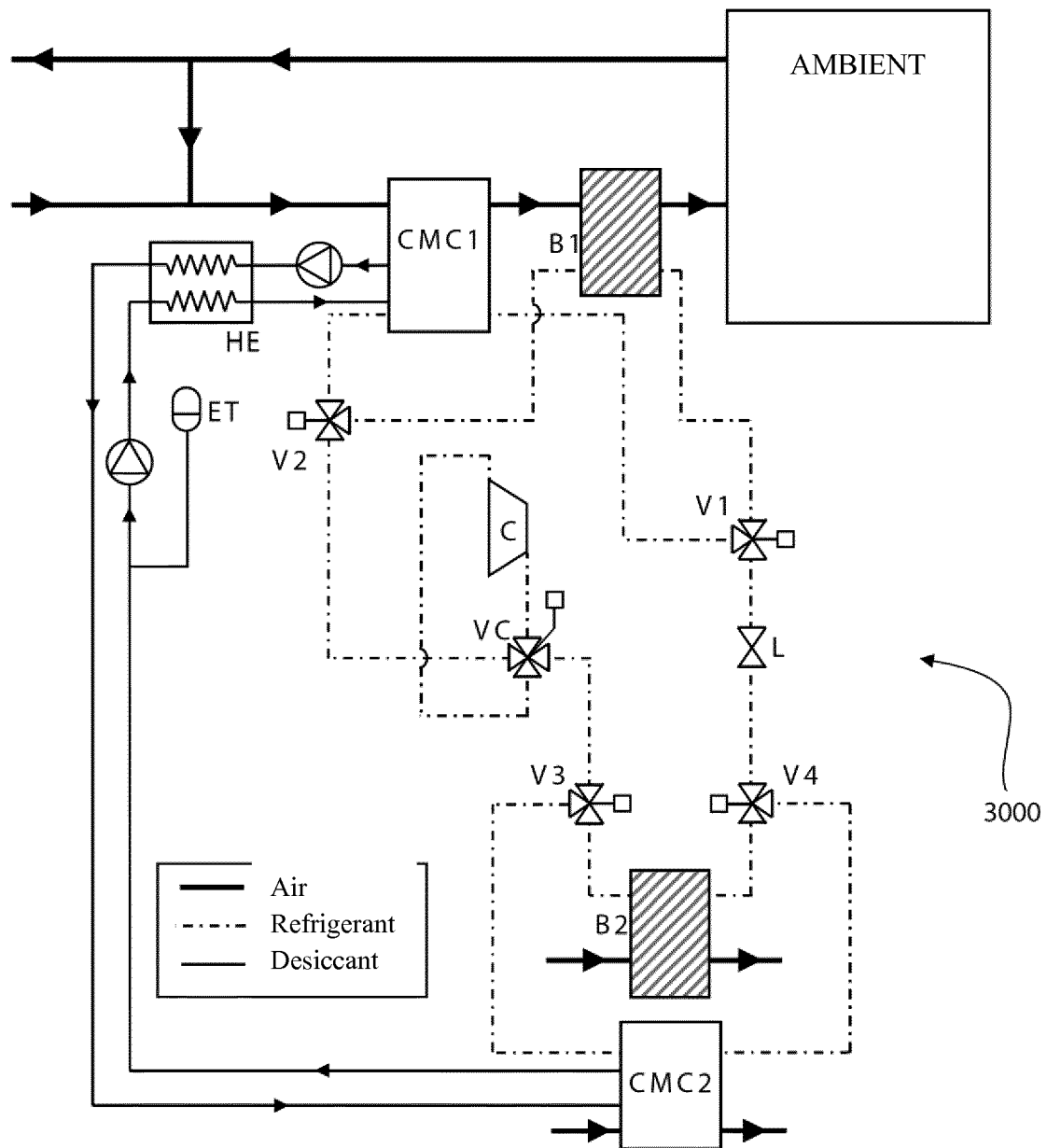
