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HEAT PUMP DEFROSTING

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In an air source heat pump having a vapor compression circuit including a condenser 3, a compressor 2 and an evaporator 5, the vapor compression circuit operates with alternating run phases in which heat is extracted and defrost phases in which a buildup of ice on the evaporator melts. The heat pump is configured such that, throughout the defrost phases, the temperature of the evaporator is maintained at a low enough level (preferably below circa 4 °C) to avoid vaporisation of the melt

water. The heat pump includes:

- A passive defrost phase in which the compressor 2 of the vapor compression circuit is turned off but the air induction fan 6 remains on.

- An active defrost phase in which supplementary heat input is used to defrost the evaporator.

The supplementary heat input may be obtained by reversing the cycle of the vapor compression circuit at reduced power or by using an auxiliary heater 15.

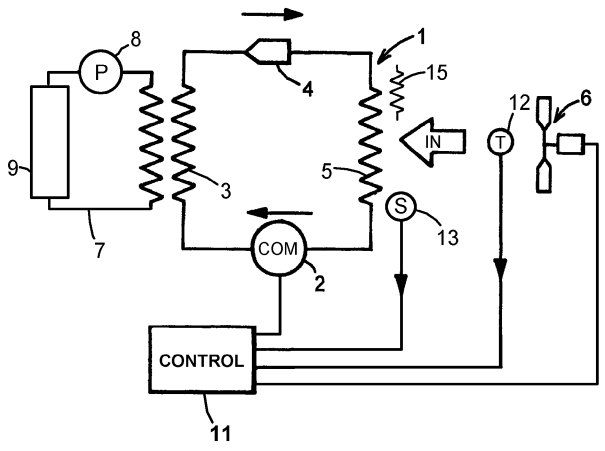


Fig. 1

Description

TECHNICAL FIELD OF THE INVENTION

[0001] This invention relates to the defrosting of heat pumps.

BACKGROUND

[0002] Air source heat pumps draw in ambient air from outside a building. Heat from the air is transferred via a refrigerant to a water circulation system which distributes the heat within the building, e.g. for use in underfloor heating.

[0003] Refrigerant heat pumps collect heat from the ambient air by evaporating the refrigerant at pressure. The evaporating refrigerant is at a lower temperature than the ambient air and thus picks up heat. This heat comes from cooling the air (sensible heat) and by condensing, and sometimes freezing, water vapor in the air (latent heat). The main objective of a heat pump is to extract heat from the ambient air as efficiently as possible. They therefore have large heat exchangers with a relatively high air flow. The temperature difference between the evaporator and the ambient air is kept below 10 °C so that the evaporator runs at a higher temperature, which increases efficiency and reduces the need for defrosting. As a guide, the heat exchanger may run about 7 °C colder than the ambient air temperature, but when the ambient air is below 7 °C water vapor in the air still freezes on the evaporator coils. Above 7 °C condensation just runs off the coils without freezing.

[0004] When frosting occurs, defrosting of the evaporator needs to be done regularly otherwise the coils get iced up preventing effective heat exchange. Defrosting can be done by reversing the cycle of the heat pump so that the cold coil becomes hot using heat extracted from the circulation water that was heated during the heating phase. Reverse-cycle defrosting therefore uses energy that has been extracted from the air and reduces the overall efficiency of the heat pump. During conventional reverse-cycle defrosting the compressor is run at maximum power to speed up the defrosting process, because rapid defrosting is considered more efficient than slow defrosting.

[0005] US 2019234676-A1 describes a heat pump in which the evaporator has an auxiliary heater. The evaporator temperature is monitored over a period of time and when it drops below a threshold temperature the heater is switched on. Conversely, when the temperature rises above the temperature/time threshold the heater is turned off.

[0006] CN 108759138-A discloses an operation method and system for a secondary throttle intermediate incomplete cooling refrigeration system. Each low-pressure-stage unit is provided with a medium-temperature evaporator and a corresponding low-temperature evaporator. By using valve switching, the low-temperature

evaporators are defrosted through a low-pressure-stage compressor heat pump cycle.

