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

(11) EP 3 361 171 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
15.08.2018 Bulletin 2018/33

(21) Application number: **18155985.7**

(22) Date of filing: **09.02.2018**

(51) Int Cl.:
F24F 11/30 *(2018.01)* ***F24F 3/14*** *(2006.01)*
F24F 3/153 *(2006.01)* ***F24F 5/00*** *(2006.01)*

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

(30) Priority: **14.02.2017 IT 201700015758**

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(54) HIGH EFFICIENCY INTEGRATED AIR CONDITIONING SYSTEM

(57) The present invention relates to a energy high efficiency integrated air conditioning system which uses 3F-CMC membrane and with three fluid contactors.

The system according to the invention is 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 for actuating with greater energy efficiency also the winter heating as well as the air conditioning in the intermediate and summer seasons.

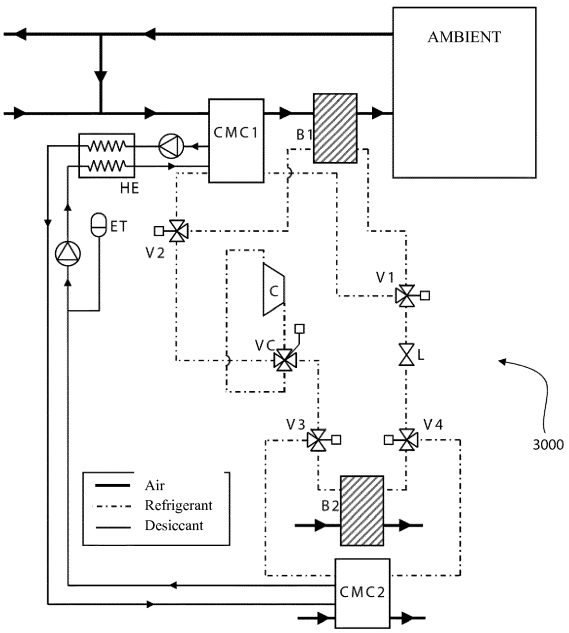

Fig. 1

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Description

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

[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 of use hygroscopic solutions (liquid desiccants) such as, for example, aqueous solutions of LiCl, $CaCl_2$, 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 passen-

ger 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, which at least partially solves the problems and overcomes the disadvantages of the prior art.

[0015] It is object of the present invention a system according to the enclosed claims.

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 $ECEV_1$ and $ECEV_2$, which ensure the output of both the evaporator

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 capacitor 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 $3V_1$, second $3V_2$, third $3V_3$ and fourth $3V_4$ 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 coolong fluid, so as to be able to send the coolong 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 $3V_1$ 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 $3V_2$ so that the passage of cooling fluid directly between said four-way valve 4V to said third three-way valve $3V_3$ is prevented;

C1. closing only one way of said third three-way valve $3V_3$ 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 $3V_4$ 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 $3V_1$ and the inlet of said refrigeration means COMP, and on the other hand between the outlet of said refrigeration means COMP and said second three-way valve $3V_2$; and

F1. opening said first ECEV1 and said second expansion valve with electronic control $ECEV_2$;

[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 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 $3V_1$;

B2. closing only one way of said second 3-way valve $3V_2$ so that the direct passage of cooling fluid between said four-way valve 4V to said third three-way valve $3V_3$ is prevented;

C2. closing only one way of said third three-way valve $3V_3$ 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 $3V_4$ 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 $3V_1$ and said refrigerating means COMP is prevented, and opening the other two ways to allow the passage of cooling fluid between the outlet of said refrigeration means 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 heat exchanger HE1 is now crossed by the cooling fluid which, by condensing, releases heat to the process air while the 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 $3V_1$ so as to interrupt the flow of cooling fluid between said evaporator HE1 and the inlet of said refrigeration means COMP;

B3. closing only one way of said second 3-way valve $3V_2$ so that the passage of cooling fluid directly between said four-way valve 4V and said third three-way valve $3V_3$ is prevented;

C3. closing only one way of said third three-way valve $3V_3$ 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 $3V_4$ 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 $3V_1$ and said refrigerating means COMP is prevented and opening the other two ways to allow the passage of cooling fluid between the outlet of said refrigeration means (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:

[0038] 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.