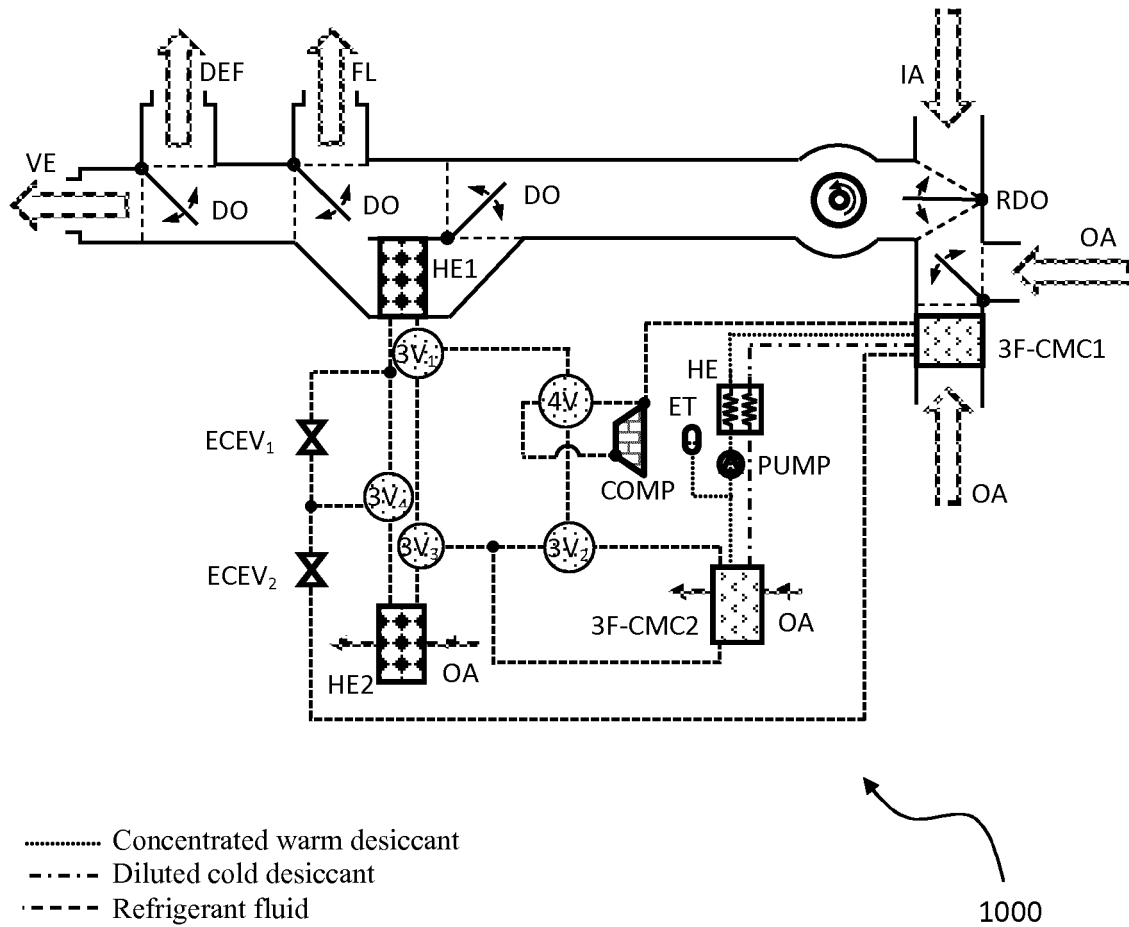
