



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
02.10.2019 Bulletin 2019/40

(51) Int Cl.:
F25B 47/02 (2006.01) F25B 13/00 (2006.01)

(21) Application number: **18163840.4**

(22) Date of filing: **26.03.2018**

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

(72) Inventors:
• **Wu, Duan**
Livingston, EH54 5DJ (GB)
• **Salvador, Michael**
Livingston, EH54 5DJ (GB)

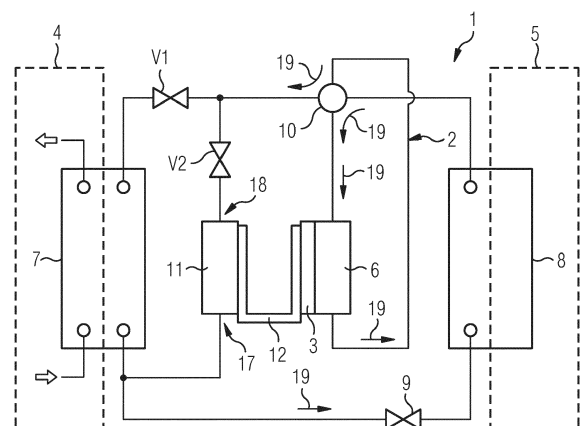
(74) Representative: **Pfenning, Meinig & Partner mbB**
Patent- und Rechtsanwälte
Theresienhöhe 11a
80339 München (DE)

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

(54) **DEFROSTING A HEAT PUMP SYSTEM WITH WASTE HEAT**

(57) The invention relates to a heat pump system (1) with a refrigerant circuit (2), where, via a refrigerant, heat is transferred between a first environment (4) and a second environment (5), the refrigerant circuit (2) comprising a compressor (6) for compressing the refrigerant, a first heat exchanger (7) for transferring heat between the first environment (4) and the refrigerant circuit (2), a second heat exchanger (8) for transferring heat between the second environment (5) and the refrigerant circuit (2), where the first heat exchanger (7) is configured to operate as a condenser to cool the refrigerant in a heating mode, and the second heat exchanger (8) is configured to operate as an evaporator in the heating mode, and a compressor driver (3) electrically coupled with the compressor (6) for powering the compressor (6), wherein the refrigerant circuit (2) comprises a heat storage means (11) with a heat storage medium, the heat storage means (11) being thermally coupled with the compressor (6) or the compressor driver (3) and being configured to store heat generated by the compressor (6) or the compressor driver (3) in the heating mode and to transfer the stored heat to the refrigerant in a defrost mode of the refrigerant circuit (2) in order to improve the efficiency of the heat pump system (1).

FIG 1



Description

[0001] The invention relates to a refrigerant circuit, where, via a refrigerant, heat is transferred between a first environment and a second environment, the refrigerant circuit comprising a compressor for compressing the refrigerant, a first heat exchanger for transferring heat between the first environment and the refrigerant circuit, a second heat exchanger for transferring heat between the second environment and the refrigerant circuit, where the first heat exchanger is configured to operate as a condenser to cool the refrigerant in a heating mode, and the second heat exchanger is configured to operate as an evaporator in the heating mode, and with a compressor driver electrically coupled with the compressor for powering the compressor.

[0002] Air source heat pumps are becoming popular in domestic applications and replace traditional gas boilers due to improved energy efficiency. Such heat pumps usually comprise a refrigerant circuit with a refrigerant such as R410a, R290, CO₂, or alike. In general, a compressor is used to increase the pressure and thus separate a low pressure side of the circuit from a high-pressure side. In such a heat pump, the refrigerant can be conducted from the high-pressure side of the compressor to a four way valve, which is used to reverse the refrigerant circuit from heating mode to cooling mode. In the heating mode, after the four way valve, the refrigerant will reach the first heat exchanger which may be a plate heat exchanger and works as condenser, and the refrigerant will change the phase from gas to liquid. This is the condensing process, where the latent heat of the refrigerant is released to another fluid in the plate heat on the exchanger, in most cases to water. After the condenser, the refrigerant will usually flow through one or more valves for pressure reduction. Then the refrigerant will pass another, second heat exchanger working as evaporator, preferably with multiple passes. The second heat exchanger may comprise an extended surface for enhancing heat exchange. In the second heat exchanger, the heat can be transferred to the refrigerant from another medium such as ambient air, for instance. This process may be supported by a fan enhancing airflow. As the refrigerant temperature is lower than the ambient air temperature and the refrigerant is in liquid form, it will evaporate and absorb heat from the ambient air. After the evaporator, the refrigerant will become gas again and then flow through the four way valve into the low pressure suction line of the compressor for the next cycle.

[0003] The main advantage of such air source heat pumps is the high coefficient of performance (COP). The air source heat pump uses only a small quantity of energy for operating the compressor and other electrical components to absorb heat from the ambient air and then release the heat to the carrier medium of a space heating/cooling circuit, for instance water, in the first heat exchanger. The COP varies from 3 to 5, which means the heat pump can supply 3 to 5 times the heat corresponding to the total power consumption of the compressor and other load units, such as electronics, of the heat pump.

[0004] Usually, heat losses in the heat pump system are not fully used. So, the heat losses of, for instance the compressor will be dissipated to the ambient even if the temperature of the (waste) heat source, i.e. the load unit, can be quite high, for instance 80 degree Celsius for electronic components or even 100 degree Celsius for the compressor.

[0005] On the other hand, when the ambient temperature is near 0°C, the humidity in the air will deposit on thin surfaces of the air side of the evaporator, the second heat exchanger, and it will form ice, which is called "frosting process". When the frost becomes significant, it will block the air passage through the evaporator and increase the thermal resistance of the heat exchanger. This lowers the systems efficiency and may disrupt the normal operation of the system. Therefore, when such a frosting process occurs, the heat pump system will reverse the cycle from heating indoor to heating outdoor by switching said four way valve, for instance. So, the heat pump will start a defrosting mode, in which it will extract heat from indoors via the first plate heat exchanger for heating up the second heat exchanger, the evaporator, to a higher temperature for de-icing the second heat exchanger. This consumes electricity and further extracts heat from indoors, which causes discomfort.