[0007] An objective of the present invention is to reduce the energy consumption and improve the efficiency of air source heat pumps.

SUMMARY OF THE INVENTION

[0008] The present invention provides a heat pump having a vapor compression circuit which includes a condenser, a compressor and an evaporator. The vapor compression circuit operates with alternating run phases in which heat is extracted and defrost phases in which a buildup of ice on the evaporator melts. The heat pump is configured such that, throughout the defrost phases, the temperature of the evaporator is maintained at a low enough level to avoid vaporisation of the melt water.

[0009] There is no optimum temperature below which the evaporator should be maintained during defrost, but the lower the temperature the lower the amount of water evaporation and the greater the potential energy saving. Maintaining a lower temperature to melt the ice means that defrosting will take longer but less heat will be used. On the other hand, using a higher temperature risks wasting energy on evaporation of the melt water but the defrost period is shorter. In general, the aim should be to keep heat input to the evaporator low enough to maintain the evaporator temperature below around 4 °C throughout the defrost phase.

[0010] The present heat pump includes an active defrost phase which requires energy input and a passive defrost phase which, under suitable conditions, takes place with no appreciable energy input.

[0011] When the ambient temperature is above about 2 °C a passive defrost cycle can be used. The compressor is turned off whilst maintaining a flow of ambient air over the evaporator by keeping the fan running. At higher ambient temperatures the fan can be turned off altogether, thereby making fully passive defrost possible.

[0012] The air flow over the evaporator will speed up the defrost time but the amount of time needed to achieve full defrost will depend on the capacity of the system. For example, if the capacity of the heat pump is sufficient to heat at 75% of its duty the defrosting time can be one-third of the run time providing there is enough thermal energy in the system. In many heating applications it may be desirable to reduce the run time and thereby the defrost time to maintain a comfortable temperature, e.g. 30 minutes on 10 minutes off as opposed to 60 minutes on and 20 minutes off.

[0013] When the external air temperature approaches freezing it becomes necessary to use supplementary heat input to defrost the evaporator (active defrost), but in such cases the heat input to the evaporator is still controlled to maintain the evaporator at a sufficient temperature to melt the ice but low enough to minimise vaporisation of the melt water (i.e. an evaporator temperature below about 4 °C).

[0014] The supplementary heat input to defrost the evaporator may be obtained by reversing the vapor compression cycle of the heat pump in known manner. Alternatively, the defrost heat input can be obtained from an auxiliary heat source such as an electrical resistance heating element, but again, the defrost temperature is controlled to minimise vaporisation.

[0015] Another option is to provide a defrost circuit to actively collect ambient heat and transfer it to the evaporator coils. The defrost circuit may use a refrigerant or water. In the case of water circulation the heat is transferred from the air to the water and then from the water to the heat pump refrigeration circuit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The following description and the accompanying drawings referred to therein are included by way of non-limiting example in order to illustrate how the invention may be put into practice. In the drawings:

Figure 1 is a diagrammatic drawing of an air source heat pump with an energy-efficient defrost system;

Figure 2 is a graphical representation to demonstrate the active and passive defrost phases of the heat pump;

Figure 3 is a graph showing the variation in evaporator temperature during a typical defrost phase.

DETAILED DESCRIPTION OF THE DRAWINGS

[0017] The air source heat pump shown in **Fig. 1** incorporates a vapor compression refrigeration circuit 1 in which a compressor 2 circulates refrigerant vapor under pressure through a condenser 3 wherein the refrigerant condenses and gives up heat. Condensed refrigerant then passes through an expansion device 4 such as a valve, a small bore tube or other device providing a restriction, which reduces the temperature and pressure of the refrigerant entering evaporator coils 5. Ambient air is drawn into the heat pump by an induction fan 6 to produce an induced flow of ambient air over the evaporator 5. Vaporisation of the refrigerant in the evaporator 5 absorbs heat from the ambient air. Depending on atmospheric conditions, the resulting temperature drop may cause water vapor in the incoming air to condense out on the surfaces of the evaporator coils. Refrigerant vapor from the evaporator is recirculated by the compressor 2 in a continuous cycle of condensation and evaporation. The condenser 3 transfers heat by heat exchange with a water circulation system 7 in which water is circulated by a pump 8, e.g. via underfloor heating pipes 9.