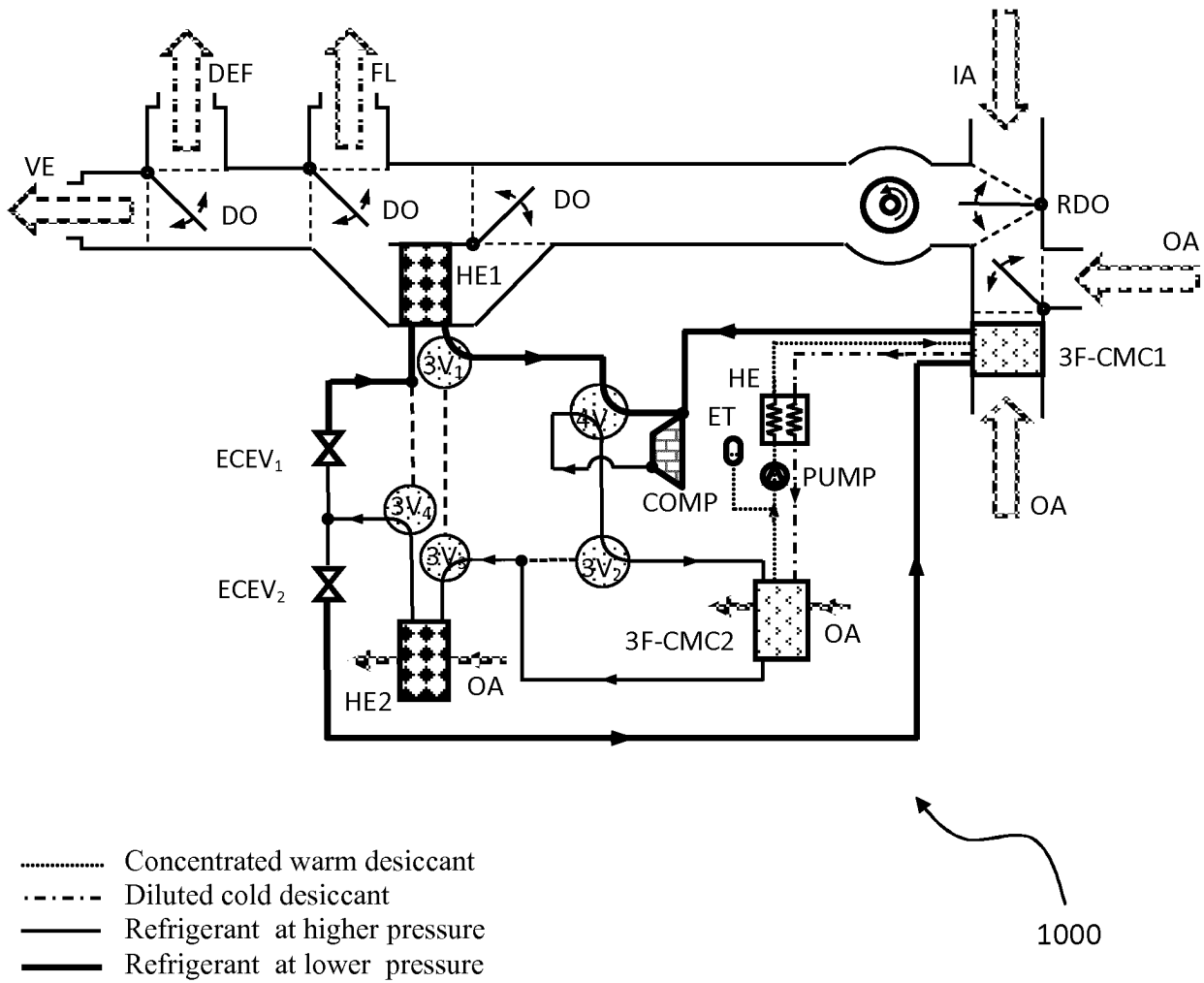