[0006] To overcome said disadvantages, the EP 324 4141 A1 discloses a heat pump system including a refrigerant circuit, a compressor driver, and a heat storage means. The refrigerant circuit includes a compressor for compressing the refrigerant, a first heat exchanger for transferring heat between the refrigerant and the interior atmosphere, a throttling device for lowering the pressure of the refrigerant, and the second heat exchanger for transferring heat between the refrigerant and the exterior atmosphere. The first heat exchanger operates as a condenser to cool the refrigerant in the heating mode and operates as an evaporator to vaporize the refrigerant in the cooling mode. The second heat exchanger operates as an evaporator in the heating mode and operates as a condenser in the cooling mode. The compressor driver is electrically connected with the compressor for powering the compressor, and it generates heat in operation. The heat storage means for storing heat generated by the compressor driver is in heat transferable contact with the refrigerant in a defrost mode to transfer stored heat energy to the refrigerant.

[0007] The US 526 9151 a discloses a passive defrost system that uses a heat exchanger/storage defrost module containing a thermal storage material such as a phase-change material to capture and store low-grade waste heat contained in the liquid refrigerant line of a refrigeration system. The waste heat stored during normal operation. Upon shutdown of the refrigeration system, the stored heat in the defrost module is released by an automatic device for defrosting the evaporator.

[0008] The EP 316 5852 a one discloses another antifrost heat pump which is capable of preventing an evaporator from frosting during a sub-cooling process by using heat released in the sampling process in sub-cooling means. The heat pump includes a refrigerant circuit having an evaporator, a condenser, sub-cooling means arranged to perform a sub-cooling process of cooling a refrigerant flowing out of the condenser, and heat transfer means arranged to transfer heat released from the refrigerant in the sub-cooling process from the sub-cooling means to the evaporator during the sub-cooling process.

[0009] The US 2009/028 2854 A1 discloses an air conditioning system with a refrigerant circuit in which a compressor, an indoor radiant panel, a first expansion valve, room air heat exchanger, a second extension valve, and an outdoor air heat exchanger are connected in this order and which operates in a refrigeration circuit by reversibly circulating refrigerant therethrough. During a defrosting operation, the first expansion valve is controlled to reduce the refrigerant pressure so that in a cooling cycle the refrigerant releases heat in the outdoor air heat exchanger and the room heat exchanger and evaporates in the indoor radiant panel. Thus, the air conditioning system concurrently provides the defrosting of the outdoor air heat exchanger and the room heating of the room air heat exchanger.

[0010] The US 2011/031 5368 A1 provides another air conditioning apparatus that can effectively utilize heat energy generated by a control unit. The US 2008/008 6981 A1 describes a composite, hybrid radiant/forced and natural convection, integrated, sandwiched, multirole panel optimally integrating heating, cooling, ventilating, air conditioning, thermoelectric effect, energy recovery, and energy storage function at very moderate operating temperature such that it can directly utilize renewable and waste energy resources having very low energy.

[0011] The objective technical problem to be solved by the present invention may therefore be regarded to improve the efficiency of a heat pump system.

[0012] This problem is solved by the subject-matter of the independent claims. Advantageous embodiments are disclosed in the dependent claims, the description, and the figures.

[0013] One aspect of the invention relates to a heat pump system with a refrigerant circuit, where, via a refrigerant, heat is transferred between a first environment, e.g. the inside of a building, and a second environment, e.g. the outside of the building, and with a compressor driver. Said environments may also be a local and/or closed environment, such as a buffer tank or buffer system, filled with, for instance, water. The heat pump system is operable in a heating mode, where heat is transferred from the second environment to the first environment. In addition, the heat pump system may be operable in a cooling mode, where heat is transferred from the first environment to the second environment.

[0014] The refrigerant circuit comprises a compressor for compressing the refrigerant, a first heat exchanger for transferring heat between the first environment and the refrigerant circuit, and a second heat exchanger for transferring heat between the second environment and the refrigerant circuit. Therein, the first heat exchanger is configured to operate as a condenser to cool the refrigerant in the heating mode. The first heat exchanger may be configured to operate as an evaporator to vaporize the refrigerant in the cooling mode. The second heat exchanger is configured to operate as an evaporator in the heating mode. The second heat exchanger may be configured to operate as a condenser in the cooling mode. The first heat exchanger may be a plate heat exchanger. In addition to the refrigerant as a first working medium, the first heat exchanger uses a second working medium which may be a liquid such as water. The second heat exchanger may feature an extended surface for enhancing heat exchanger with ambient air. In addition to the refrigerant as a first working medium, the second heat exchanger uses a second working medium which may be a gas such as ambient air. The refrigerant circuit may comprise a throttling device such as a valve or several valves for lowering the pressure of the refrigerant in the refrigerant circuit or in a specific section of the refrigerant circuit. The compressor driver is electrically coupled with the compressor for powering the compressor.

[0015] In addition to the compressor and said two heat exchangers, the refrigerant circuit comprises a heat storage means with a heat storage medium different from the refrigerant. Said heat storage means may also be referred to as distinct heat storage means. The heat storage means is thermally coupled with the compressor and/or the compressor driver, and is configured to store heat (which may be referred to as waste heat) generated by the compressor and/or the compressor driver in a normal operating mode. The normal operating mode may comprise the heating mode or the cooling mode or the heating and the cooling mode. The heat storage means is configured to transfer the stored heat to the refrigerant in a defrost mode of the refrigerant circuit, in particular only in a defrost mode of the refrigerant circuit.

[0016] So, the heat storage is thermally coupled with the rest of the refrigerant circuit by the refrigerant running through or along the heat storage when heat is transferred from the heat storage medium to the refrigerant. As part of the refrigerant circuit, the heat storage means is coupled to the refrigerant circuit directly, and heat is transferred from the heat storage medium to the refrigerant directly, that is, preferably not via another liquid medium or gas medium. In particular, the heat storage means does not comprise another circuit for another medium, in particular another liquid and/or gas medium, that may be thermally coupled to the refrigerant circuit. So, the heat storage means may form an additional heat exchanger in the refrigerant circuit, with the refrigerant as first working medium and the heat storage medium as second working medium.

