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(54) **System and method for optimized defrosting**

(57) Device for defrosting evaporators of heat pumps comprising at least a fluid-fluid heat exchanger (20) exchanging heat between two thermo-vector fluids, one heated by the heat pump in the condenser (12), and one circulating in a circuit where there are introduced at least a circulation pump and and at least a gas-fluid heat exchanger (14) which at the fluid side is provided with two

independent circuits, of which one is dedicated to defrosting and is crossed by the thermo-vector fluid circulating in said secondary circuit (26) and another where the evaporation phase of the vapor compression cycle occurs. The defrosting of the evaporation battery occurs by conveying therein the whole or a portion of the heat power of the heat pump, by means of the described circuit.

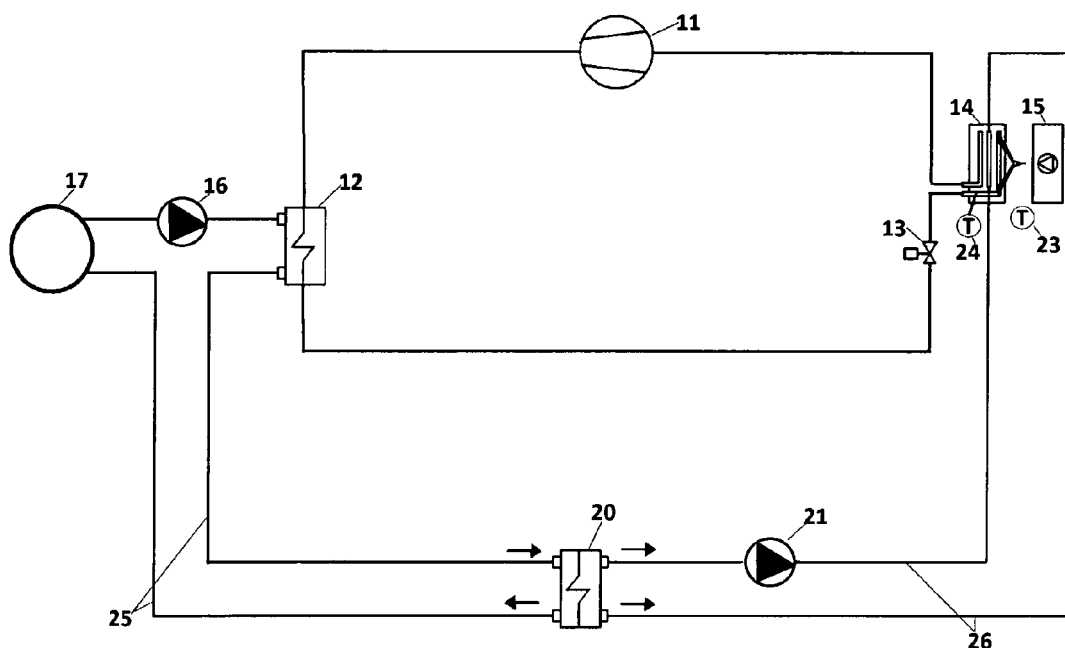


Fig. 1

Description

[0001] The present patent application for industrial invention relates to a device and a method for optimized defrosting to be applied for defrosting the outer heat exchangers of the heat pumps.

[0002] In the state of the art, there are known and commonly diffused in various applications machines operating vapor compression cycles, with different kinds of coolant. The vapor compression cycles transfer heat from a low temperature heat source to a higher temperature heat source. In many cases, for example in the heating systems for civil use, the low temperature heat source is made up of ambient air, which gives heat to the fluid operating the vapor compression cycle in a heat exchanger, which is generally of the finned type with fan. By giving heat to the thermo-vector fluid, the air gets colder and as a consequence, it increases the value of the respective humidity of the same air at the heat exchanger. It is known as in some functioning conditions the increase of the respective humidity of air at the heat exchanger can lead to condensation of such humidity on the heat exchange surfaces, and that the low surface temperature of the heat exchanger is then firstly the cause of hoarfrost formation and later of real ice layers. The ice layers formation on the exchange surfaces is disadvantageous in that the ice acts as insulating, and it makes less efficient the heat exchange between the low temperature source and the thermo-vector fluid operating the cycle, with a series of negative consequences on the carrying out of the same cycle.