[0039] In fact, the heat exchanger HE1 is activated (with cooling fluid which is desuperheatedand condensed inside). The two contactors 3FCMC1 and 3F-CMC2 are excluded.

[0040] 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 $3V_1$ 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 $3V_2$ so that the passage of cooling fluid between the inlet of said refrigerating means and said second contactor 3F-CMC2 is prevented;

C4. closing only one way of said third three-way valve $3V_3$ 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 $3V_4$ 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 refrigeration means COMP and said first three-way valve $3V_1$ and the two other ways so as to allow the flow of the cooling fluid between the inlet of said refrigeration means COMP and said second three-way valve $3V_2$; and

F4. Opening said first $ECEV_1$ and closing said second ECEV2 expansion valve with electronic control.

Novelties with respect the prior art

[0041] 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).

[0042] 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.

[0043] 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.

[0044] 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

[0045] 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).

[0046] 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.

[0047] 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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[0048]

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[0049] 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, comprising:

- a first three-fluids membrane contactor (3F-CMC1) air, cooling fluid and desiccant fluid, as air conditioning and/or dehumidifying unit;
- a second three-fluids membrane contactor (3F-CMC2) air, cooling fluid and desiccant fluid, such as regeneration unit for regeneration of said liquid desiccant, connected to said first contactor (3F- CMC1);
- refrigerating means (COMP), connected to said first contactor (3F-CMC1), said refrigeration means having a refrigerating means inlet and outlet;
- an evaporator (HE1) with two channels each being alternately evaporator inlet or outlet;
- a condenser (HE2) having two channels each being alternately evaporator inlet or outlet;

characterized in that:

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

  ◦ the outlet and the inlet of said refrigeration means (COMP) with each other;

◦ the inlet of said refrigeration means (COMP) with a first three-way valve ($3V_1$) and the outlet of said refrigeration means (COMP) with a second three-way valve ($3V_2$);
◦ the inlet of said refrigeration means (COMP) with said second three-way valve ($3V_2$) and the outlet of said refrigeration means (COMP) with said first three-way valve ($3V_1$);

- said second three-way valve (3V2) is placed along one of said two evaporator channels (HE1);
- said first three-way valve ($3V_1$) is placed along one of said two evaporator channels (HE1) and is configured to connect alternately:

◦ said evaporator (HE1) with said four-way valve (4V);
◦ said evaporator (HE1) with a third three-way valve ($3V_3$);

- said third three-way valve ($3V_3$) is configured to connect in an exclusive way:

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

- it is comprised a first ($ECEV_1$) and a second expansion valve with electronic control (ECEV2) inserted in cascade between said evaporator (HE1) and said first three-fluids membrane contactor (3F-CMC1);
- it is comprised a fourth three-way valve ($3V_4$) configured to connect alternately and exclusively:

◦ said condenser (HE2) to a node between said first ($ECEV_1$) and said second (ECEV2) expansion valve with electronic control;
◦ said evaporator (HE1) to said node between said first ($ECEV_1$) and said second (ECEV2) expansion valve with electronic control;

being further provided electronic control means to open and close selectively one or more ways of said first ($3V_1$), second ($3V_1$), third ($3V_3$) and fourth ($3V_4$) three- way valve, as well as of said 4-way valve (4V) as well as to open and close selectively said first ($ECEV_1$) and second (ECEV2) expansion valve with electronic control.