[0018] The operation of the heat pump is overseen by an electronic controller 11 which controls the compressor 2 and the fan 6 such that, when conditions are such that defrosting of the evaporator is required, a defrost system

is implemented in which the compression circuit operates in defrost cycles with alternating run (heat transfer) and defrost phases. The controller has an air temperature sensor 12 to monitor the temperature of the incoming ambient air, and an evaporator sensor 13 to monitor the temperature of the evaporator 5 and predict frosting of the evaporator coils.

[0019] The refrigeration circuit is optimised to maintain the difference between the evaporator temperature and the incoming air temperature at circa 7 °C. For much of the time, under normal seasonal weather conditions, the evaporating point is above freezing, which maintains good heat transfer efficiency and reduces the need for defrosting.

[0020] The heat pump is also arranged to minimise energy consumption during defrost periods. During the heat transfer phase the amount of latent heat due to condensation and freezing of water vapor from the air can be up to 50% of the total heat extracted by the evaporator 5. When the process is reversed during defrost the same amount of energy is required to change the frozen water back to liquid and then to water vapor. However, it is not necessary to vaporise the water during defrost; the most important requirement is to melt the ice. The energy required to melt the ice is 334 kilo joules per kilogram (KJ/Kg) while vaporising the water requires a further 2,260 KJ/Kg. Therefore melting the ice without vaporisation has the potential to save significant amounts of energy.

[0021] It has been found that vaporisation is considerably reduced if the defrosting temperature is kept low, ideally below circa 4 °C. Therefore, during active defrost requiring energy input the controller 11 aims to keep the defrosting temperature at or below this temperature. Without control, the defrosting temperature can easily exceed 20 °C causing a large proportion of the melt water to vaporise.

[0022] The heat pump also uses an even more energy efficient method of defrosting, which is to use the ambient air, which only requires a relatively small amount of energy. It has been found that ambient air defrosting can be used with air temperatures as low as circa 2 °C. This method of defrosting takes longer than active defrosting using additional heat input, and the lower the air temperature the longer the time needed. Run times between defrost is about 60 minutes and an ambient defrost could take as long as 30 minutes, but the defrost period is significantly reduced at relatively low energy cost by running the fan 6 to increase the induced flow of ambient air over the evaporator.

[0023] **Fig. 2** demonstrates the different defrost phases which the heat pump may enter when the ambient air temperature is low enough to require operation of the defrost system.

[0024] Above circa 7 °C there is no icing of the evaporator, so no defrost is required and the defrost system is therefore inactive. When the air temperature drops below 7 °C frosting of the evaporator may occur so the de-

frost system is then brought into operation. Although operation of the defrost system may be initiated by monitoring the incoming air temperature, a preferred and more accurate method is to initiate the defrost system when the evaporator temperature falls below 0 °C as detected by the evaporator sensor 13.

[0025] When the detected evaporator temperature falls below freezing and the defrost system is brought into operation the vapor compression circuit operates in defrost cycles with alternating run and defrost phases. However, when a defrost phase commences the ambient air temperature may still be significantly above freezing and warm enough to defrost the evaporator. The compressor 2 is therefore switched off, entering a passive defrost phase. When the incoming air temperature is close to 7 °C the fan 6 may also be switched off so that the defrost phase is entirely passive requiring no supplementary energy input, but it is normally desirable to keep the fan running for at least part of the defrost period to speed up defrosting. Nevertheless, since the energy input during the defrost phase is considerably less than during the run phase this is conveniently referred to as a passive defrost phase.