[0017] This gives the advantage that the waste heat generated in the compressor driver or the compressor is used for defrosting, which saves electricity and renders the extraction of heat from the first environment, which causes dis-

comfort in the state-of-the-art, unnecessary. Hence, the overall efficiency of the heat pump system is improved. Here, the integration of the heat storage means into the refrigerant circuit that allows a direct transfer from the waste heat to the refrigerant and renders the design particularly simple and efficient.

[0018] In an advantageous embodiment, the heat storage means is connected to the rest of the refrigerant circuit parallel to the first heat exchanger, so that the first heat exchanger can be bypassed by the heat storage means, and the heat storage means can be bypassed by the heat exchanger.

[0019] This gives the advantage that the heat stored in the heat storage means can either be contained in the heat storage means or transferred to the refrigerant flowing through the refrigerant circuit, in particular to the second heat exchanger by, for instance simply switching one valve of the refrigerant circuit causing of the refrigerant flow through the heat storage means instead of the first heat exchanger, or through the first heat exchanger instead of the heat storage means respectively. Hence, said setup results in a particularly simple and efficient heat pump system.

[0020] In another advantageous embodiment, in addition to the compressor and/or compressor driver, a control unit and/or at least one additional electrical load is thermally coupled to the heat storage means.

[0021] This gives the advantage that more wasted heat is stored and used for defrosting, hence the efficiency of the system is further improved. This is particularly advantageous in combination with the embodiment described below, where several storage cells are provided in the heat storage means. Therein, individual characteristics of the different waste heat sources, the electrical loads or the control unit or the compressor or the compressor driver, such as different temperature levels of the waste sources, can be optimally taken advantage of by the different storage cells with different phase-change temperatures, for instance.

[0022] In a further advantageous embodiment, the compressor and/or compressor driver and/or the control unit and/or the at least one additional electrical load of the heat pump system are thermally coupled to the heat storage means by respective heat pipes or thermosiphons. Each waste heat source may be thermally coupled to the heat storage means by an individual heat pipe or thermosiphon. Alternatively, several waste heat sources may be thermally coupled to the heat storage by one respective heat pipe or thermosiphon.

[0023] This gives the advantage that the thermal coupling of the heat storage means to the compressor driver, the compressor, the control unit, or another electrical load, shortly, to the waste heat sources, is realized in a particularly efficient and technically simple, robust way.

[0024] In another advantageous embodiment, the heat pump system may comprise a casing for the compressor, the compressor driver, and the heat storage means, as well as, in particular, the other load units or waste heat sources. In the intended use of the heat pump system, the heat storage means is preferably arranged above the compressor and/or the compressor driver and/or the other load that are thermally coupled with the heat storage means.

[0025] This gives the advantage that gravity supports the heat transfer from the waste heat sources, the electric load units, to the heat storage means. Consequently the system is particularly simple, robust, and efficient.

[0026] Therein, storage cells (see below) with lower phase-change temperature may be attached to the casing in between the casing and the storage cells with higher phase-change temperature. This gives the advantage of improved thermal efficiency, where excess heat of the storage cells with higher phase-change temperature is transferred to storage cells with a lower phase-change temperature, i.e. used to charge storage cells with a lower phase-change temperature.

[0027] In yet another advantageous embodiment, the heat storage medium comprises or is a phase-change material. The phase-change material may comprise one or more compositions of different phase-change materials. This gives the advantage that the heat can be stored particularly efficiently, and that, by the selection of a phase-change material with appropriate phase-change temperature, the rate of the heat transfer can be adjusted optimally to the working conditions of the compressor driver and the other electrical load units.

[0028] In a further advantageous embodiment, the heat storage means comprises at least two storage cells with different phase-change materials. Said phase-change materials may also be different compositions of identical phase-change materials. Each storage cell has a different phase-change temperature, and each of the cells is thermally coupled to at least one, i.e. one or several or all, of the following load units: the compressor and/or the compressor driver and/or the control unit and/or the at least one additional electrical load. Vice versa, each of the compressor and/or the compressor driver and/or the control unit and/or the at least one additional electrical load is thermally coupled to one or several of the storage cells, in particular exactly one of the storage cells. In particular, the thermal coupling may be realized by respective individual thermosiphons or heat pipes, so that, for instance, each storage cell is coupled to one or more load units by respective thermosiphons or heat pipes, or each load unit is coupled to one or more of the storage cells by respective thermosiphons or heat pipes.

[0029] This gives the advantage that multiple heat losses in different temperature ranges can be recovered and stored in a latent form in the respective storage cells with multiple phase-change temperature values. Thus, a particularly efficient heat storage is achieved. The stored heat can then be used in different ways for improving the overall efficiency in the flow arrangement, for instance it enables the refrigerant flow through or along a phase-change material with a low phase-change temperature, a low temperature phase-change material cell, and afterwards through or along a phase-change material with a high phase-change temperature, a high temperature phase-change material cell, as described

below.

[0030] Therein, a first storage cell with a lower phase-change temperature than a second storage cell may be thermally coupled with a first load unit of the load units, which may for instance be (or comprise) the control unit, where the first load unit has a lower heat generation, in particular lower average heat generation, and/or a lower power consumption, in particular lower average power consumption, than a second load unit of the load units, which may for instance be (or comprise) the compressor driver, and the second storage cell is thermally coupled with the second load unit. In particular, the first load unit is not thermally coupled by a heat pipe or thermosiphon to the second load unit and vice versa. Such a heat storage means may also comprise further storage cells with other phase-change temperatures, for instance a third storage cell with a higher phase-change temperature than the second storage cell. The refrigerant may then flow through a cascade of different storage cells.

[0031] This gives the advantage of a particularly efficient usage of the waste heat, which allows to adapt the individual storage cells to the characteristics of the different load units. Furthermore, not only phase-change temperature but also heat storage capacity of the respective storage cells may be adapted to the load units thermally coupled with the respective storage cell.

[0032] In another embodiment, the refrigerant circuit, that is, the additional heat exchanger formed by the heat storage means, is configured to conduct the refrigerant through or along the storage cells in ascending order of the respective phase-change temperatures in the defrost mode. So, the refrigerant is receiving heat from a storage cell with a lower phase-change temperature before receiving heat from storage cell with a higher phase-change temperature.

[0033] This gives the advantage that the heat transfer from the heat storage means to the refrigerant is optimized, and the overall efficiency is improved.

