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# (54) ANTI-FROST HEAT PUMP

(57) An anti-frost heat pump according to the present invention is capable of preventing an evaporator from frosting during a sub-cooling process by using heat released in the sub-cooling 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. A method of defrosting according to the present invention includes a sub-cooling step of performing a sub-cooling process of cooling a refrigerant flowing out of the condenser, and a heat transfer step of transferring heat released from the refrigerant in the sub-cooling process of the sub-cooling step to the evaporator during the sub-cooling process.

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## Description

**[0001]** The present invention relates to an anti-frost heat pump capable of preventing an evaporator from frosting during a sub-cooling process by using heat released in the sub-cooling process in sub-cooling means.

**[0002]** A heat pump including a refrigerant circuit typically has an evaporator, and a condenser. Under certain operating conditions the temperature of a surface of an outdoor heat exchanger, i.e. the evaporator, can fall below water freezing point temperature, and frost can start to accumulate and grow on the surface.

**[0003]** Frosting on a heat exchanger or evaporator can be the key factor behind several problems, namely restricting the air passing through the heat exchanger, or even blocking the air flow across the heat exchanger, if it is not defrosted, building up an insulation layer of frost and ice on a surface of the heat exchanger that degrades the evaporator's heat transfer performance, and reducing system operation reliability and causing some heat pump components, especially compressor and electric motor, to fail if long-term operation under such frosting conditions is maintained. Thus, efficient performance of the heat pump requires the removal of frosting and icing on the surface of the evaporator.

**[0004]** Conventionally, a defrosting operation on the evaporator is performed with heat accumulated during a normal heating operation separate from the defrosting operation. This means, the defrosting operation is performed at a different time than the normal heating operation. US 5 269 151 for example describes such a passive defrost system using waste heat, where waste heat is accumulated during normal heating operation in a storage module and then transported to the evaporator by a refrigerant circuit during a separate defrosting operation.

**[0005]** In the non-frost air source heat pump water heater of CN 201285159 the defrosting is alternatively performed by preheating an ambient air flow before reaching the evaporator by using waste heat from a refrigerant sub-cooling process.

**[0006]** In the passive defrost system of US 5 269 151 it is necessary to form a thermosyphon loop in order for refrigerant to be circulated naturally from the storage module to the evaporator during defrosting process due to gravity effect. Therefore the evaporator and the storage module have to be properly positioned to form this thermosyphon mechanism. Otherwise heat could not move from the storage module to the evaporator for defrosting operation. As refrigerant circulation naturally depends on the density difference between a hot refrigerant in the storage module and a cold refrigerant in the evaporator, controlling the defrosting process is very hard, not like an active defrost operation.

**[0007]** In the active defrost system of US 2013/0312437, the system configuration is similar. It requires the use of an additional refrigerant pump to circulate refrigerant from the storage module to the evaporator during defrosting operation. Therefore, an external energy input is required to run the refrigerant pump. Furthermore, the refrigerant pump has to be specially designed to work with high pressure refrigerant without leakage.

**[0008]** Moreover, for both passive and active defrost systems as mentioned above, the normal heating operation is interrupted by the defrosting operation.

**[0009]** In the non-frost air source heat pump water heater of CN 201285159 the pressure drop on the evaporator's air-side is increased due to an additional heat exchanger. Thus, a higher fan capacity is required. Further, the rate of the evaporator's air temperature reduction can be faster than the rate of an additional condenser's air temperature heating due to heat transfer delay from the refrigerant to air in the additional condenser.

**[0010]** The present invention is made to solve the above problems, and its object is to provide a heat pump capable of preventing an evaporator from freezing during a normal operation without interrupting this normal heating operation.

**[0011]** The above mentioned problems are solved by the heat pump according to claim 1 and the method of frost prevention according to claim 12. The respective dependent claims 2 to 11 relate to advantageous embodiments of the heat pump according to claim 1.

**[0012]** By a heat pump according to the present invention it is possible to perform a frost prevention operation during normal operation of the heat pump. Heat released from the refrigerant during the sub-cooling process can be accumulated and the heat can be continuously transported to the evaporator to maintain its surface temperature above the freezing point temperature. No external energy input is required in order to perform this frost prevention operation and the heat transfer of heat released in the sub-cooling process to the evaporator according to the present invention is highly efficient. It is a double benefit of the present invention that the higher the amount of the transported heat from the sub-cooling process for anti-frost operation is, the better the efficiency of the heat pump will be. Accordingly the surface of the evaporator, i.e. outdoor heat exchanger, can be kept clear without frosting and icing.

**[0013]** The present invention relates to a heat pump including a refrigerant circuit which includes 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.