Fig. 1



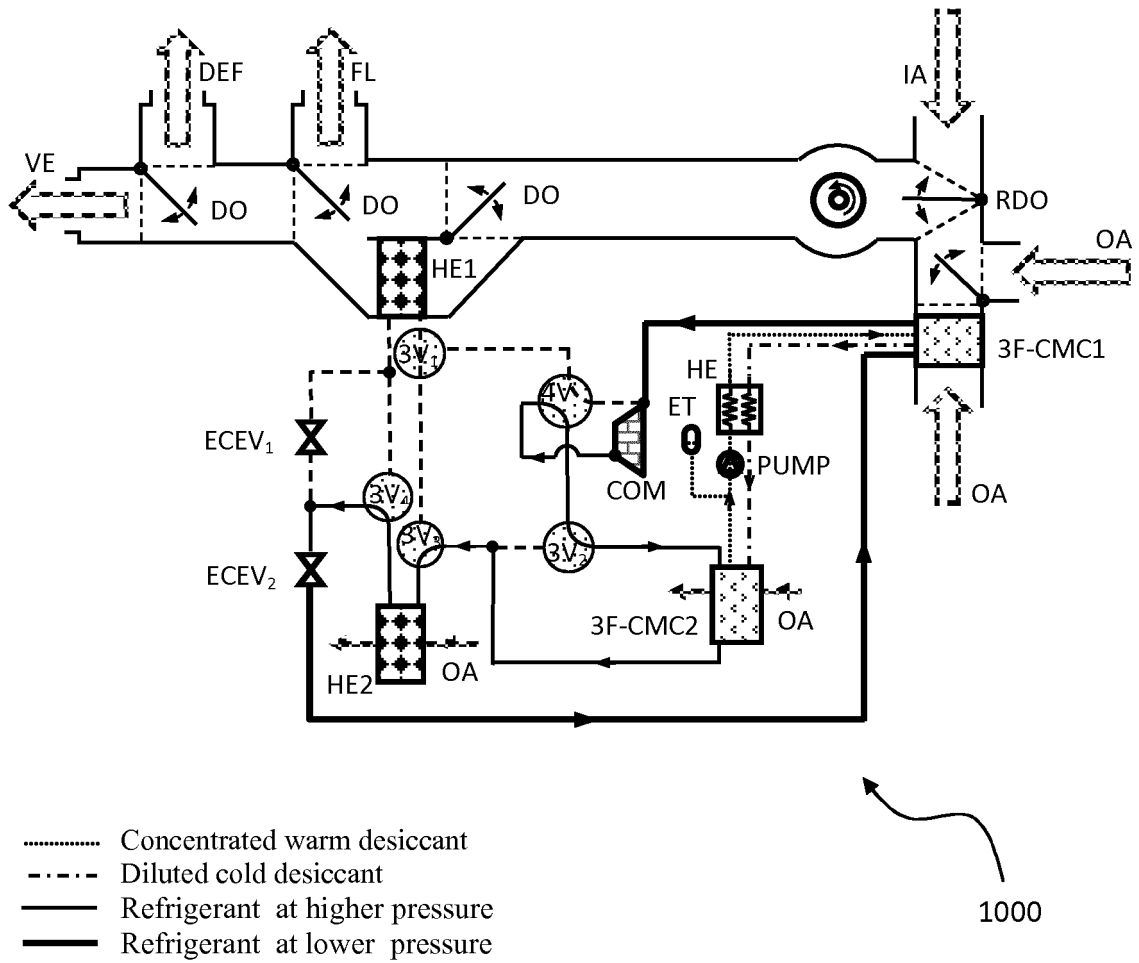
HE	Heat exchanger
3F-CMC	Three-fluids combined membrane contactor
3V	Three-way valve
4V	Four-way valve
ET	Expansion tank
COMP	Compressor
ECEV	Electronic-controlled expansion valve
DO	Door
RDO	Recycle Door
DEF	Defrost
OA	Outside Air
VE	Vent
FL	Floor
IA	Inside Air