[0034] In another advantageous embodiment, one or several first storage cells, in particular one or several first storage cells with a lower phase-change temperature, are configured to transfer heat to one or several second storage cells, in particular one or several second storage cells with a higher phase-change temperature.

[0035] This gives the advantage that the overall amount of stored heat can be optimized and the working temperature of the load units connected to the respective storage cells, in particular the first storage cells, can be maintained.

[0036] In a further advantageous embodiment, the heat pump system comprises a temperature sensor for sensing the temperature of a working medium such as water in a space heating/cooling circuit, where the space heating/cooling circuit is connected with the first heat exchanger for heating and/or cooling the first environment. Therein, the heat pump system is configured to automatically transfer heat from the space heating/cooling circuit to the refrigerant passing through the first heat exchanger when a temperature of the working medium decreases to a lower limit value, in particular the lowest phase-change temperature of the heat storage means, while a temperature of the second heat exchanger does not reach a predetermined value in the defrost mode.

[0037] This gives the advantage that defrosting is achieved even when the heat stored in the heat storage means is depleted while the discomfort in the first environment as well as the usage of electricity for defrosting is minimized.

[0038] In yet another advantageous embodiment, the heat pump system is, in particular in the heating mode, operable in a partial-load mode. In said partial-load mode, the refrigerant is used to store heat in the heat storage means in addition to the heat generated by the compressor and/or the compressor driver, and, when the heat stored in the heat storage means reaches a preset limit, in particular a maximum heat that can be stored in the heat storage means, the compressor is switched off and the heat stored in the heat storage means is transferred to the first environment, in particular by the refrigerant circuit.

[0039] This gives the advantage that when the heat load is low and the heat pump will, according to the state-of-the-art, experience frequent on-off cycling behavior, the frequency of the on-off cycling is decreased. Furthermore, the heat storage means can be charged, that is heat can be transferred to the heat storage means under a high COP. When the heat storage means is fully charged, the compressor can stop and the heat storage means can supply heat to the first environment, for instance the living space, with a low rate. Consequently, the overall efficiency is improved.

[0040] Therein, in particular, the heat storage means may comprise a connection to the space heating/cooling circuit, where the space heating/cooling circuit is to be connected with the first heat exchanger in order to heat or cool the first environment. The heat storage means is then configured to transfer heat to the working medium of the space heating/cooling circuit directly, that is, not via another liquid or gas medium, in particular, not the refrigerant. In particular, the heat storage means may be configured to transfer the heat to the working medium when the compressor is switched off, preferably only when the compressor is switched off.

[0041] This gives the advantage that heat, in particular waste heat, can be transferred to the first environment very efficiently.

[0042] Another aspect of the invention relates to a method for operating a heat pump system with said refrigerant circuit, where, via a refrigerant, heat is transferred between a first environment and a second environment, and with said compressor driver. The refrigerant circuit is operable in a heating mode and may be operable in a cooling mode.

[0043] As described above, the refrigerant circuit comprises a compressor for compressing the refrigerant, a first heat exchanger for transferring heat between the first environment and the refrigerant circuit, and a second heat exchanger

for transferring heat between the second environment and the refrigerant circuit. Therein, the first heat exchanger is configured to operate as a condenser to cool the refrigerant in the heating mode. The first heat exchanger may be configured to operate as an evaporator to vaporize the refrigerant in the cooling mode. The second heat exchanger is configured to operate as an evaporator in the heating mode. The second heat exchanger may be configured to operate as a condenser in the cooling mode. The first heat exchanger may be a plate heat exchanger. In addition to the refrigerant as a first working medium, the first heat exchanger uses a second working medium which may be a liquid such as water. The second heat exchanger may feature an extended surface for enhancing heat exchanger with ambient air. In addition to the refrigerant as a first working medium, the second heat exchanger uses a second working medium which may be a gas such as ambient air. The refrigerant circuit may comprise a throttling device such as a valve or several valves for lowering the pressure of the refrigerant in the refrigerant circuit or in a specific section of the refrigerant circuit. The compressor driver is electrically coupled with the compressor for powering the compressor.

[0044] The method comprises the method step of storing heat generated by the compressor and/or the compressor driver in a heat storage means of the refrigerant circuit, where the heat storage means comprises a heat storage medium, via a thermal coupling of the compressor and/or the compressor driver to the storage means in the heating and/or cooling mode. Furthermore, the method comprises the method step of transferring the stored heat directly from the heat storage medium to the refrigerant in a defrost mode of the refrigerant circuit.

[0045] Therein, advantages and advantageous embodiments of the described heat pump system apply to the claimed method.

[0046] The features and combinations of features described above, as well as the features and combinations of features disclosed in the figure description or the figures alone may not only be used alone or in the described combination, but also with other features or without some of the disclosed features without leaving the scope of the invention. Consequently, embodiments that are not explicitly shown and described by the figures but that can be generated by separately combining the individual features disclosed in the figures are also part of the invention. Therefore, embodiments and combinations of features that do not comprise all features of an originally formulated independent claim are to be regarded as disclosed. Furthermore, embodiments and combinations of features that differ from or extend beyond the combinations of features described by the dependencies of the claims are to be regarded as disclosed.

[0047] Exemplary embodiments are further described in the following by means of schematic drawings. Therein,

Fig. 1 shows an exemplary embodiment of a heat pump system;

Fig. 2 Fig. 1; and shows an exemplary control flow chart of the embodiment of

Fig. 3 system. shows parts of another exemplary embodiment of a heat pump

[0048] In the figures, identical or functionally identical elements have the same reference signs.

[0049] Figure 1 shows an exemplary embodiment of a heat pump system. The shown heat pump system 1 comprises a refrigerant circuit 2 and a compressor driver 3. The refrigerant circuit 2 is operable in a heating mode and, in the present example, also in a cooling mode, where, via a refrigerant, in the cooling mode heat is transferred from a first environment 4 to a second environment 5, and in the heating mode heat is transferred from the second environment 5 to the first environment 4.

[0050] Therein, the refrigerant circuit 2 comprises a compressor 6 for compressing the refrigerant, a first heat exchanger 7 for transferring heat between the first environment 4 and the refrigerant circuit 2, a second heat exchanger 8 for transferring heat between the second environment 5 and the refrigerant circuit 2, as well as a throttling device 9 and a four way valve 10 in the present example. The compressor driver 3 is electrically coupled with the compressor 6 for powering the compressor 6. The arrows 19 along the refrigerant circuit 2 indicate the flow direction of the refrigerant in the heating mode.