**[0014]** A heat pump preferably is a device that moves heat from one location (a heat source) to another location (a heat sink). The transfer of the heat from the heat source to the heat sink can be achieved by means of a refrigerant circuit wherein the refrigerant undergoes a refrigeration cycle like, for example a vapor-compression cycle.

**[0015]** In the refrigerant circuit a refrigerant is preferably flowing through a pipe in a circuit, preferably a closed loop which includes the evaporator, the condenser and the sub-cooling means.

**[0016]** The evaporator is the part in the refrigerant circuit where the refrigerant can evaporate. This can cause the refrigeration effect, because a supply of energy to the refrigerant is needed in order for the process of evaporation to occur. The refrigerant can absorb heat from its environment in the evaporator and consequently cool this environment.

**[0017]** The evaporator can for example comprise a finned tube heat exchanger, comprising for example tubes provided with fins, arranged to exchange heat between the refrigerant and an environment of the heat exchanger. Furthermore, the evaporator can for example be arranged in a container.

**[0018]** The condenser is the part in the refrigerant circuit where the refrigerant can be condensed and liquefied by cooling down the refrigerant. Heat is released in the process of condensing and absorbed by the environment of the condenser, consequently cooling the refrigerant and heating its environment. Thus heat is extracted from the refrigerant and can be used for heating elsewhere. The condenser for example is in contact with a heat exchanger, such as a plate heat exchanger, arranged to exchange heat between the refrigerant and an environment of the heat exchanger, for example by radiating heat by a plate, preferably made of a heat conducting metal. The heat can for example also be used to heat up water in contact with the heat exchanger.

**[0019]** The sub-cooling means in the refrigerant circuit can be used to perform a sub-cooling process of cooling a refrigerant flowing out of the condenser. In the sub-cooling means the refrigerant can be further cooled. For example, if the liquefaction in the condenser is not complete, the refrigerant can preferably be completely liquefied in the sub-cooling means by cooling the refrigerant. The refrigerant can be cooled in the sub-cooling means due to an absorption of heat by its environment. Thus, heat is extracted from the refrigerant and can be used for heating elsewhere.

**[0020]** The sub-cooling means for example can comprise a meandering pipe and/or a piping coil containing a refrigerant, wherein the meandering pipe and/or the piping coil can be part of the refrigerant circuit. The meandering pipe and/or the piping coil can for example extend in a plane.

**[0021]** In the sub-cooling means the refrigerant can be cooled and the heat can be extracted from the refrigerant along the length of the piping in which the refrigerant is flowing. A certain amount of heat is exchanged per length of the piping. Thus by a meandering of the pipe, a larger amount of heat exchange can be achieved in a smaller volume of the sub-cooling means.

**[0022]** Heat transfer means can be used to transfer heat released by the refrigerant in the sub-cooling process from the sub-cooling means to the evaporator during the sub-cooling process. The heat transfer means preferably have a sufficient thermal conductivity, such that heat released in the sub-cooling means can reach the evaporator before the surface temperature of the evaporator is reduced to water freezing point temperature.

**[0023]** It is thus an idea of the present invention to maximise waste heat transportation obtained from the sub-cooling process to the evaporator for anti-frost operation, for example by rearranging the components of the heat pump or by using heat pipes.

**[0024]** The heat transfer means for example can comprise at least one pipe containing a refrigerant and/or a plurality of heat pipes, wherein the pipe and/or the heat pipes can extend from the sub-cooling means to the evaporator and can be in a heat conducting contact with both the sub-cooling means and the evaporator.

**[0025]** The meandering pipe and/or the piping coil of the sub-cooling means can for example extend in a first plane, and the evaporator can have a largest surface extending in a second plane different from said first plane, wherein the heat transfer means comprise at least one piping containing a refrigerant and/or a plurality of heat pipes, and the piping or the heat pipes extend partially in said first plane and extend partially parallel to and/or in contact with said largest surface of the evaporator in said second plane. The meandering pipe and/or the piping coil of the sub-cooling means preferably extends in a horizontal plane and the meandering pipe and/or the piping coil of the sub-cooling means is preferably arranged in the base of and/or below the evaporator. For example, by this arrangement, a close heat conducting contact of the sub-cooling means and the evaporator can be achieved and heat transfer means transferring heat from the sub-cooling means to the evaporator can be set up advantageously.