2. Air-conditioning method, **characterized by** the fact to use the system (1000) according to claim 1 and by the fact to perform the following first steps to obtain process air cooling and dehumidification:

A1. closing only one way of said first 3-way valve ($3V_1$) 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 ($3V_2$) so that the passage of cooling fluid directly between said four-way valve (4V) to said third three-way valve ($3V_3$) is prevented;
C1. closing only one way of said third three-way valve ($3V_3$) 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 ($3V_4$) 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 ($3V_1$) and the inlet of said refrigeration means (COMP), and on the other hand between the outlet of said refrigeration means (COMP) and said second three-way valve ($3V_2$); 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 ($3V_1$);
B2. closing only one way of said second 3-way valve ($3V_2$) so that the direct passage of cooling fluid between said four-way valve (4V) to said third three-way valve ($3V_3$) is prevented;
C2. closing only one way of said third three-way valve ($3V_3$) 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 ($3V_4$) 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 ($3V_1$) and said refrigerating means (COMP) is prevented, and opening the other two ways to allow the passage of cooling

fluid between the outlet of said refrigeration means (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 ($3V_1$) so as to interrupt the flow of cooling fluid between said evaporator (HE1) and the inlet of said refrigeration means (COMP);

B3. closing only one way of said second 3-way valve ($3V_2$) so that the passage of cooling fluid directly between said four-way valve (4V) and said third three-way valve ($3V_3$) is prevented;

C3. closing only one way of said third three-way valve ($3V_3$) 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 ($3V_4$) 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 ($3V_1$) and said refrigerating means (COMP) is prevented and opening the other two ways to allow the passage of cooling fluid between the outlet of said refrigeration means (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 ($3V_1$) 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 ($3V_2$) so that the passage of cooling fluid between the inlet of said refrigerating means and said second contactor (3F-CMC2) is prevented;

C4. closing only one way of said third three-way valve ($3V_3$) 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 ($3V_4$) 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 refrigeration means (COMP) and said first three-way valve ($3V_1$) and the two other ways so as to allow the flow of the cooling fluid between the inlet of said refrigeration means (COMP) and said second three-way valve ($3V_2$); and