[0051] In the shown example, the refrigerant circuit 2 comprises a heat storage means 11 with a heat storage medium. The heat storage means 11 is connected to the rest of the refrigerant circuit 2 parallel to the first heat exchanger 7. The heat storage means 11 is thermally coupled with the compressor driver 3 in the present example by a heat pipe or thermosiphon 12. In the example at hand, the heat storage means 11 is configured to store heat generated by the compressor driver 3 in the heating and/or cooling mode, and configured to transfer the stored heat to the refrigerant in the refrigerant circuit 2 in a defrost mode of the refrigerant circuit 2 or the heat pump system 1, respectively. In order to switch between defrost and heating/cooling mode, a first valve V1 and a second valve V2 is part of the refrigerant circuit 2. The first valve V1 enables/disables the flow of the refrigerant through the first heat exchanger 7, whereas the second valve V2 enables/disables the flow of the refrigerant through the heat storage means 11.

[0052] In operation of the heat pump system 1, in the heating mode or cooling mode, first valve V1 is open and second valve V2 closed. The compressor 6 and in particular the compressor driver 3 generate waste heat that is transferred to the heat storage means by the heat pipe or thermosiphon 12. As the second valve V2 is disclosed, the stored heat is

not transferred to the refrigerant in a noteworthy extent. When a defrosting mode is activated and the cycle in the refrigerant circuit 2 is reversed, the first valve V1 can be closed and the second valve V2 opened. Consequently, heat is transferred not from the first heat exchanger 7 to the second heat exchanger 8, but from the heat storage means 11 to the second heat exchanger 8 for defrosting the second heat exchanger 8. This is also shown by the control flowchart of figure 2.

[0053] Figure 2 shows an exemplary control flow chart of the embodiment of Fig. 1. Here, in a first step 20, normal operation of the heat pump system 1 (Fig. 1) is started. Hence, in a second step 21, heat is transferred to the heat storage means 11 (Fig. 1) and stored therein. In the third step 22, it is decided whether defrosting of the second heat exchanger 8 (Fig. 1) is necessary or not. If not, the system proceeds to the final step 29, which is identical to the first step 20 and leads to the desired normal operating mode as long as the heat pump system 1 is running.

[0054] If defrosting is required, the system proceeds to another step 23, where it is checked if there is still heat stored in the heat storage means 11. If heat is still stored and available for transferring in the heat storage means 11, in a subsequent step 24 valve V1 is closed and valve V2 is opened. In a next step 25 following step 24, the refrigerant circuit is switched to reverse cycle for the defrosting and the system goes back to step 22.

[0055] If there is no heat stored in the heat storage means 11, that is, heat storage means 11 is depleted, the system proceeds to another step 26, where the valve V1 is opened and the valve V2 is closed. Then, it is checked again in step 27 whether defrosting is required or not for the second heat exchanger 8. If not, the system proceeds to the final step 29, if yes, the system proceeds to step 28. In step 28, the normal reverse defrosting cycle is run as known in the state of the art.

[0056] Figure 3 shows parts of another exemplary embodiment of a heat pump system. Therein, the heat pump system 1 has a casing 13 in which the compressor 6, the thermosiphons 12, 12' as well as the heat storage means 11 and a control unit 14 are enclosed together with other parts of the refrigerant circuit 2 that are not shown for the sake of simplicity.

[0057] In the shown example, the heat storage means 11 comprises a first storage cell 15 and a second storage cell 16. Therein, each storage cell 15, 16 comprises a phase-change material with a specific phase-change temperature.

The phase-change temperature of the phase-change material of the first storage cell 15 is lower than the phase-change temperature of the phase-change material of the second storage cell 16. The compressor 6 is thermally coupled to the second storage cell 16 by the heat pipe or, preferably, thermosiphon 12. The control unit 14 is thermally coupled to the first storage cell 15 by another heat pipe or, preferably, thermosiphon 12'. This is reasonable as the compressor 6 (or, alternatively or in addition, the compressor driver 3 (Fig. 1) that might be thermally coupled to the second storage cell 16) generates more heat at a higher temperature than the control unit 14 (or, alternatively or in addition, other load units such as a transformer or diodes dissipating significant heat that might be thermally coupled to the first storage cell 15).

[0058] The heat storage means 11 also features an inlet 17 as well as an outlet 18 for the refrigerant of the refrigerant circuit 2. Inlet 17 and outlet 18 are used to conduct the refrigerant through or along the first storage cell 15 with the lower phase-change temperature first, and through or along the second storage cell 16 with the higher phase-change temperature afterwards. Consequently, the heat storage means 11 can be considered as an additional heat exchanger. As the heat storage means 11 is attached to the casing 13, the casing 13 functions as the evaporating section of the additional heat exchanger and the phase-change material of the heat storage means 11 as the condensing section additional heat exchanger. Advantageously, the first storage cell 15 might be arranged in between the second storage cell 16 and the casing 13.

[0059] In the present example, the heat storage means 11 is arranged above the compressor 6 and the control unit 14 in the x-direction. As said x-direction corresponds to the direction of the negative gravitational force, simple and robust thermosiphons 12, 12' may be used instead of technologically more advanced heat pipes.

[0060] The integration of the heat storage means 11 in the refrigerant circuit 2, preferably arranged in the casing 13, enables a sleek design, where the described advantageous heat pump system 1 with improved defrosting can be installed even without having to change potentially already existing circuitry. So the heat pump system 1 with casing 13 can be provided as a plug-in module. Hence, the proposed heat pump system is particularly advantageous.

Claims

1. A heat pump system (1) with

a) a refrigerant circuit (2), where, via a refrigerant, heat is transferred between a first environment (4) and a second environment (5), the refrigerant circuit (2) comprising:

- a compressor (6) for compressing the refrigerant;
- a first heat exchanger (7) for transferring heat between the first environment (4) and the refrigerant circuit (2);
- a second heat exchanger (8) for transferring heat between the second environment (5) and the refrigerant

circuit (2);

where the first heat exchanger (7) is configured to operate as a condenser to cool the refrigerant in a heating mode, and the second heat exchanger (8) is configured to operate as an evaporator in the heating mode;

b) a compressor driver (3) electrically coupled with the compressor (6) for powering the compressor (6);

characterized in that

the refrigerant circuit (2) comprises a heat storage means (11) with a heat storage medium, the heat storage means (11) being thermally coupled with the compressor (6) or the compressor driver (3) and being configured to store heat generated by the compressor (6) or the compressor driver (3) in the heating mode and to transfer the stored heat to the refrigerant in a defrost mode of the refrigerant circuit (2).