**[0026]** The heat transfer means can advantageously comprise heat pipes. Heat pipes are heat transfer devices. Preferably they have a thermal conductivity between 50 and 140 times greater than copper, wherein the specific thermal conductivity is preferably chosen as a function of the size of the evaporator. The heat pipes can for example comprise an envelope, as well as a wick and a working fluid arranged within this envelope. The envelope can for example comprise a sealed pipe or tube made of a material that is compatible with the working fluid, for example copper for water heat pipes, or aluminum for ammonia heat pipes. Preferably, a vacuum pump is used to remove the air from the empty heat pipe. The heat pipe can be partially filled with a working fluid and then sealed. The working fluid mass can preferably be chosen such that the heat pipe contains both vapor and liquid over the operating temperature range. Below the operating temperature, the liquid would be too cold and could not vaporize into a gas. Above the operating temperature, all the liquid would have turned to gas, and the environmental temperature would be too high for any of the gas to condense. For the heat pipe to transfer heat, it preferably contains both a saturated liquid, i.e. a liquid at vapor-liquid equilibrium, which is about to vaporize, and its vapor (gas phase). The saturated liquid then vaporizes at a position within the envelope, which is close to the sub-cooling means and travels to a position next to the evaporator, where it is cooled and turned back to a saturated liquid. In a standard heat pipe, the condensed liquid can for example be returned to a point close to the sub-cooling means using a wick structure exerting a capillary action on the liquid phase of the working fluid. Heat pipes preferably do not restrict an air flow passing through the evaporator due to a small diameter of the heat pipes.

**[0027]** The heat pipes preferably are in heat conducting contact with both the sub-cooling means and the evaporator. If for example the meandering pipe or the piping coil of the sub-cooling means extends in a plane and if the evaporator is arranged such that a largest surface of the evaporator is perpendicular and/or in a non-zero angle to said plane, the heat pipes can then for example extend partially in said plane and extend partially parallel to and in contact with said largest surface of the evaporator.

**[0028]** The heat transfer means can alternatively or additionally comprise an additional refrigerant circuit between the sub-cooling means and the evaporator. In this additional refrigerant circuit heat can be transferred from the sub-cooling means to the evaporator by refrigerant flowing through the additional refrigerant circuit. The refrigerant can preferably absorb heat at the sub-cooling means and release heat at the evaporator.

**[0029]** The heat pump can also include heat transfer controlling means arranged to control the transfer of heat by the heat transfer means during the sub-cooling process, wherein the heat transfer controlling means preferably comprise at least one valve, for example a solenoid valve or a proportional valve, which for example can be a motor driven valve, a stepper motor driven valve or a magnetic valve. The at least one valve can for example allow for a switching over between different operation modes, e.g. standard operation and anti frost operation, by opening or closing a connection of an additional refrigerant circuit, i.e. of the heat transfer means, between the sub-cooling means and the condenser and/or a connection between a refrigerant conduit from the condenser to the sub-cooling means and the main refrigerant circuit of the heat pump.

**[0030]** Preferably, the refrigerant circuit can additionally have a compressor. The compressor can provide pressure in the refrigerant circuit and compress gaseous refrigerant. The compressor preferably is a mechanical device that increases the pressure of the refrigerant for example by reducing its volume. The compressor can force the refrigerant to circulate through the refrigerant circuit, by applying pressure.

**[0031]** Moreover, the refrigerant circuit can additionally have expansion means, preferably including an expansion valve. The expansion means, can expand the refrigerant. The expansion valve preferably is an expansion device that can remove pressure from the refrigerant.

**[0032]** Furthermore, at least one additional refrigerant conduit conducting refrigerant from an outlet of the condenser to the sub-cooling means and from the sub-cooling means back to the main refrigerant circuit can be provided. The refrigerant can be conducted back to the main refrigerant circuit for example to a point directly after the outlet port of the condenser and before the expansion device. The additional refrigerant conduit can be separate from and/or have the same refrigerant as the main refrigerant circuit, which is the refrigerant circuit having the condenser and the evaporator. The additional refrigerant conduit can furthermore be connected to the main refrigerant circuit of the heat pump by valves, preferably solenoid valves and/or proportional valves, which for example can be motor driven valves, stepper motor driven valves or magnetic valves. Moreover, a closed additional refrigerant conduit between condenser and sub-cooling means can be arranged by closing respective valves in the main refrigerant circuit.

**[0033]** Moreover, the sub-cooling means of the main refrigerant circuit can for example include at least one storage module arranged to store heat released in the sub-cooling process, wherein the storage module can be in heat conducting contact with the heat transfer means. The storage module can for example comprise a phase change material adapted to store the heat released in the sub-cooling means. The phase change material can be a substance, which is melting and solidifying at a certain temperature corresponding to the temperature range of the refrigerant in the refrigerant circuit of the heat pump and is therefore capable of storing and releasing heat. Heat can be absorbed when the material liquefies from solid to liquid and can be released when it solidifies from liquid to solid. The phase change material preferably has a lateral heat of fusion of at least 100 kJ/kg, particularly preferably of at least 200 kJ/kg and/or preferably has a melting point of at least 20°C, particularly preferably of at least 30°C and/or preferably has a melting point of less than 80°C, particularly preferably of less than 50°C.