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

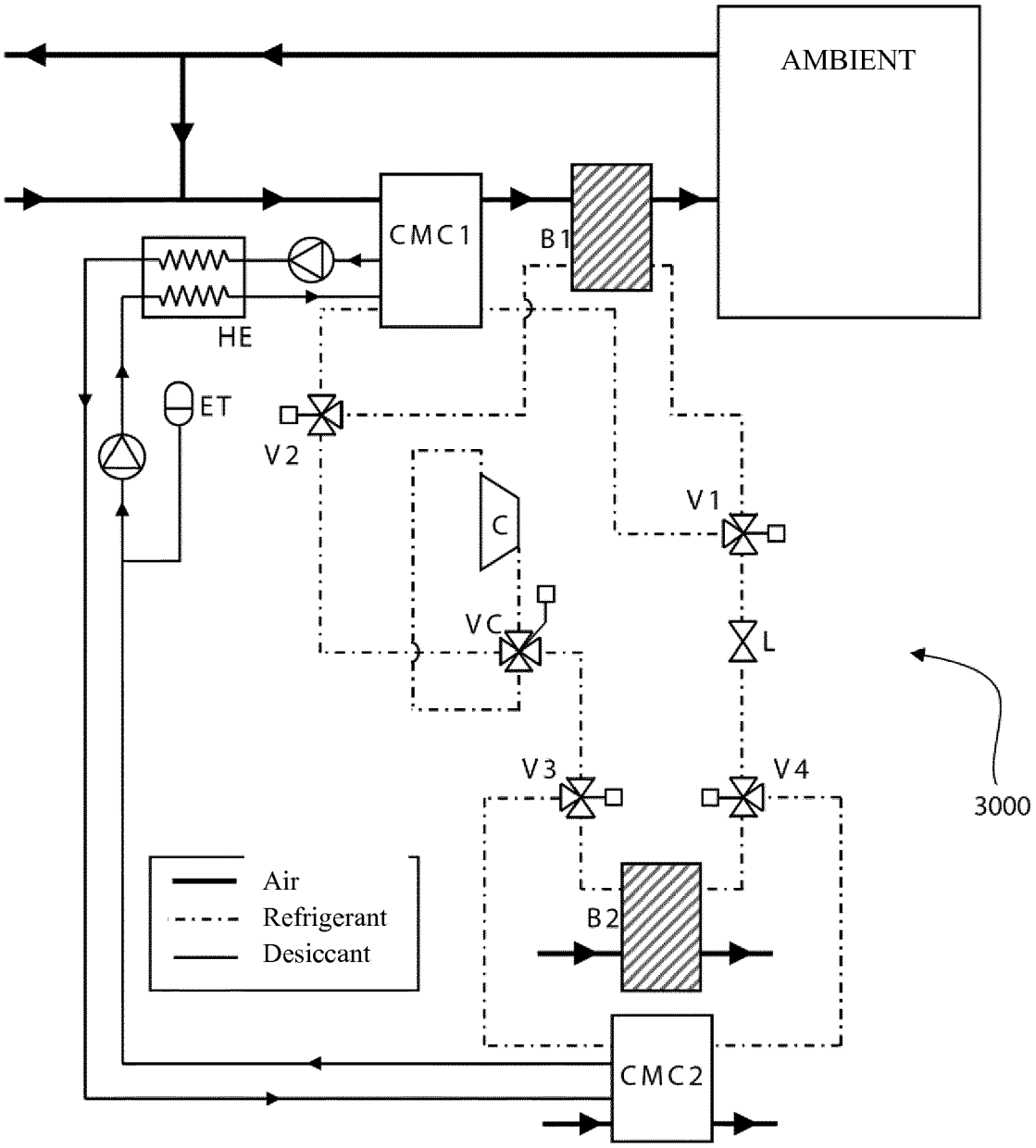