[0026] At incoming air temperatures below about 2 °C an active defrost phase is required, with supplementary heat input during the defrost phase of the defrost cycle. This can be achieved by reversing the refrigerant flow to heat up the evaporator 6 as in a conventional heat pump. However, the temperature of the evaporator is closely controlled, e.g. by reducing the speed of the compressor or turning it on and off, to ensure that the evaporator does not rise above circa 4 °C and thereby avoiding significant vaporisation of the melt water. It has been found that running the compressor at half speed throughout a defrost period is a good compromise, ensuring, on the one hand, that the evaporator temperature remains low enough to avoid vaporisation whilst, on the other hand, enabling the defrost to be achieved quickly enough to maintain heat input.

[0027] The heat pump preferably uses a BLDC (brush less direct current) variable speed compressor driven by an inverter which allows the applied frequency and voltage to be varied to achieve the required running speed.

[0028] Although passive defrost using ambient heat and active defrost with reduced compressor speed both tend to increase the defrost time this can be compensated by using a more powerful compressor during the heat extraction phase, thereby increasing the amount of heat which is available to compensate for the defrost period. The volume of water in the water circulation system may be increased to allow extra heat storage, but in some cases the water circulation system can run at a higher temperature.

[0029] Fig. 3 shows the typical operating temperature curve of the heat pump evaporator during a defrost phase (active or passive). It is assumed that the incoming ambient air temperature is below 7 °C so that the defrost system is active and the evaporator 5 will eventually start

to collect ice. After the heat pump has been running for a sufficient period for the vapor compression circuit to stabilise (point A) the controller 11 commences taking periodic temperature readings from the evaporator using sensor 13 and calculates the rate of temperature change. When ice eventually starts to form the evaporator temperature will start to fall at an increasing rate. When the rate of fall exceeds a threshold value, indicating that ice has built up on the evaporator to a point where the rate of heat transfer is significantly reduced, a passive or active defrost period commences (point B) depending on the measured ambient air temperature, as described above. By way of example, if the ambient air temperature is say 5 °C the evaporating temperature will fall to -2 °C (a 7 °C differential with the air). As the ice builds up the evaporator temperature will fall further due to the reduced heat transfer caused by the ice. The fall rate will increase when the ice is thicker, and the defrost phase will start at this point. It is this rate of change which determines the need for defrosting.

[0030] As the ice melts the temperature of the evaporator tends to rise to zero and remain at this value until the ice has melted before continuing to rise. When the sensor 13 indicates that the evaporator is above freezing, say 1 or 2 °C, the defrost period ends (point C) and normal heat collection re-commences. The evaporator temperature then increases again to stabilise at the normal running temperature, as shown. After a minimum running period (e.g. one hour), and assuming that the ambient air temperature is still below the level at which icing is likely to occur, the controller re-commences monitoring the evaporator temperature to look for another dip due to icing, when a similar defrost period is initiated.

[0031] As an alternative to reversing the cycle of the refrigeration circuit when the external air temperature falls below about 2 °C the supplementary heat input to defrost the evaporator may be obtained from other heat sources, such as an auxiliary heat source which uses a thermostatically controlled electrical resistance heating element 15 (Fig. 1).

[0032] Another option is to use an auxiliary defrost circuit which actively collects ambient heat and transfers it to the heat pump circuit. The defrost circuit may use a refrigerant or water with antifreeze. In the case of a refrigerant the ambient coil would be the evaporating part of the auxiliary defrost circuit, and in the condensing phase the collected heat would be transferred to the main heat pump circuit. The compressor would run at a low speed to keep the condensing gas in the heat pump evaporator at a high enough temperature to melt the ice but not vaporise the frozen water. In the case of water circulation the heat is transferred from the air to the water and then from the water to the heat pump refrigeration circuit. Having an auxiliary defrost circuit to take heat from the air and transfer it to the heat pump evaporator could make continuous running possible with no defrost "off" periods. Again, the auxiliary heat source is controlled to maintain the heat pump evaporator below about 4 °C during the

active defrost phase.