**[0034]** In the following the invention is exemplified based on the drawings, without limiting the invention to the embodiments illustrated there. The features described in the examples can also be combined between the examples and be realized independent of the examples.

Fig. 1 illustrates the heat pump according to Embodiment 1 of the present invention.

Fig. 2 illustrates the heat pump according to Embodiment 2 of the present invention.

Fig. 3 illustrates a configuration for anti-frost operation of an evaporator using heat pipes according to Embodiment 3 of the present invention.

Fig. 4 illustrates a part of a refrigerant circuit of a heat pump according to Embodiment 4 of the present invention.

**[0035]** Fig. 1 illustrates a heat pump refrigerant circuit according to Embodiment 1 of the present invention. In the refrigerant circuit of Fig. 1 a refrigerant is flowing through a pipe 16, wherein arrows indicate the flow direction of the refrigerant. A compressor 5 compresses the refrigerant and forces the refrigerant to circulate through the pipe 16 of the refrigerant circuit. After being compressed by the compressor 5, the refrigerant enters the condenser 3 through an inlet port 12 of the condenser. Subsequently the refrigerant can be condensed in the condenser 3 and exit the condenser 3 through the outlet port 13 of the condenser. The condenser 3 of Fig. 1 is a plate heat exchanger. In the plate heat exchanger of Fig. 1 water enters the condenser 3 through an water inlet port 14. The water is heated in the plate heat exchanger. It exchanges heat with the refrigerant, i.e. it absorbs heat of the refrigerant and cools the refrigerant down. The heated water then exits the plate heat exchanger through the water outlet port 15.

**[0036]** In Fig. 1 after leaving the condenser 3, the refrigerant, which is cooled in the condenser 3, is conducted to sub-cooling means 1 where it cools further down. This is called sub-cooling process. Arrows indicate that the refrigerant is radiating heat during the sub-cooling process. From the sub-cooling means 1, where the sub-cooling process is taking place, a large bold arrow 4 illustrates the principle of the invention to transfer the heat released in the sub-cooling process to the evaporator 2 during the sub-cooling process.

**[0037]** The refrigerant in the refrigerant circuit of Fig. 1 is conducted from the sub-cooling means 1, to a strainer 10b, an expansion valve 6b, further to a strainer 10a, then to a receiver 9, again to a strainer 10, through an expansion valve 6a and a strainer 10c. The refrigerant is expanded at the expansion valves 6a, 6b and is then lead to the evaporator 2 where it can evaporate by absorbing heat from its environment. After reaching the evaporator 2 the refrigerant reaches the compressor 5, where it is again compressed.

**[0038]** Fig. 2 shows a refrigerant circuit according to Embodiment 2 of the present invention. In the refrigerant circuit of Fig. 2 a refrigerant is flowing through a pipe 16, wherein arrows indicate the flow direction of the refrigerant. A compressor 5 compresses the refrigerant and forces the refrigerant to circulate through the refrigerant circuit. After being compressed by the compressor 5, the refrigerant enters the condenser 3, which is arranged as described above with respect to Embodiment 1. After leaving the condenser 3 the refrigerant, which is cooled in the condenser 3, enters sub-cooling means 1, where it cools further down. The sub-cooling means 1, where the sub-cooling process can take place, are arranged subsequent to the condenser 3.

**[0039]** In this example the sub-cooling means 1 are connected to the main refrigerant circuit by an additional refrigerant conduit 7 conducting refrigerant from an outlet 13 of the condenser to the sub-cooling means 1 and from the sub-cooling means 1 back to the refrigerant circuit. As illustrated in Fig. 2 a solenoid valve 8b is installed in the main refrigerant circuit. The additional refrigerant conduit 7 branches off from the main refrigerant circuit between the outlet 13 of the condenser and solenoid valve 8b and conducts the refrigerant to the sub-cooling means 1. Between the junction of the additional refrigerant conduit 7 and the main refrigerant circuit in the piping directed to the sub-cooling means 1 another solenoid valve or proportional valve 8a is installed in the additional refrigerant conduit 7, as illustrated in Fig. 2. By closing the solenoid valve 8b and opening the solenoid valve or proportional valve 8a, the refrigerant exiting the condenser 3 can be forced to circulate through the sub-cooling means 1.