[0003] In the state of the art, there are known a series of systems apt to face the problems caused by the hoarfrost and ice formation. The systems known in the state of the art consist of defrosting the heat exchange battery of the outer unit by means of the inversion of the vapor compression cycle, and their activation is controlled by sensing the evaporation pressure.

[0004] Such systems are disadvantageous in that the evaporation pressure inside the heat exchangers varies significantly only after the formation of significant hoarfrost or even ice layers, which require long defrosting cycles with consequently clear energy consumption.

[0005] Object of the present invention is to provide a device apt to defrost efficiently the evaporation batteries of the outer units of the heat pumps without requiring the inversion of the vapor compression cycle. According to another object of the present invention, it is provided a control logic able to sense the initial hoarfrost formation and to actuate the defrosting device before the hoarfrost formation is significant, thus obtaining the advantage of considerably shortening the defrosting cycle time and of avoiding off-design functioning conditions of the heat pump caused by low heat exchange efficiency.

[0006] These and other advantages will be highlighted by the following description, which refers to the appended figures.

Figure 1 shows an installation diagram of the device according to the present invention;

Figure 2 shows a graph describing the functioning conditions actuating the device according to the present invention.

[0007] As it is shown in figure 1, the device according to the present invention can be introduced in any vapor compression cycle functioning system. As a way of example, it is shown introduced in a system comprising a compressor (11), a heat exchanger (12) exchanging heat with the user circuit where there are introduced a pump (16) and an accumulation tank (17), a throttling valve (13) and a heat exchanger (14), which according to the present invention is provided with fan (15) exchanging with ambient air. It is to be précised that in a system operating a vapor compression cycle there is available a series of devices useful for safely and reliably carrying out the cycle, as for example valves, tanks, and any other component, which are not described in figure 1 for simplicity and whose use is known in the state of the art.

[0008] Yet in figure 1, there are shown the elements of the device according to the present invention. In particular, it is shown a heat exchanger (20) which exchanges heat between the thermo-vector fluid heated by the heat exchanger (12) and a thermo-vector fluid which, moved by the circulation pump (21) crosses a dedicated rank (22) of the heat exchanger (14), where it heats the surfaces of the heat exchanger covered with hoarfrost. As a way of example, the thermo-vector fluid can be a mixture of water and ethylene glycol or other fluid apt to exchange heat between the condensation temperatures and the cycle evaporation one. When the circulation pump (21) is switched on, the whole or a portion of the heat power provided by the heat pump to the user connected to the heat exchanger (12) is given in the heat exchanger (20) to the thermo-vector fluid which, moved by the pump (21) crosses one or more dedicated ranks (22) of the heat exchanger (14), heating its surfaces and thus avoiding the hoarfrost and ice formation on the same. The system functioning does not require the inversion of the vapor compression cycle, and according to the dimensioning of the heat exchanger (20) and to the adjusting of the pump (21), it subtracts a greater or lower heat fraction to the user. According to the embodiment shown in figure 1, the thermo-vector fluid in output from the heat exchanger (12) crosses necessarily the heat exchanger (20) before arriving in the accumulation tank (17). Except for the initial passage, there is no appreciable heat exchange in the heat exchanger (20) when the circulation pump (21) of the defrosting circuit is off. It is clear that any other circuit configuration connecting the heat exchanger (12) to the heat exchanger (20) and to the tank (17), apt to transfer, when needed, the heat power of the condenser (12) to the heat exchanger (20), is in the protection scope of the present patent claims. The heat exchanger (14) according to the present invention is provided with a rank (22) which is crossed by the ther-

mo-vector fluid moved by the pump (21). Any air-water heat exchanger provided with two separated fluid circuits at the fluid side, one for the coolant operating the vapor compression cycle and one for a second thermo-vector fluid needed for defrosting, is in the protection scope of the present patent claims.

[0009] In figure 1 there are shown two temperature probes (23) and (24) respectively measuring the outer air temperature and the evaporation temperature of the the fluid operating the vapor compression cycle. It was shown in fact that the usage of the temperature difference between the outer air and the evaporating fluid as a control variable is a more reliable and sensible index of the possible hoarfrost formation than the evaporation pressure and therefore allows to actuate the defrosting system in conditions of initial hoarfrost formation, thus limiting the defrosting cycle time and the heat energy quantity to be used for the same defrosting. What is more important is that in this way it is avoided the need for cycle inversions, from heat pump to chiller.