Fig. 2



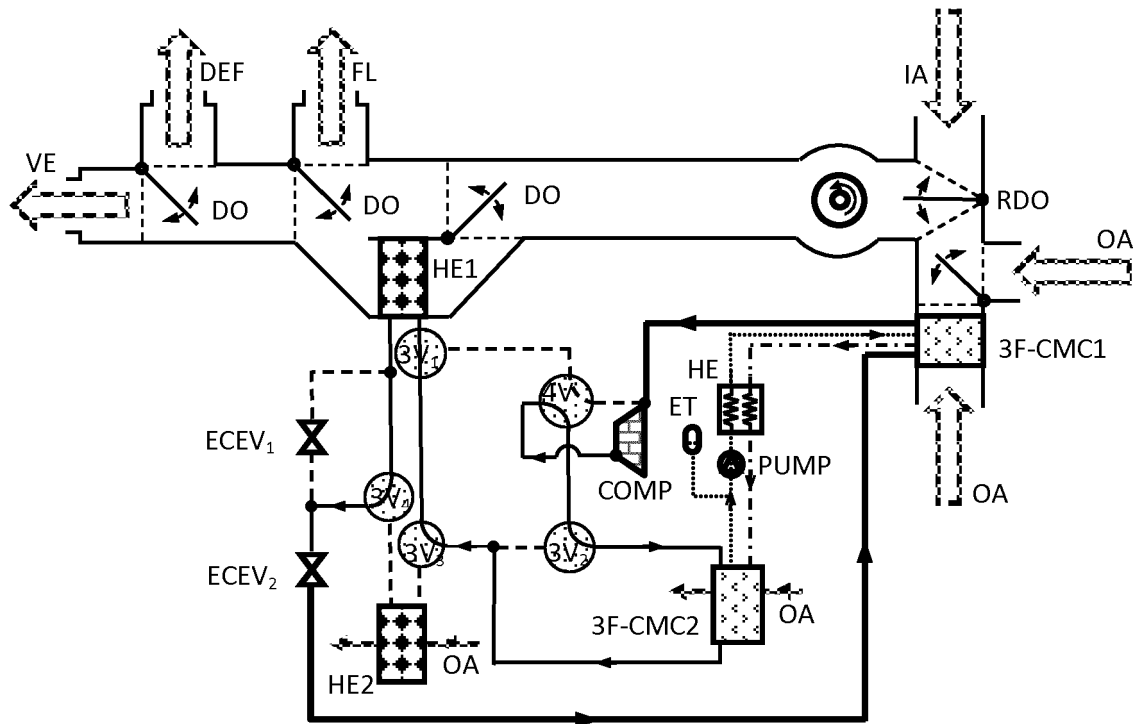
HE	Heat exchanger
3F-CMC	Three-fluids combined membrane contactor
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ECEV	Electronic-controlled expansion valve
DO	Door
RDO	Recycle Door
DEF	Defrost
OA	Outside Air
VE	Vent
FL	Floor
IA	Inside Air
OA	Outside Air

Fig. 3



HE	Heat exchanger
3F-CMC	Three-fluids combined membrane contactor
3V	Three-way valve
4V	Four-way valve
ET	Expansion tank
COMP	Compressor
ECEV	Electronic-controlled expansion valve
DO	Door
RDO	Recycle Door
DEF	Defrost
OA	Outside Air
VE	Vent
FL	Floor
IA	Inside Air
OA	Outside Air