**[0040]** In Fig. 2 the sub-cooling means are arranged right below the evaporator 2. The sub-cooling means 1 are in heat conducting contact with the evaporator 2. The evaporator 2 of Fig. 2 can be a finned tube heat exchanger, which comprises tubes provided with fins, arranged to exchange heat between the refrigerant and its environment. The heat conducting contact of the sub-cooling means 1 and the evaporator 2 in Fig. 2 is implemented by heat transfer means 4, which in Fig. 2 are pointing to the pre-heating stage of the evaporator 2 and can transfer heat from the sub-cooling means to the evaporator 2.

**[0041]** In Fig. 2 the refrigerant after leaving the sub-cooling means 1, is conducted back to the main refrigerant circuit. The second junction of the additional refrigerant conduit and the main refrigerant circuit of Fig. 2 is arranged directly subsequent to the solenoid valve 8b in the main refrigerant circuit. After the second junction the refrigerant passes a strainer 10b, is expanded in an expansion valve 6b, passes a strainer 10a, a receiver 9, another strainer 10, and is again expanded in an expansion valve 6a, before it passes another strainer 10c and enters the evaporator 2. In the evaporator 2, the refrigerant evaporates, which can cause the refrigeration effect. Finally, the refrigerant is conducted back to the compressor 5.

**[0042]** Fig. 3 illustrates a configuration for anti-frost operation of an evaporator 2 using heat transfer means 4 according to an Embodiment 3 of the present invention. The sub-cooling means of Fig. 3 for example comprise a meandering pipe 17, i.e. a pipe which is arranged as a meander, and which wiggles in a horizontal plane and contains the refrigerant. The refrigerant in the meandering pipe 17 can for example arrive from a plate heat exchanger 3 (such as in Fig. 2) to the right and flow through the meandering pipe 17 in three loops before leaving the meandering pipe 17 towards an expansion valve (such as in Fig. 2) for example to the right. The meandering pipe 17 of the sub-cooling means extends substantially in said horizontal plane. It is for example arranged in four straight parallel sections extending in longitudinal direction and connected by three loops of 180°. Two loops are arranged at the side averted from the inlet and the outlet on the right side connecting the first and the second and the third and the fourth straight pipe as illustrated in Fig. 3. The third loop is in between those two loops connecting the second and the third straight pipe at the side of the inlet and the outlet.

**[0043]** The evaporator 2 of Fig. 3 is for example arranged above the meandering pipe 17 such that a largest surface of the evaporator 2 is perpendicular to said horizontal plane. The largest surface of the evaporator 2 is for example curved by 90° after three quarters of its extension as seen from the right side such that the right end of the largest surface extends parallel to the four straight pipes and the left end of said largest surface extends perpendicular to and across the four straight pipes.

**[0044]** The heat transfer means 4 of Fig. 3 comprise for example a plurality of seven heat pipes arranged in uniform distances along the longitudinal direction of the meandering pipe. The heat pipes 4 are for example extending partially in said horizontal plane perpendicular to and across the four straight pipes and after being bended by 90° are extending partially parallel to and in contact with said largest surface of the evaporator 2.

**[0045]** The meandering pipe 17 of the sub-cooling means of Fig. 3 is for example embedded in a storage module 11 which is arranged to store and release heat, respectively, for anti-frost operation. The storage module 11 for example comprises a box-shaped container in heat conducting contact with both the heat pipes 4 and the meandering pipe 17 with its largest surface extending in said horizontal plane. The container can for example serve as a base for the evaporator 2 arranged above the meandering pipe 17 in the storage module 11.

**[0046]** Fig. 4 shows a part of a refrigerant circuit according to an Embodiment 4 of the present invention. Like in the refrigerant circuit of Embodiment 2, in the refrigerant circuit of Fig. 4 a refrigerant is flowing through a pipe 16, wherein arrows indicate the flow direction of the refrigerant. The refrigerant enters the condenser 3, which is arranged as in Embodiment 1 of the present invention. Like in Embodiment 2, sub-cooling means 1 are arranged subsequent to the condenser.

**[0047]** According to Embodiment 4 of the present invention the sub-cooling means 1 are connected to the main refrigerant circuit by an additional refrigerant conduit 7 conducting refrigerant from an outlet 13 of the condenser to the sub-cooling means 1 and from the sub-cooling means 1 back to the main refrigerant circuit. The refrigerant can enter the main refrigerant circuit directly before the inlet port 12 of the condenser and/or before entering the expansion devices 6a and 6b.