[0033] It would be possible to use two or more evaporator coils in the heat pump circuit so that only one is in heat extraction mode while the others are switched off to allow the ice to melt.

[0034] As already noted, the maximum evaporator defrost temperature of around 4 °C is not rigid, but above this temperature some vaporisation of the melt water could occur reducing overall efficiency. The fan 5 could be allowed to run when the outside air temperature is as high as 5 °C, or even 6 °C, and still achieve a significant energy saving. The important thing is that in all of the defrost phases the temperature of the evaporator is kept low enough to avoid significant vaporisation of the melt water and wasted heat energy. When the external air temperature is high enough for ambient air defrost the energy input is low, but even when supplementary heat input is required the energy input is significantly reduced.

[0035] Whilst the above description places emphasis on the areas which are believed to be new and addresses specific problems which have been identified, it is intended that the features disclosed herein may be used in any combination which is capable of providing a new and useful advance in the art.

Brief explanation of the terms used herein

[0036] *Defrost cycle*: The vapor compression circuit operates with alternating run (heat exchange) and defrost phases.

[0037] *Defrost phase*: The part of a defrost cycle where ice melts.

[0038] *Run phase*: The part of the defrost cycle where heat is extracted.

[0039] *Defrost period (defrost time)*: Duration of the defrost phase.

[0040] *Defrost system*: The refrigeration circuit is operated with successive defrost cycles.

Claims

1. A heat pump having a vapor compression circuit including a condenser (3), a compressor (2) and an evaporator (5), wherein the vapor compression circuit operates with alternating run phases in which heat is extracted and defrost phases in which a build-up of ice on the evaporator melts, and wherein the heat pump is configured such that, throughout the defrost phases, the temperature of the evaporator is maintained at a low enough level to avoid vaporisation of the melt water.
2. A heat pump according to claim 1 wherein heat input to the evaporator (5) during defrost is kept low enough to maintain the evaporator temperature below 5 °C, preferably below 4 °C.

3. A heat pump according to claim 1 or 2 which includes a passive defrost phase in which the compressor (2) of the vapor compression circuit is stopped whilst maintaining an induced flow of ambient air over the evaporator (5).
4. A heat pump according to claim 3 in which the passive defrost phase is initiated when the ambient air temperature is between 7 °C and 2 °C.
5. A heat pump according to any preceding claim which includes an active defrost phase in which supplementary heat input is used to defrost the evaporator (5) whilst maintaining the heat input to the evaporator at a low enough level to avoid vaporisation of the melt water.
6. A heat pump according to claim 5 wherein the active defrost phase is initiated when the ambient air temperature falls below 2 °C.
7. A heat pump according to claim 5 or 6 wherein the supplementary heat input to defrost the evaporator (5) during the active defrost phase is obtained by reversing the vapor compression cycle of the heat pump and wherein the power of the compressor (2) is reduced relative to the run phase of the vapor compression cycle.
8. A heat pump according to claim 5, 6 or 7 wherein the supplementary heat input to defrost the evaporator (5) during the active defrost phase is obtained from an auxiliary heat source (15).
9. A heat pump according to any preceding claim wherein the vapor compression circuit is optimised to maintain a difference of less than 10 °C, preferably circa 7 °C, between the evaporator and the ambient air.
10. A heat pump according to any preceding claim which includes an electronic controller (11).
11. A heat pump according to claim 10 wherein the vapor compression circuit has an air temperature sensor (12) by which the electronic controller (11) monitors the temperature of the ambient air.
12. A heat pump according to claim 10 or 11 wherein the vapor compression circuit has an evaporator temperature sensor (13) by which the electronic controller (11) monitors the temperature of the evaporator (5).
13. A heat pump according to claim 12 wherein the electronic controller (11) is configured to take periodic readings from the evaporator using the evaporator temperature sensor (13) and calculate the rate of

temperature change.