[0010] The system for controlling the hoarfrost formation according to the present invention uses the temperatures sensed by the two temperature probes (23) and (24) as input variables and it compares them with the temperatures proven indicative by the experimental tests of a functioning without hoarfrost on the evaporation battery, with probable hoarfrost formation or even sure ice presence on the evaporation battery. This method is efficient in that it anticipates the formation of ice layers on the battery, which are more difficult to be eliminated, by actuating the defrosting cycle for short time intervals. It is clear that this method for individuating the functioning conditions which provide probable hoarfrost formation is applicable also to heat pumps not provided with the defrosting circuit shown in figure 1 : in this case the sign of probable hoarfrost presence on the heat exchange surfaces can be used to actuate a cycle inversion. As input data, the method uses the evaporation and outer air temperature values. In figure 2, it is shown a graph indicating the air temperature value on the x-axis and the sensed evaporation temperature value on the y-axis. On this graph, the points (38) and (39) define the variability range considered for the outer air temperature. Therefore, there are individuated two points, (31) and (32) in figure 2, defining, at the ends of such range, the minimum evaporation temperature values (24) guaranteeing the optimal system functioning, without hoarfrost on the heat exchange surfaces. These two points are united in the graph with a straight line, above which it is defined the optimal working area, indicated with (33) in figure 2.

[0011] For evaporation temperatures lower than the ones indicated by the straight line uniting the points (31) and (32), it increases the possible ice formation. In particular, in figure 2 it is shown an area of probable presence of hoarfrost (34) and an area of sure presence of ice (35).

[0012] The individuation of the area of probable presence of hoarfrost (34) allows to carry out rapid defrosting cycles such that the hoarfrost is eliminated before an ice

layer is formed. In addition, by operating in this way it is possible to define a probability value for the hoarfrost presence, which results from the ratio between the distance of the indicative point of the operating conditions inside the area (34) from the curve (40) and the distance between the curve (41) and the curve (40) delimiting, as said, the conditions of sure presence of ice and sure absence of hoarfrost. The probability value of the hoarfrost presence thus determined can be therefore compared with a tolerated value of the maximum probability of hoarfrost formation before actuating the defrosting system. If the probability sensed exceeds the tolerated maximum probability, it is carried out a defrosting cycle of variable duration, directly proportional to the calculated formation probability of hoarfrost. The condition needed for the output from the defrosting cycle is air and evaporation temperatures reading which define a point of low probability of hoarfrost, lower than a predefined value considered sufficiently low to interrupt the defrosting cycle.

[0013] After carrying out the defrosting cycle, to avoid the rapid re-start of the cycle, the tolerated maximum probability value of hoarfrost formation before activating the defrosting system is increased by for example a quantity equal to 10%.

[0014] In the description of the method, there is no mention to the outer air temperature values, which define the points (31) and (32), since such values can vary as a function of the kind of the heat exchanger used without this leading to a variation in the sensing method of the initial formation of hoarfrost. As a way of example and in a not limiting way, it can be said that the average values for defining the points (31) and (32) are - 20°C and 7°C for the outer air temperature corresponding to values -25°C and -2°C for the evaporation temperature. For the same reasons, it was not defined the dimension of the area indicated with (34) where there is probable hoarfrost formation. As a way of example it can be said that the distance between the two curves is between 5 and 10°C and that this value can also be function of the outer air temperature.

Claims

1. Device for defrosting evaporators of heat pumps comprising at least a fluid-fluid heat exchanger (20), exchanging heat between two thermo-vector fluids, one circulating in a primary circuit (25) and heated by the heat pump in the condenser (12), and one circulating in a secondary circuit (26) where there are introduced at least a circulating pump (21) and at least a gas-fluid heat exchanger (14) **characterized in that** said gas-fluid heat exchanger (14) has at the fluid side two independent circuit, of which one is dedicated to defrosting (22) and is crossed by said thermo-vector fluid circulating in said secondary circuit (26) and another where the evaporation phase of the vapor compression cycle occurs, and **in that**

when said circulation pump (21) moves said thermo-vector fluid circulating in said secondary circuit (26) in the heat exchanger (20), heat is given by the fluid circulating in said primary circuit (25) to the fluid circulating in said secondary circuit (26), and **in that** by crossing said circuit (22) of said heat exchanger (14) such fluid heats its heat exchange surfaces, thus preventing the formation of hoarfrost or dissolving the possibly formed hoarfrost.