**[0048]** As illustrated in Fig. 4, a solenoid valve 8f is installed in the main refrigerant circuit. The additional refrigerant conduit 7 branches off from the main refrigerant circuit between the outlet 13 of the condenser and a solenoid valve 8f and conducts the refrigerant to the sub-cooling means 1. Between the junction of the additional refrigerant conduit 7 with the main refrigerant circuit another solenoid valve or proportional valve 8d is installed in the piping directed towards the sub-cooling means 1. By closing the solenoid valve 8f and opening the solenoid valve or proportional valve 8d, the refrigerant exiting the condenser 3 can be forced to exit the main refrigerant circuit and to circulate through the additional refrigerant conduit and the sub-cooling means 1.

**[0049]** The sub-cooling means of Fig. 4 comprise a meandering pipe 17, i.e. a pipe arranged as a meander, which wiggles in a plane and contains the refrigerant. The additional refrigerant conduit 7 comprises the meandering pipe 17. In Fig. 4 the sub-cooling means 1 are arranged right below the evaporator 2. The sub-cooling means 1 are in heat conducting contact to the evaporator 2. The evaporator 2 of Fig. 4 can be a finned tube heat exchanger arranged to exchange heat between the refrigerant and its environment. The finned tube heat exchanger can have tubes provided with fins. The fins can be arranged on the surface of the tubes, in order to provide a large surface for heat exchange. The heat conducting contact of the sub-cooling means 1 and the evaporator 2 in Fig. 4 is implemented by heat transfer means 4, which can transfer heat from the sub-cooling means 1 to the evaporator 2. The heat transfer means 4 of Fig. 4 for example are heat pipes being in heat conducting contact with both the sub-cooling means 1 and the evaporator 2.

**[0050]** In Fig. 4 the refrigerant after leaving the sub-cooling means 1, is conducted back to the main refrigerant circuit. After a second junction the additional refrigerant conduit 7 subsequent to the sub-cooling means 1 is connected to the main refrigerant circuit via two separate branches which can be opened or closed by two solenoid valves 8e and 8g respectively. If the solenoid valve 8e is opened the refrigerant can flow back towards the inlet port 12 of the condenser 3. If the solenoid valve 8g is opened the refrigerant can flow back into the main refrigerant circuit in a third junction directly following the solenoid valve 8f in the flow direction. After this third junction the refrigerant can be conducted further to expansion devices 6a and 6b not shown in the section of the refrigerant circuit illustrated in Fig. 4. Subsequently the refrigerant reaches the evaporator 2, which is shown in the center of Fig. 4, where it evaporates due to heat absorbed from its environment.

**[0051]** In the refrigerant circuit of Fig. 4, the condenser 3 is positioned at a higher level than the sub-cooling means 1 such that the device can operate as a thermosyphon mechanism. A thermosyphon mechanism allows for natural circulation of a liquid based on convection without external supply of energy, as for example by a pump. This arrangement is in particular beneficial when using a water tank to store water and when the water tank temperature is higher than for hot domestic hot water supply operation. When the hot water tank temperature is reduced (for example, from 60°C to 50°C), heat from the water tank can be transferred back to refrigerant via the plate heat exchanger (i.e. the condenser 3). In this case the heat pump would be off and solenoid valves and/or proportional valves 8c,f,g would be closed while solenoid valves 8e,d would be opened. This establishes a closed refrigerant loop between the condenser 3 and the sub-cooling means 1 only. Thus the purpose is to get heat back from the hot water when the hot water tank overheats (usually from a change in desired temperature) and store it in the sub-cooling means 1.

**[0052]** Due to receiving heat back from hot water, the condenser 3 can become a heat source for the refrigerant while the sub-cooling means 1 can absorb heat from the refrigerant, functioning as a heat sink for the refrigerant. By this way, the refrigerant can circulate naturally between the condenser 3 and the sub-cooling means 1 (e. g. a thermosyphon mechanism) and heat can transfer continuously from the condenser 3 to the sub-cooling means 1 for anti-frost operation or heat storage.

Reference sign list

**[0053]**

| | |
|---|---|
| 1 | Sub-cooling means |
| 2 | Evaporator |
| 3 | Condenser |
| 4 | Heat transfer means |
| 5 | Compressor |
| 6a, 6b | Expansion devices, i.e. expansion valves |
| 7 | Additional refrigerant conduit |
| 8a-8f | Solenoid and/or proportional valves |
| 9 | Receiver |
| 10, 10a-10c | Strainer |
| 11 | Storage module |
| 12 | Condenser inlet port |
| 13 | Condenser outlet port |
| 14 | Water inlet port |
| 15 | Water outlet port |
| 16 | Piping of the main refrigerant circuit containing refrigerant |
| 17 | Meandering pipe |

## Claims

**1.** A heat pump including 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.

**2.** The heat pump of claim 1, wherein the refrigerant circuit further has:

a compressor, preferably a scroll compressor, that forces refrigerant to circulate through the refrigerant circuit comprising the evaporator and the condenser, and/or
expansion means, preferably including an expansion valve.