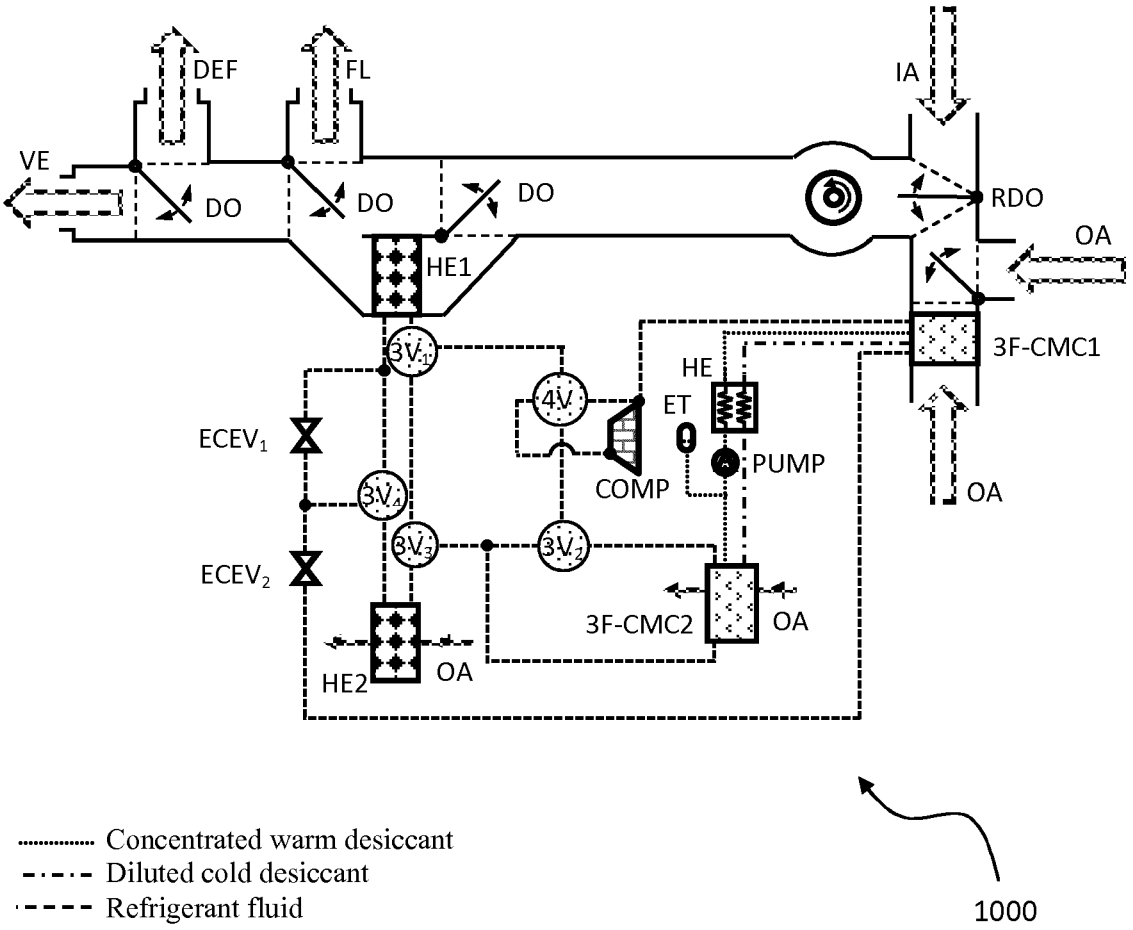
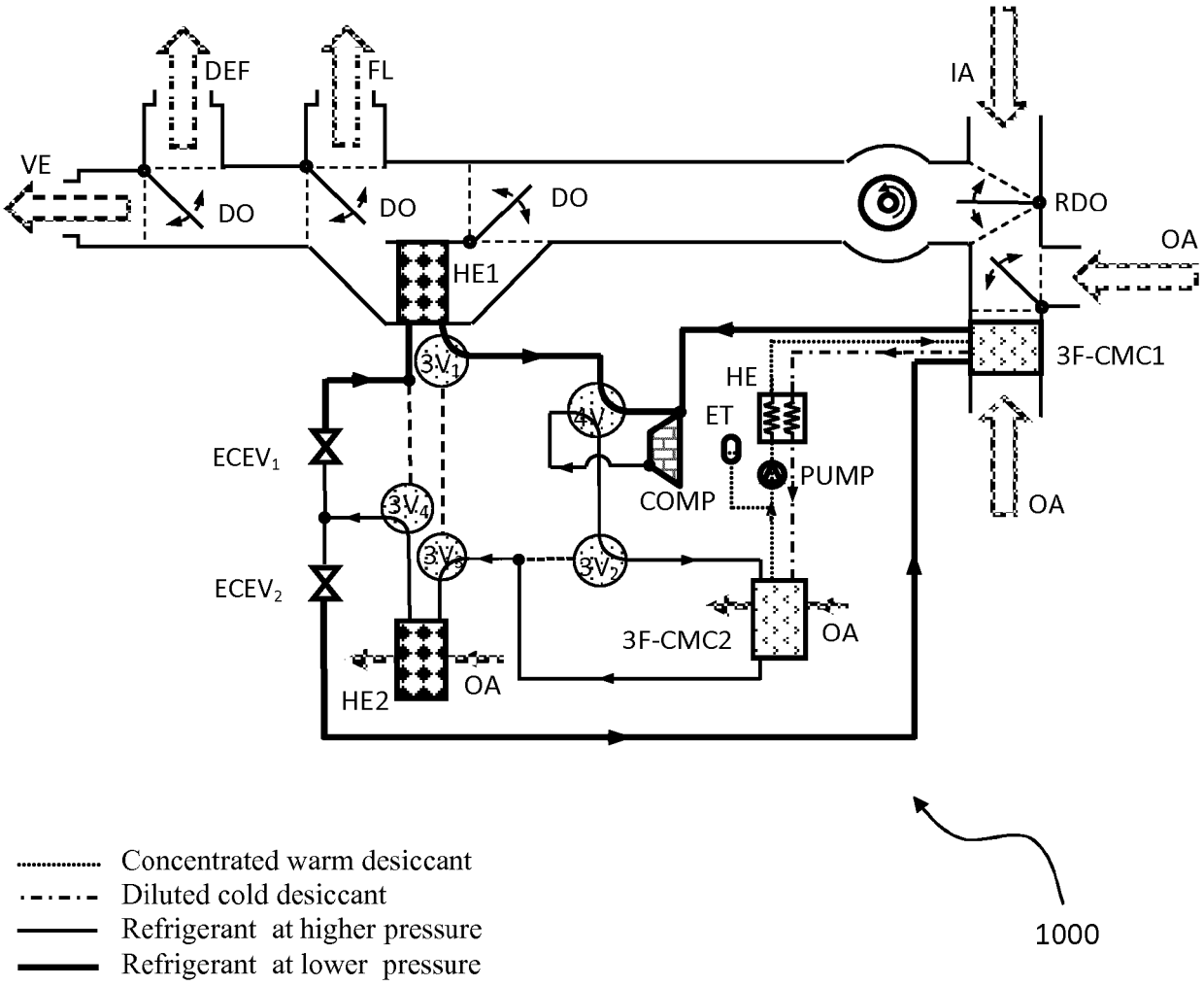