2. The heat pump system (1) according to claim 1,

characterized in that

the heat storage means (11) is connected to the rest of the refrigerant circuit (2) parallel to the first heat exchanger (7).

3. The heat pump system (1) according to any of the preceding claims,

characterized by

a control unit (14) and/or at least one additional electrical load which is thermally coupled to the heat storage means (11).

4. The heat pump system (1) according to any of the preceding claims,

characterized in that

the compressor (6) and/or the compressor driver (3) and/or the control unit (14) and/or the at least one additional electrical load of the heat pump system (1) are thermally coupled to the heat storage means (11) by respective heat pipes or thermosiphons (12, 12').

5. The heat pump system (1) according to any of the preceding claims,

characterized in that

the heat storage medium comprises a phase-change material.

6. The heat pump system (1) according to claims 4 and 5,

characterized in that

the heat storage means (11) comprises at least two storage cells (15, 16) with different phase-change materials, where each storage cell (15, 16) has a different phase-change temperature, and each of the storage cells (15, 16) is thermally coupled to at least one of the following load units: the compressor (6) and/or the compressor driver (3) and/or the control unit (14) and/or the at least one additional electrical load.

7. The heat pump system (1) according to claim 6,

characterized in that

a first storage cell (15) with a lower phase-change temperature than a second storage cell (16) is thermally coupled with a first load unit of said load units, where the first load unit has a lower heat generation than a second load unit of said load units, and the second storage cell (16) is thermally coupled with the second load unit.

8. The heat pump system (1) according to claim 6 or 7,

characterized in that

the refrigerant circuit (2) is configured to conduct the refrigerant through or along the storage cells (15, 16) in ascending order of the respective phase-change temperatures in the defrost mode.

9. The heat pump system (1) according to claim 6 or 7 or 8,

characterized in that

one or several first storage cells (15, 16), in particular one or several first storage cells (15) with a lower phase-change temperature, are configured to transfer heat to one or several second storage cells (15, 16), in particular one or several second storage cells (16) with a higher phase-change temperature.

10. The heat pump system (1) according to any of the preceding claims,

characterized by

a temperature sensor for sensing the temperature of a working medium in a space heating/cooling circuit connected

with the first heat exchanger (7) for heating or cooling the first environment (4), wherein the heat pump system (1) is configured to transfer heat from the space heating/cooling circuit to the refrigerant passing through the first heat exchanger (7) when a temperature of the working medium decreases to a lower limit value, in particular the lowest phase-change temperature of the heat storage means (11), while a temperature of the second heat exchanger (8) does not reach a predetermined value.

11. The heat pump system (1) according to any of the preceding claims,
characterized in that

the heat pump system (1) is operable in a partial-load mode, where the refrigerant is used to store heat in the heat storage means (11) in addition to the heat generated by the compressor (6) or the compressor driver (3), and where, when the heat stored in the heat storage means (11) reaches a preset limit, in particular a maximum heat that can be stored in the heat storage means (11), the compressor (6) is switched off and the heat stored in the heat storage means (11) is transferred to the first environment (4).

12. The heat pump system (1) according to claim 11,
characterized in that

the heat storage means (11) comprises a connection to the space heating/cooling circuit, where the space heating/cooling circuit is to be connected with the first heat exchanger (7), and is configured to transfer heat to the working medium of the space heating/cooling circuit.

13. Method for operating a heat pump system (1) with

a) a refrigerant circuit (2), where, via a refrigerant, heat is transferred between a first environment (4) and a second environment (5), the refrigerant circuit (2) comprising:

- a compressor (6) for compressing the refrigerant;
- a first heat exchanger (7) for transferring heat between the first environment (4) and the refrigerant circuit (2);
- a second heat exchanger (8) for transferring heat between the second environment (5) and the refrigerant circuit (2);

where the first heat exchanger (7) is configured to operate as a condenser to cool the refrigerant in a heating mode, and the second heat exchanger (8) is configured to operate as an evaporator in the heating mode;

b) a compressor driver (3) electrically coupled with the compressor (6) for powering the compressor (6);

characterized by

- storing heat generated by the compressor (6) or the compressor driver (3) in a heat storage means (11) of the refrigerant circuit (2) in the heating mode, and
- transferring the stored heat directly to the refrigerant in a defrost mode of the refrigerant circuit (2).