**3.** The heat pump of any one of claims 1 or 2, wherein the heat transfer means is an additional refrigerant circuit between the sub-cooling means and the evaporator.

**4.** The heat pump of claim 1 to 3, wherein the heat transfer means comprise at least one pipe containing a refrigerant and/or a plurality of heat pipes, the pipe and/or the heat pipes extending from the sub-cooling means to the evaporator and being in a heat conducting contact with both the sub-cooling means and the evaporator.

**5.** The heat pump of any one of claims 1 to 4, wherein the sub-cooling means comprise a meandering pipe and/or a piping coil containing a refrigerant, the meandering pipe and/or the piping coil being part of the refrigerant circuit.

**6.** The heat pump of claim 5, wherein
the meandering pipe and/or the piping coil of the sub-cooling means extends in a first plane,
the evaporator has a largest surface extending in a second plane different from said first plane,
and the heat transfer means comprise at least one piping containing a refrigerant and/or a plurality of heat pipes,
the piping and/or the heat pipes extending partially in said first plane and extending partially parallel to and/or in contact with said largest surface of the evaporator in said second plane.

**7.** The heat pump of claim 6, wherein the meandering pipe and/or the piping coil of the sub-cooling means extends in a horizontal plane and the meandering pipe and/or the piping coil of the sub-cooling means is arranged in the base of and/or below the evaporator.

**8.** The heat pump of any one of claims 1 to 7, wherein the sub-cooling means include at least one storage module arranged to store heat released in the sub-cooling process, wherein the storage module is in heat conducting contact with the heat transfer means.

**9.** The heat pump of claim 8, wherein the storage module comprises a phase change material adapted to store the heat released in the sub-cooling means, wherein the phase change material has a lateral heat of fusion of at least 100 kJ/kg preferably of at least 200 kJ/kg a melting point of at least 20°C, preferably of at least 30°C and/or a melting point of less than 80°C, preferably of less than 50°C.

**10.** The heat pump of any one of claims 1 to 9, further including an additional refrigerant conduit conducting refrigerant from an outlet of the condenser to the sub-cooling means and from the sub-cooling means back to the refrigerant circuit.

**11.** The heat pump of any one of claims 1 to 10, further including heat transfer controlling means arranged to control the transfer of heat by the heat transfer means during the sub-cooling process, wherein the heat transfer controlling means preferably comprise a solenoid valve and/or a proportional valve.

**12.** A method of frost prevention executed with a heat pump of any one of claims 1 to 11 including
a sub-cooling step of performing a sub-cooling process of cooling a refrigerant flowing out of the condenser, and
a heat transfer step of transferring heat released from the refrigerant in the sub-cooling process of the sub-cooling step to the evaporator during the sub-cooling process.