AMBIENT
CMC1
B1
HE
ET
V2
C
V1
VC
L
3000
V3
V4
Air
Refrigerant
Desiccant
B2
CMC2

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



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VE	Vent
FL	Floor
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OA	Outside Air

Fig. 3

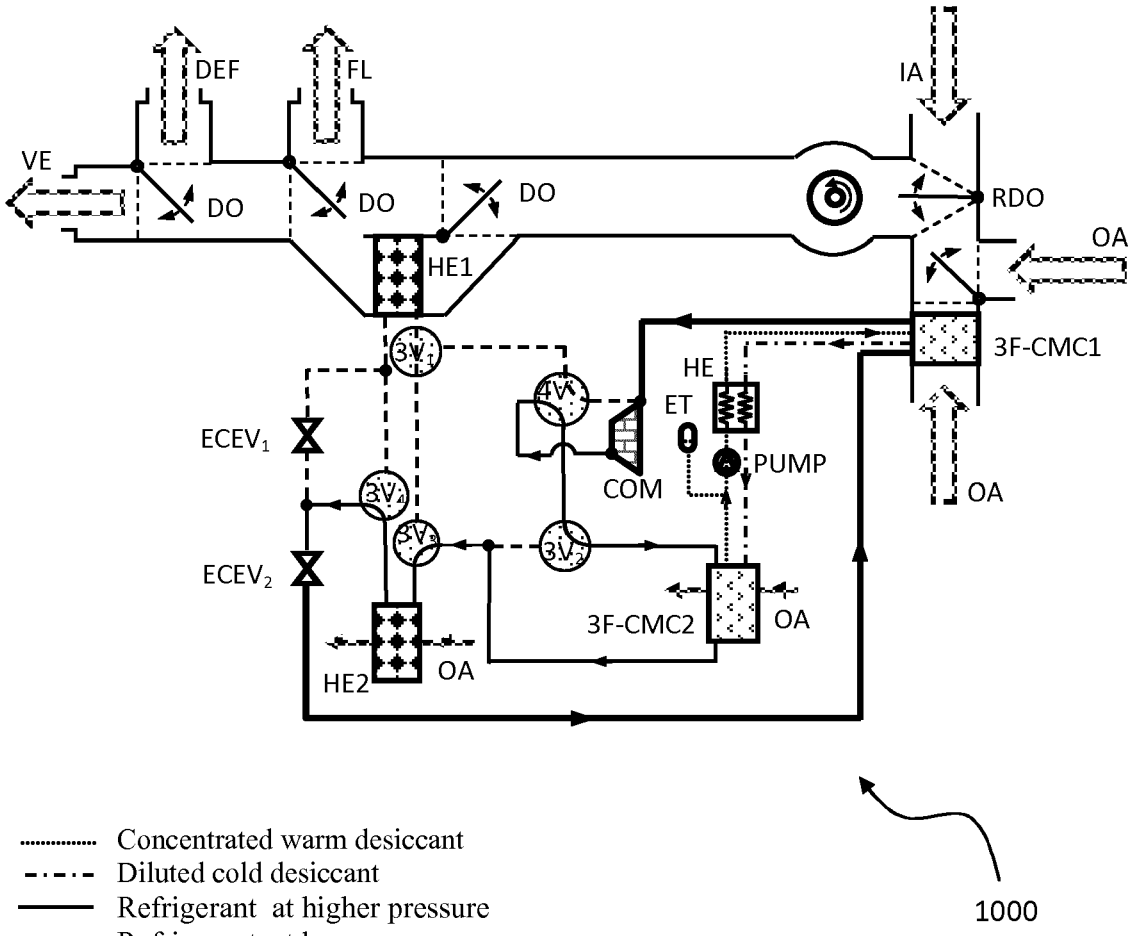

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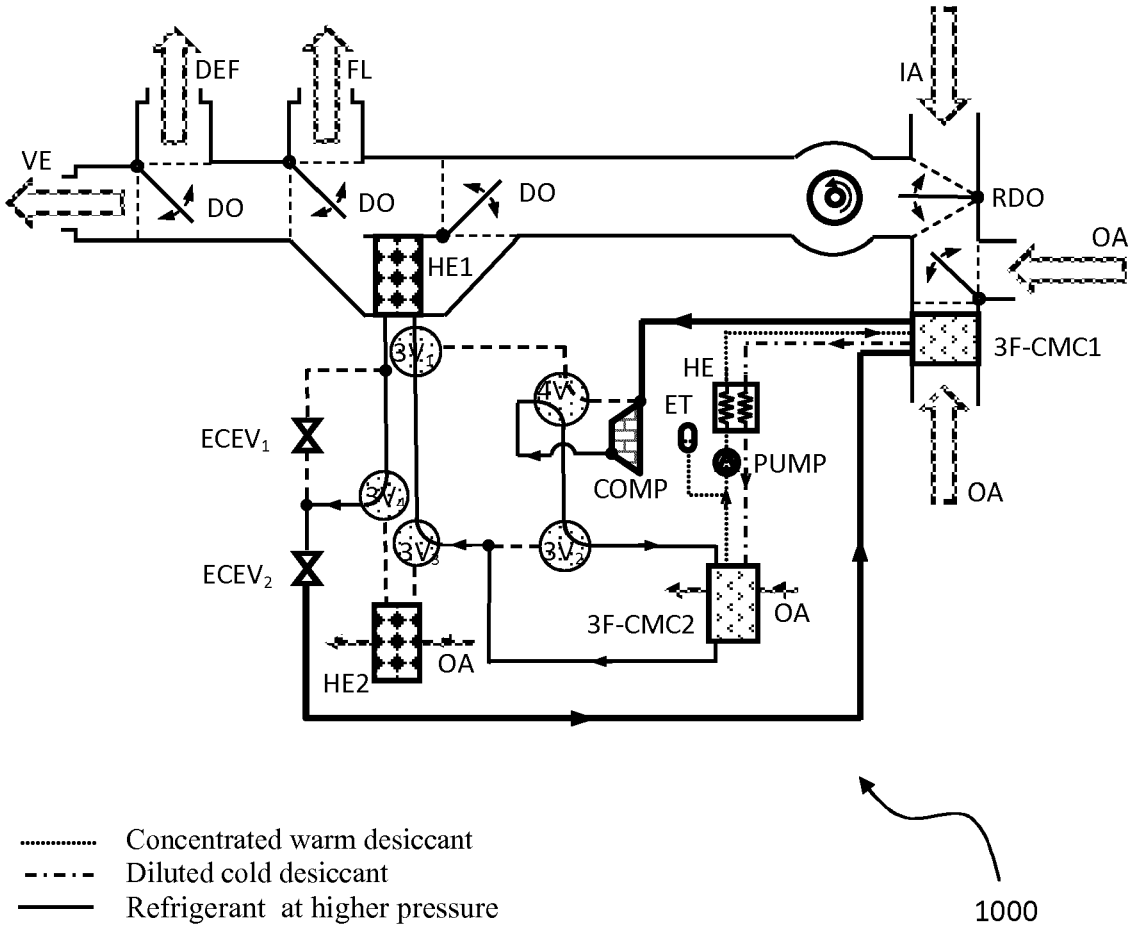
Fig. 4