FIG 1

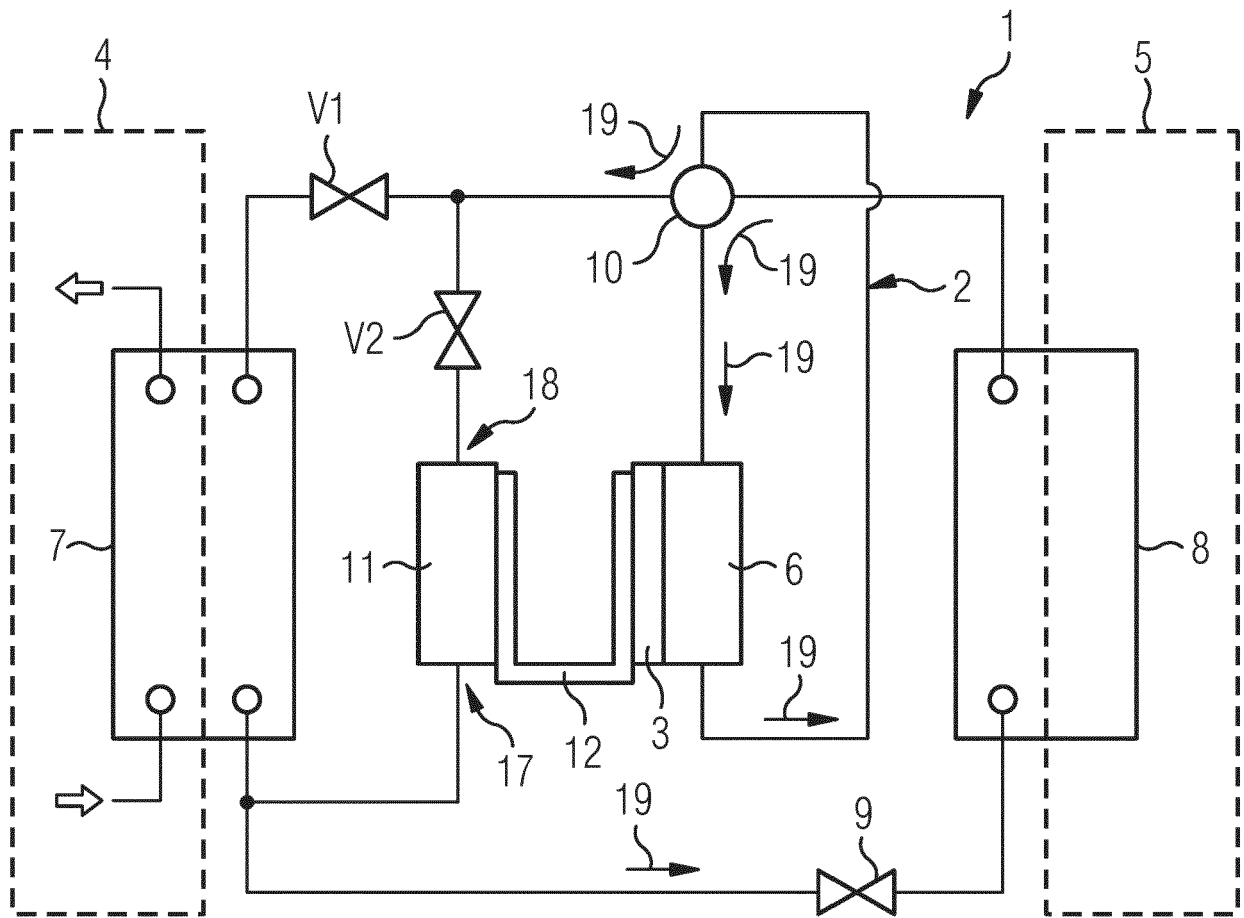


FIG 2

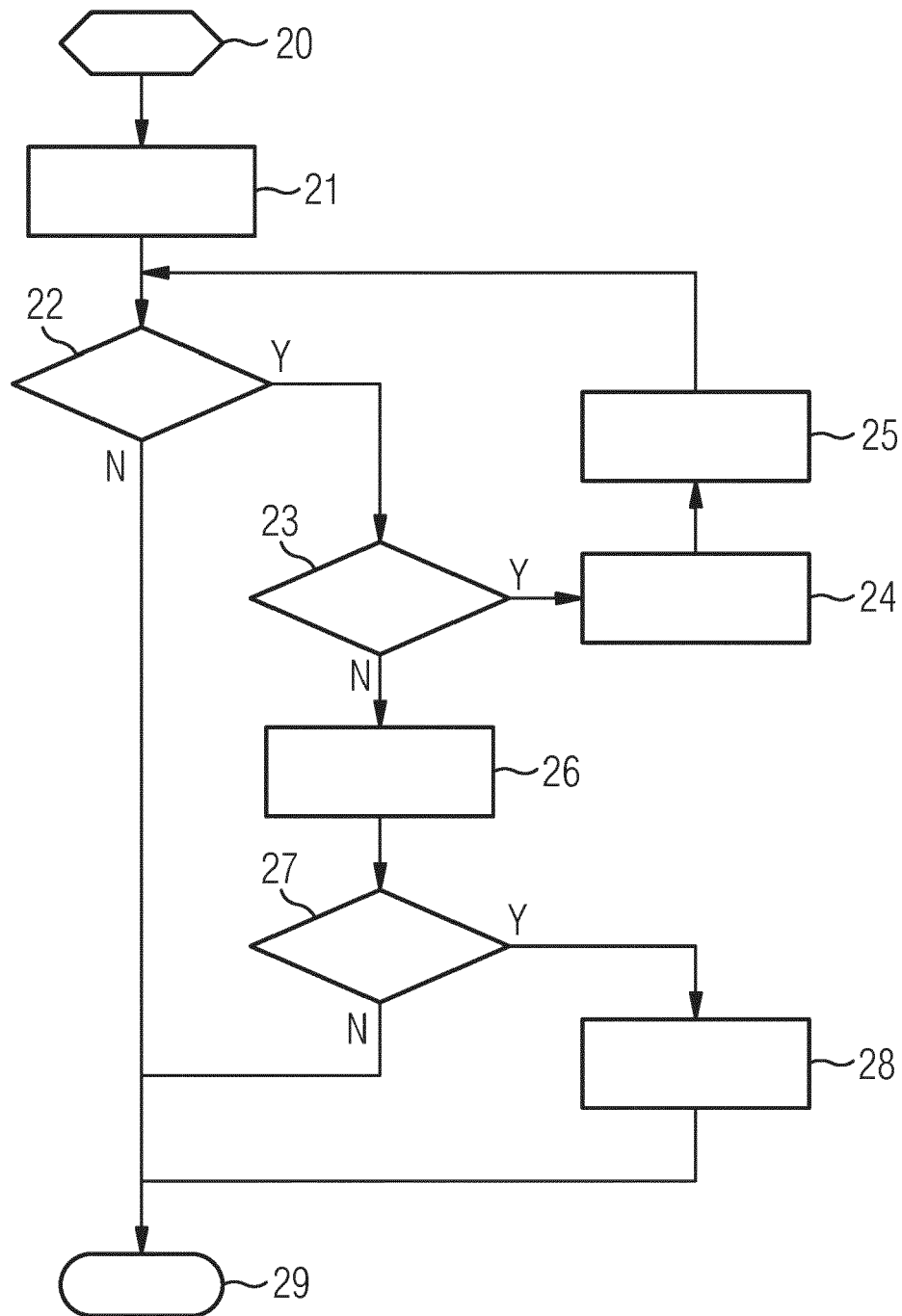
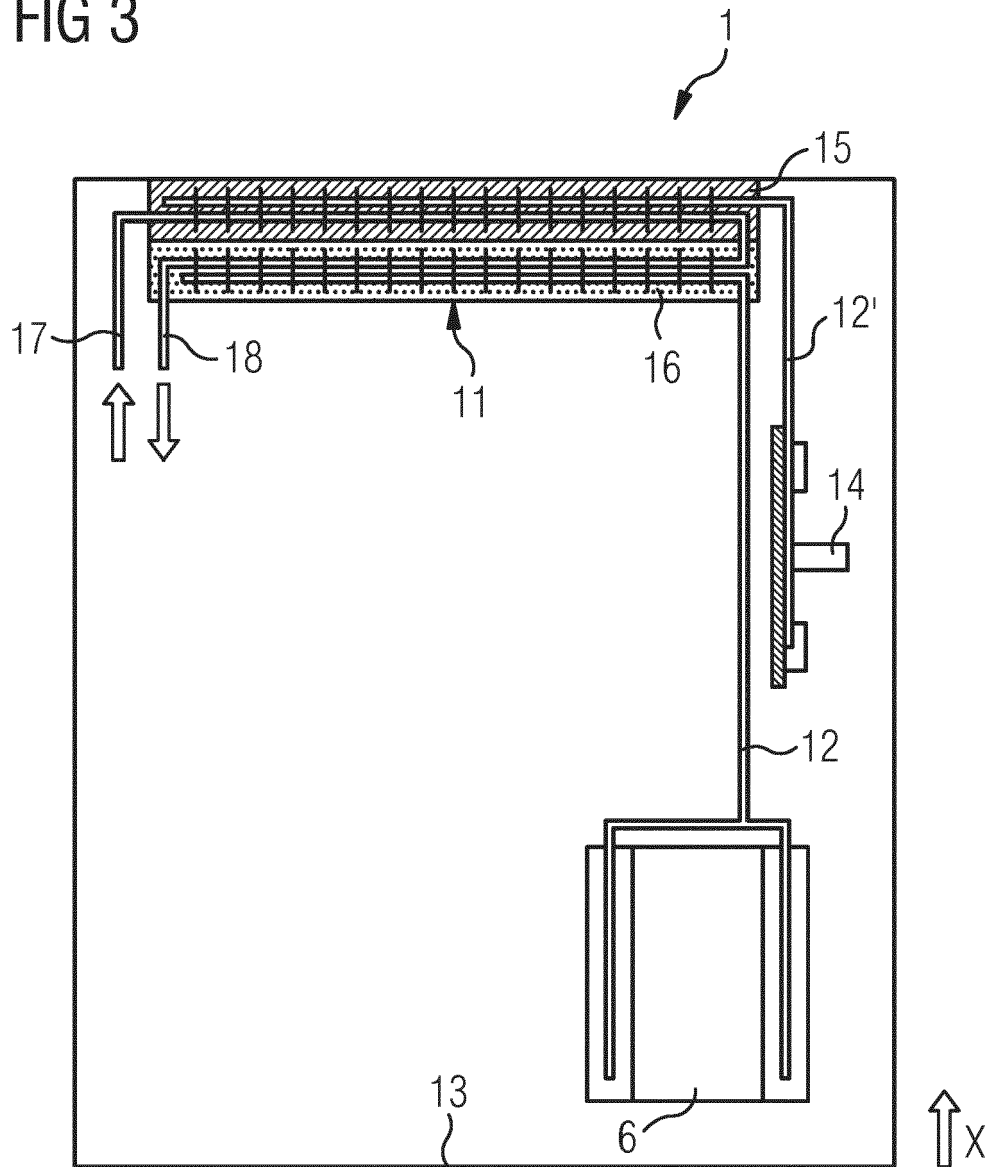