14. A heat pump according to claim 13 wherein the electronic controller (11) initiates the passive defrost phase when the rate of temperature fall exceeds a predetermined threshold value indicative of ice formation on the evaporator. 5
15. A heat pump according to claim 12, 13 or 14 wherein the electronic controller (11) ends the passive defrost phase when the temperature of the evaporator rises above freezing, and preferably above 1 °C. 10

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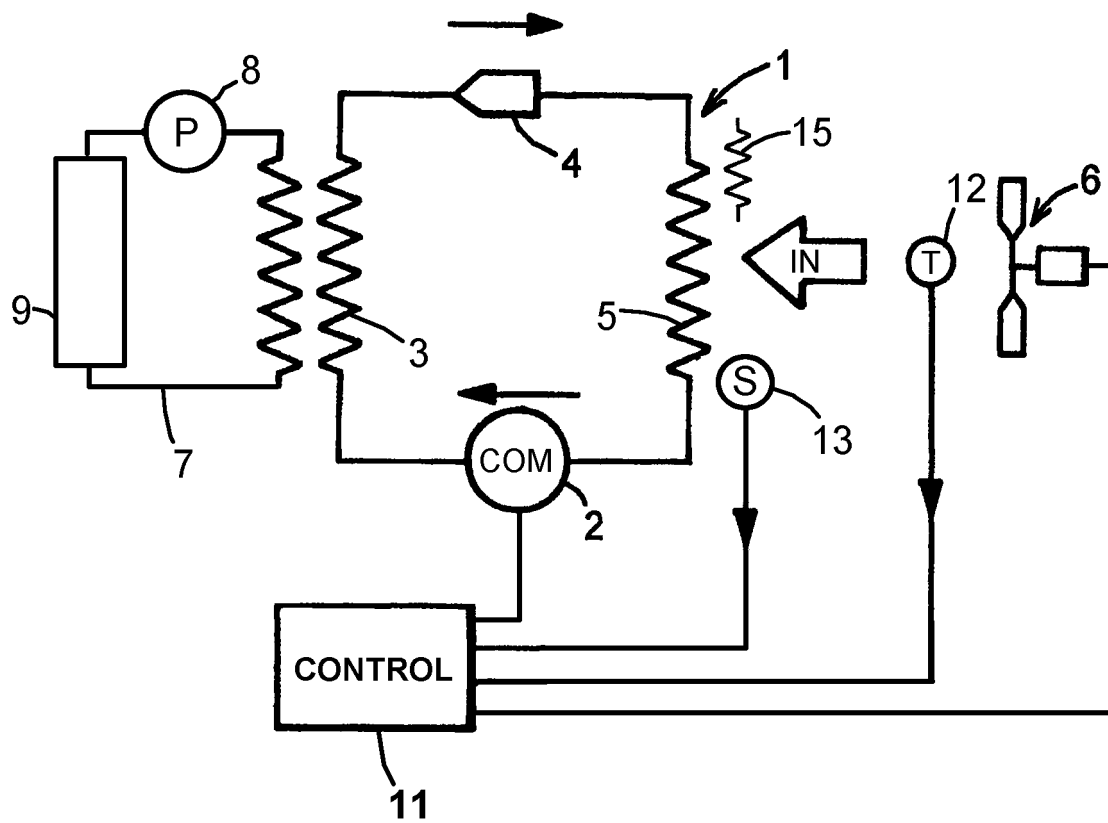