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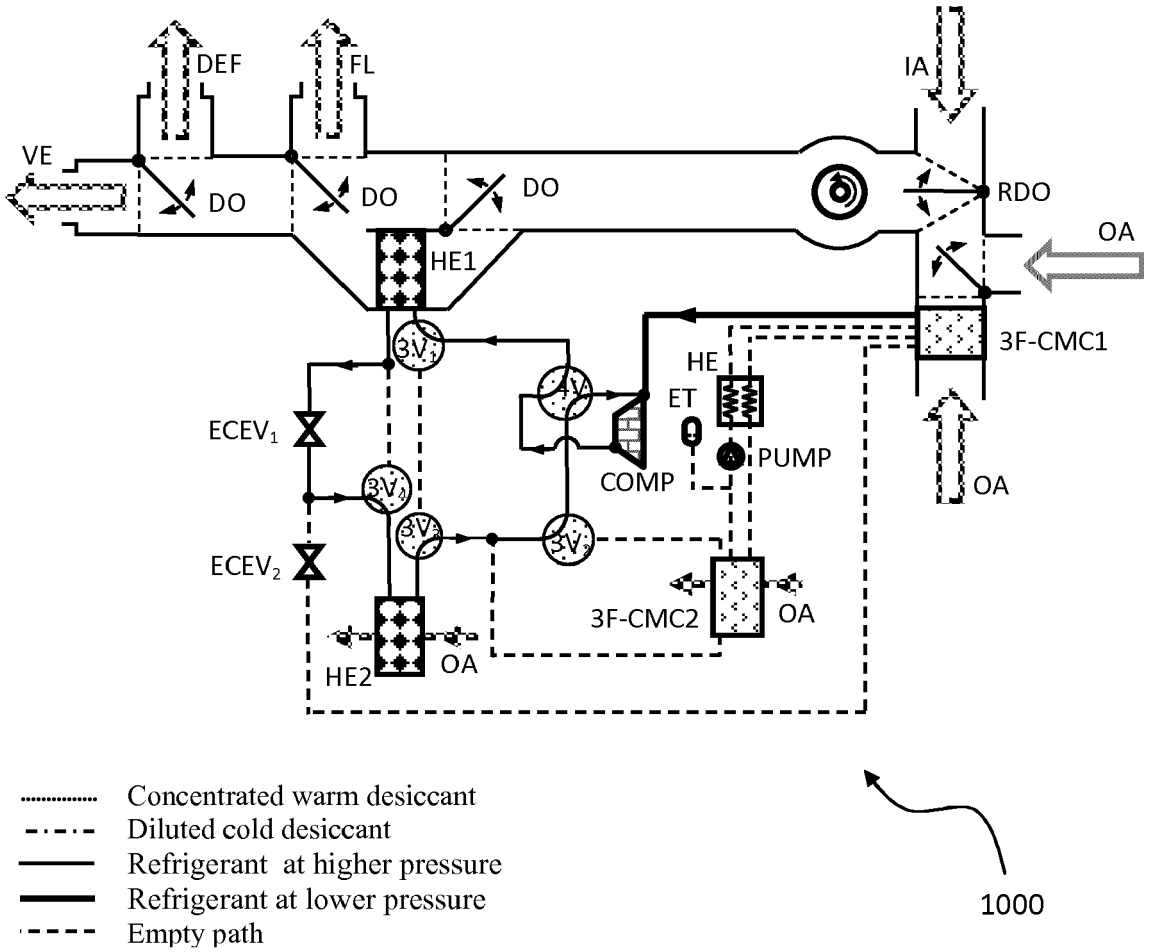
OA	Outside Air
VE	Vent
FL	Floor
IA	Inside Air
OA	Outside Air

Fig. 5



HE	Heat exchanger
3F-CMC	Three-fluids combined membrane contactor
3V	Three-way valve
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VE	Vent
FL	Floor
IA	Inside Air

Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 18 15 5985

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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	15 June 2018	Degen, Marcello

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15-06-2018

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