2. Method for defining the functioning conditions which can lead to the hoarfrost or ice formation on the surfaces of the outer heat exchanger of a heat pump based on sensing the evaporation temperature and the outer air temperature, **characterized by** the following steps:

- defining the ends (38, 39) of outer air temperature variability range inside which the method has to be applied;
- defining, for the extreme temperatures (38, 39) of said variability range of outer air temperature, the minimum evaporation temperatures (31, 32) guaranteeing the absence of hoarfrost on the heat exchange surfaces and the maximum evaporation temperatures (36, 37) under which there is sure formation of ice on the exchange surfaces;
- defining, for the permissible values of outer air temperature, the curve (40) of the minimum values of the evaporation temperatures guaranteeing the absence of hoarfrost on the heat exchange surfaces, by means of interpolation between the values (31, 32) previously defined for the considered range ends;
- defining, for the permissible values of outer air temperature, the curve (41) of the maximum values of the evaporation temperature under which there is sure formation of ice on the exchange surfaces by means of interpolation between the values (36, 37) defined for the considered range ends;
- for the evaporation temperature values between the curve (41) of the maximum temperatures under which there is sure formation of ice and the curve (40) of the minimum temperatures above which there is absence of hoarfrost, defining the probability of calculated hoarfrost formation as ratio between the difference between said temperature guaranteeing the absence of hoarfrost and the temperature considered, and the difference between said temperature guaranteeing the absence of hoarfrost and said temperature under which there is sure formation of ice.

3. Application of the method according to claim 2 to the use of the device according to claim 1, **character-**

ized by the following steps:

- sensing the outer air temperature by means of said temperature probe (23) and the evaporation temperature by means of said temperature probe (24);
- determining, in the temperature conditions sensed, the ice presence, the probable hoarfrost presence or sure absence of hoarfrost on the heat exchange surfaces by means of the method according to claim 2;
- in case of sure presence of ice, activating a defrosting cycle by means of the device according to claim 1;
- in case of probable hoarfrost presence comparing the probability of calculated hoarfrost presence by means of the method according to claim 2 with the predefined value for the maximum probability of tolerable hoarfrost presence, and activating a defrosting cycle by means of the device according to claim 1 of duration proportional to said calculated probability of hoarfrost presence only if said calculated probability of hoarfrost presence is greater than said predefined value for the maximum tolerated probability of hoarfrost formation;
- increasing said predefined value for the maximum probability of tolerated hoarfrost formation for a predefined time interval in order to avoid the rapid re-start of the defrosting cycle at the end of the same.

4. Method according to claim 2, **characterized in that** said variability range of outer air temperature inside which the method has to be applied is between -20°C and 7°C and **in that** said evaporation minimum temperatures (31, 32) guaranteeing the absence of hoarfrost on the heat exchange surfaces at said extreme temperatures of the variability range of the outer air temperatures are respectively -25°C and -2°C.
5. Method according to claim 2, **characterized in that** the difference between said minimum evaporation temperatures (31, 32) guaranteeing the absence of hoarfrost on the heat exchange surfaces and said maximum evaporation temperatures (36, 37) under which there is sure formation of ice on the exchange surfaces is between 5°C and 10°C.