FIG 3





EUROPEAN SEARCH REPORT

 Application Number
 EP 18 16 3840

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2016/008134 A1 (ELECTROLUX HANGZHOU HOME APPLIANCE CO LTD [CN]; LIU WEI [CN]) 21 January 2016 (2016-01-21) * paragraphs [0013] - [0015], [0018], [0019]; figures 1-3, 1a, 2a, 3a *	1-5, 10-13	INV. F25B47/02 F25B13/00
Y		6-9	
X	EP 3 187 811 A1 (SAMSUNG ELECTRONICS CO LTD [KR]) 5 July 2017 (2017-07-05) * paragraphs [0035] - [0060]; figures 1-3 *	1-5, 10-13	
Y		6-9	
Y	WO 2017/221025 A1 (SUNAMP LTD [GB]) 28 December 2017 (2017-12-28) * claim 9; figures 7, 8 *	6-9	
X	US 4 727 726 A (MITANI AKIO [JP] ET AL) 1 March 1988 (1988-03-01) * column 6, line 38 - column 7, line 31; figure 4 *	1, 13	
A	DE 10 2012 004094 B3 (GLEN DIMPLEX DEUTSCHLAND GMBH [DE]) 13 June 2013 (2013-06-13) * paragraphs [0051], [0052]; figure 2 *	1-13	TECHNICAL FIELDS SEARCHED (IPC) F25B
A, D	EP 3 244 141 A1 (VAILLANT GMBH [DE]) 15 November 2017 (2017-11-15) * the whole document *	1-13	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 4 September 2018	Examiner Ritter, Christoph
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 18 16 3840

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

04-09-2018

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2016008134 A1	21-01-2016	AU 2014401283 A1 EP 3169950 A1 US 2017211861 A1 WO 2016008134 A1	02-02-2017 24-05-2017 27-07-2017 21-01-2016
EP 3187811 A1	05-07-2017	EP 3187811 A1 JP 2016109411 A KR 20160049994 A US 2018231278 A1	05-07-2017 20-06-2016 10-05-2016 16-08-2018
WO 2017221025 A1	28-12-2017	NONE	
US 4727726 A	01-03-1988	GB 2196727 A IT 1216864 B JP S63116073 A US 4727726 A	05-05-1988 14-03-1990 20-05-1988 01-03-1988
DE 102012004094 B3	13-06-2013	NONE	
EP 3244141 A1	15-11-2017	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- EP 3244141 A1 [0006]
- US 5269151 A [0007]
- EP 3165852 A [0008]
- US 20090282854 A1 [0009]
- US 20110315368 A1 [0010]
- US 20080086981 A1 [0010]