Fig. 1

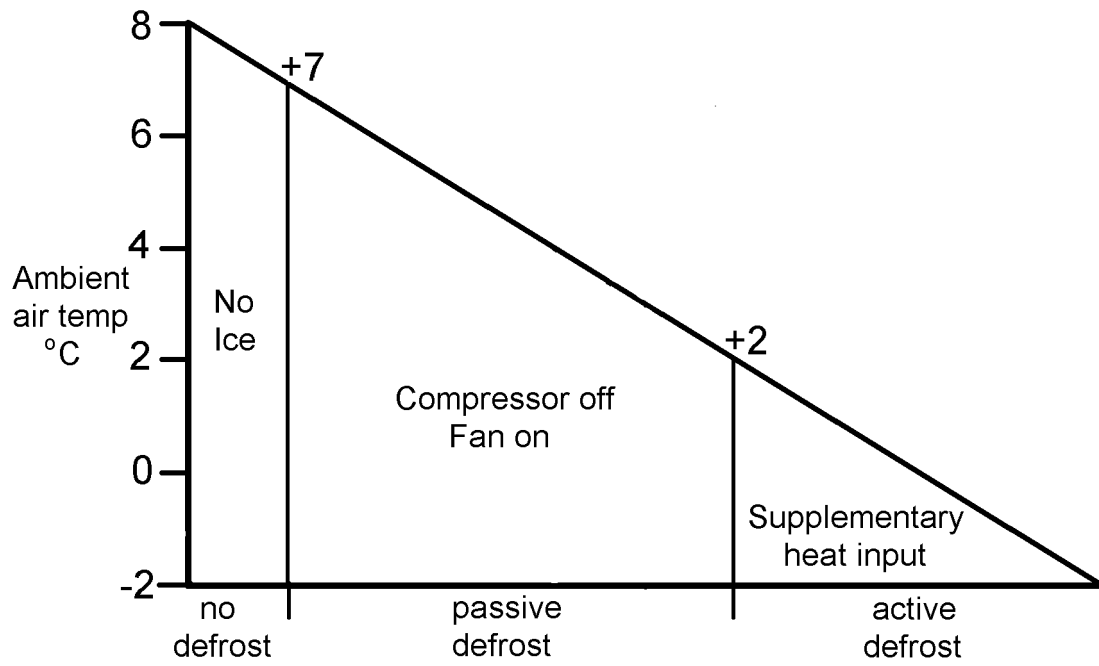


Fig. 2

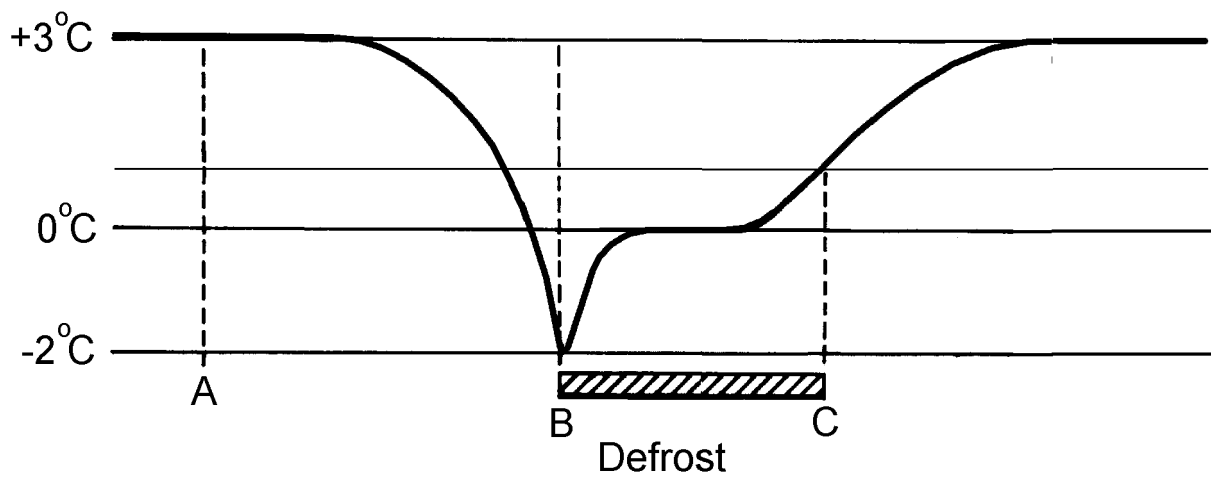


Fig. 3



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Application Number

EP 23 02 0385

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Place of search Munich		Date of completion of the search 19 December 2023	Examiner Gaspar, Ralf
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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