Fig. 4

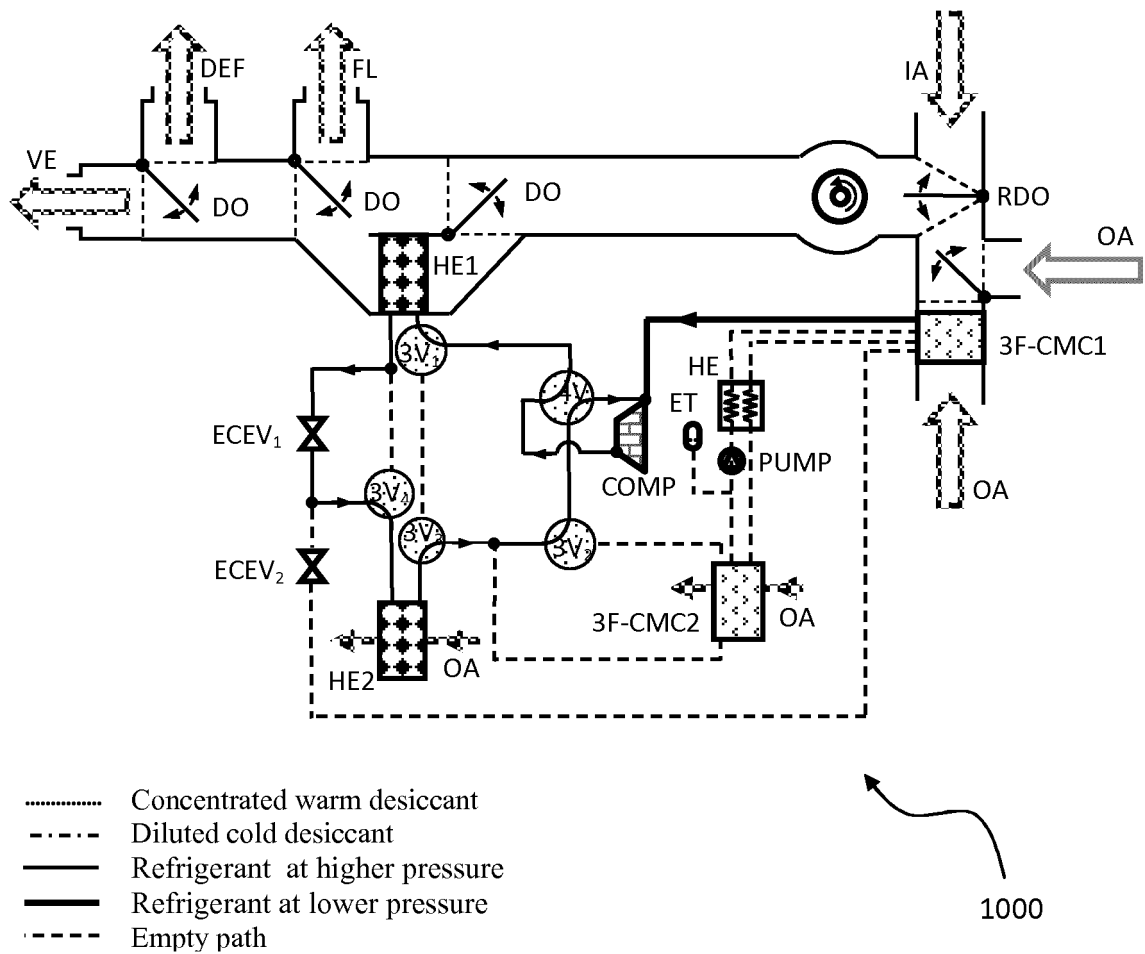


..... Concentrated warm desiccant
 - . - . - Diluted cold desiccant
 — Refrigerant at higher pressure
 — Refrigerant at lower pressure
 - - - - - Empty path

1000

HE	Heat exchanger
3F-CMC	Three-fluids combined membrane contactor
3V	Three-way valve
4V	Four-way valve
ET	Expansion tank
COMP	Compressor
ECEV	Electronic-controlled expansion valve
DO	Door
RDO	Recycle Door
DEF	Defrost
OA	Outside Air
VE	Vent
FL	Floor
IA	Inside Air
OA	Outside Air

Fig. 5



HE	Heat exchanger
3F-CMC	Three-fluids combined membrane contactor
3V	Three-way valve
4V	Four-way valve
ET	Expansion tank
COMP	Compressor
ECEV	Electronic-controlled expansion valve
DO	Door
RDO	Recycle Door
DEF	Defrost
OA	Outside Air
VE	Vent
FL	Floor
IA	Inside Air

Fig. 6

REFERENCES CITED IN THE DESCRIPTION

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