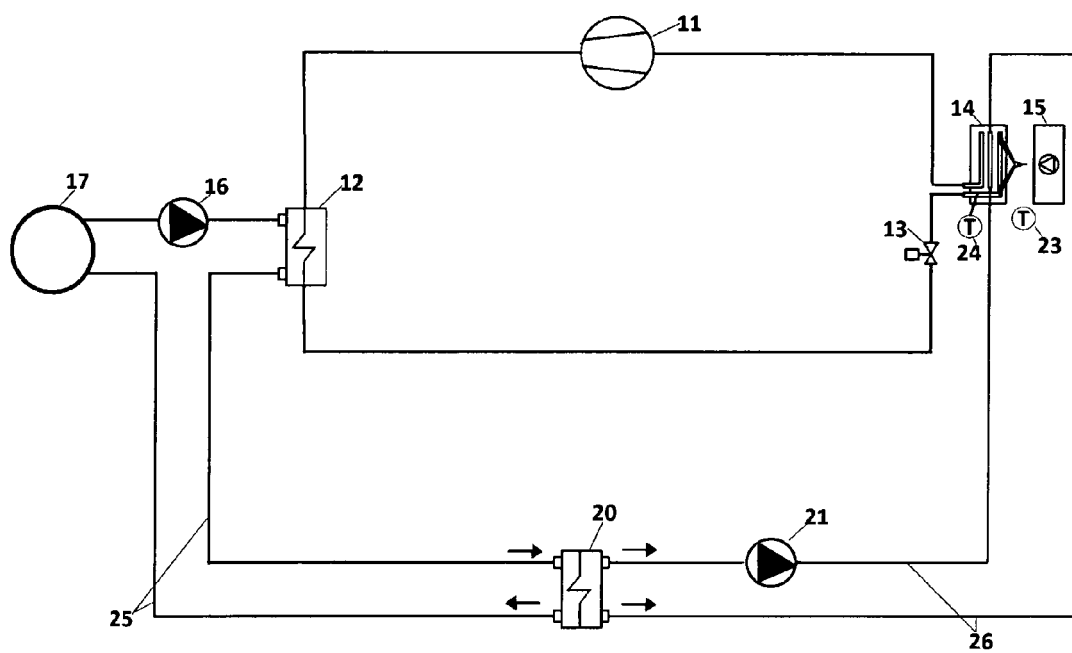


Fig. 1

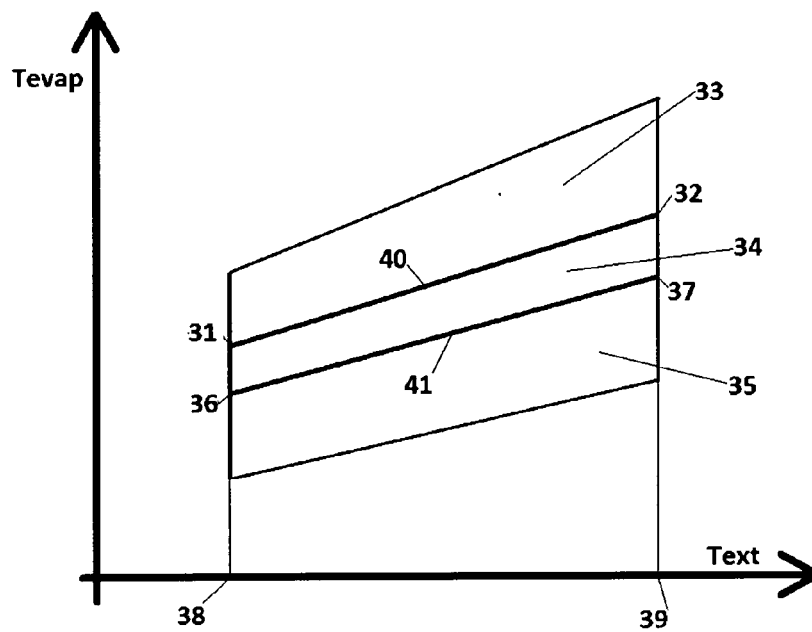


Figura 2



EUROPEAN SEARCH REPORT

Application Number
EP 11 42 5039

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	EP 2 048 451 A1 (SANDEN CORP [JP]) 15 April 2009 (2009-04-15) * paragraph [0013] - paragraph [0066]; figures 1-6 *	1	INV. F25B25/00 F25B47/02 F25B30/02 F25D21/12
A	FR 2 508 143 A1 (DIETRICH DE [FR]) 24 December 1982 (1982-12-24) * page 2, line 38 - page 4, line 40 *	1	
X	JP 4 263758 A (KANSAI ELECTRIC POWER CO; KYUSHU ELECTRIC POWER; CENTRAL RES INST ELEC) 18 September 1992 (1992-09-18) * figure 1 *	1	
			TECHNICAL FIELDS SEARCHED (IPC)
			F25B F25D
2 The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 29 July 2011	Examiner Szilagyi, Barnabas
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)



Application Number

EP 11 42 5039

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

see additional sheet(s)

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).



**LACK OF UNITY OF INVENTION
SHEET B**

Application Number
EP 11 42 5039

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claim: 1

Device for defrosting evaporators of heat pumps.

2. claims: 2-5

Method for defining the functioning conditions which can lead to the hoarfrost or ice formation on the surfaces of the outdoor heat exchanger of a heat pump.

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

EP 11 42 5039

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
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29-07-2011

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