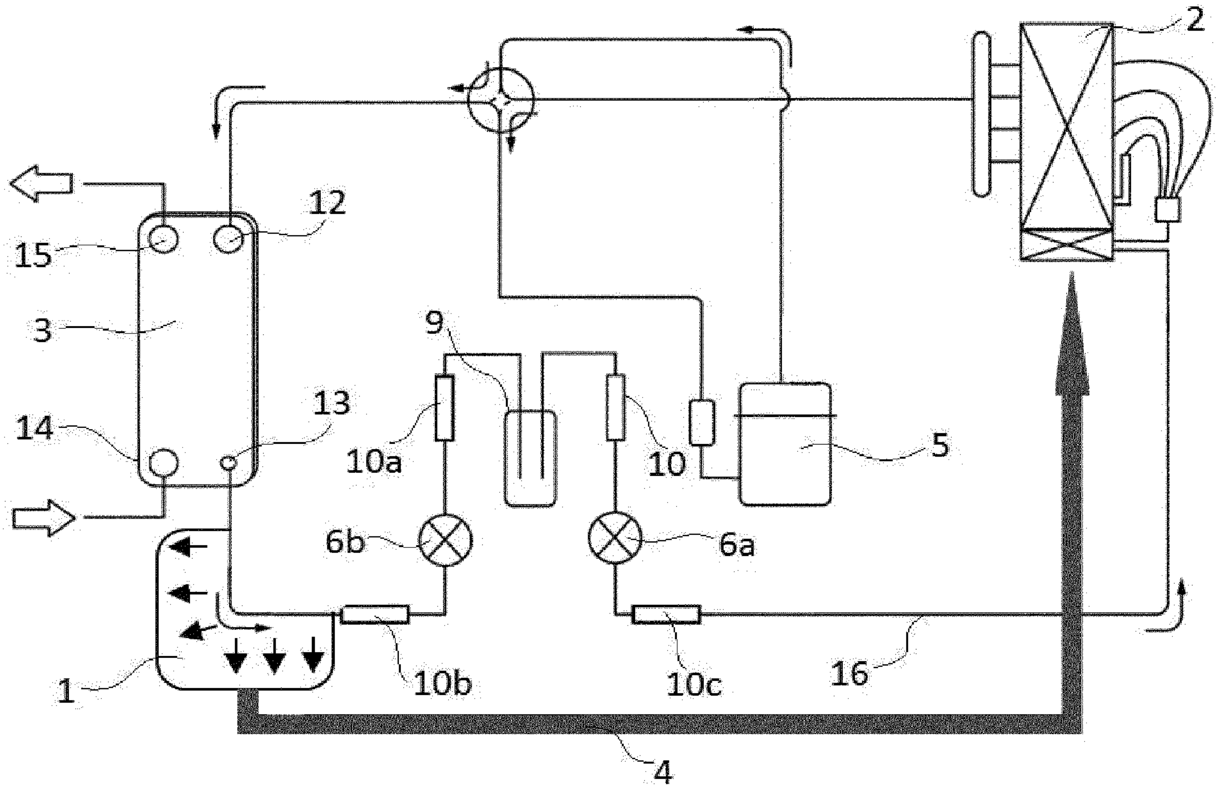


Fig. 1

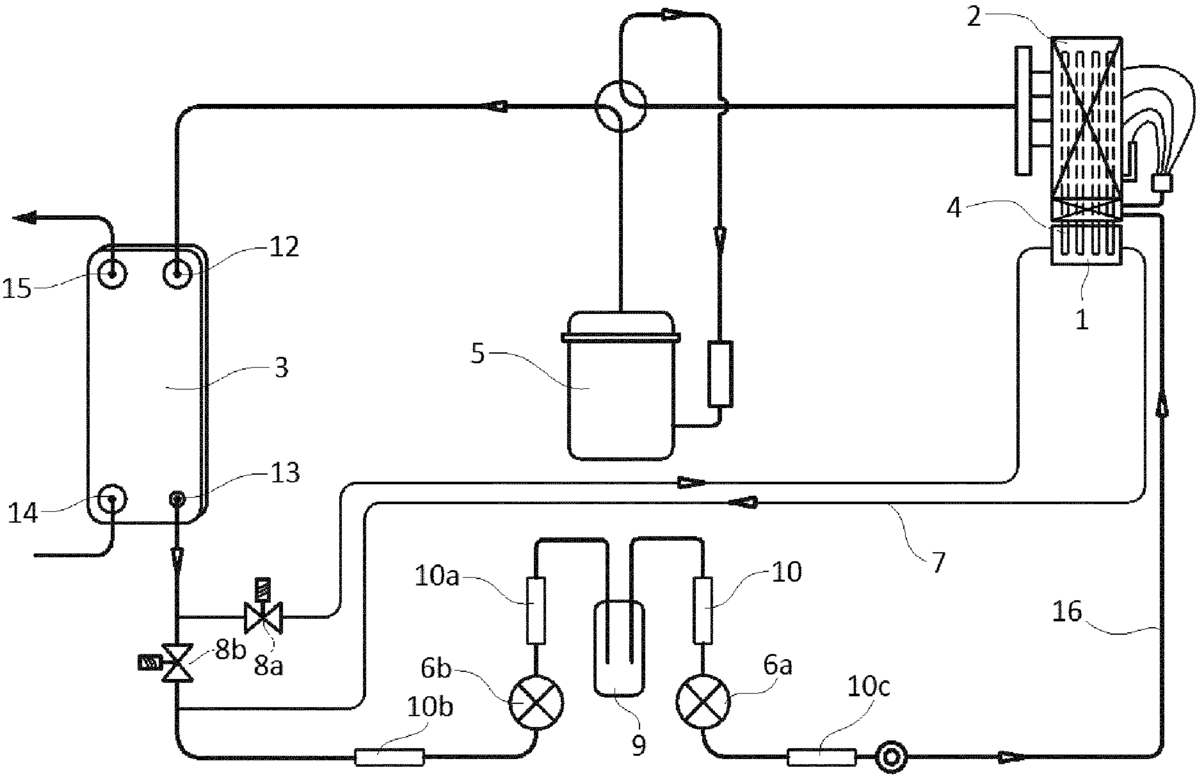


Fig. 2

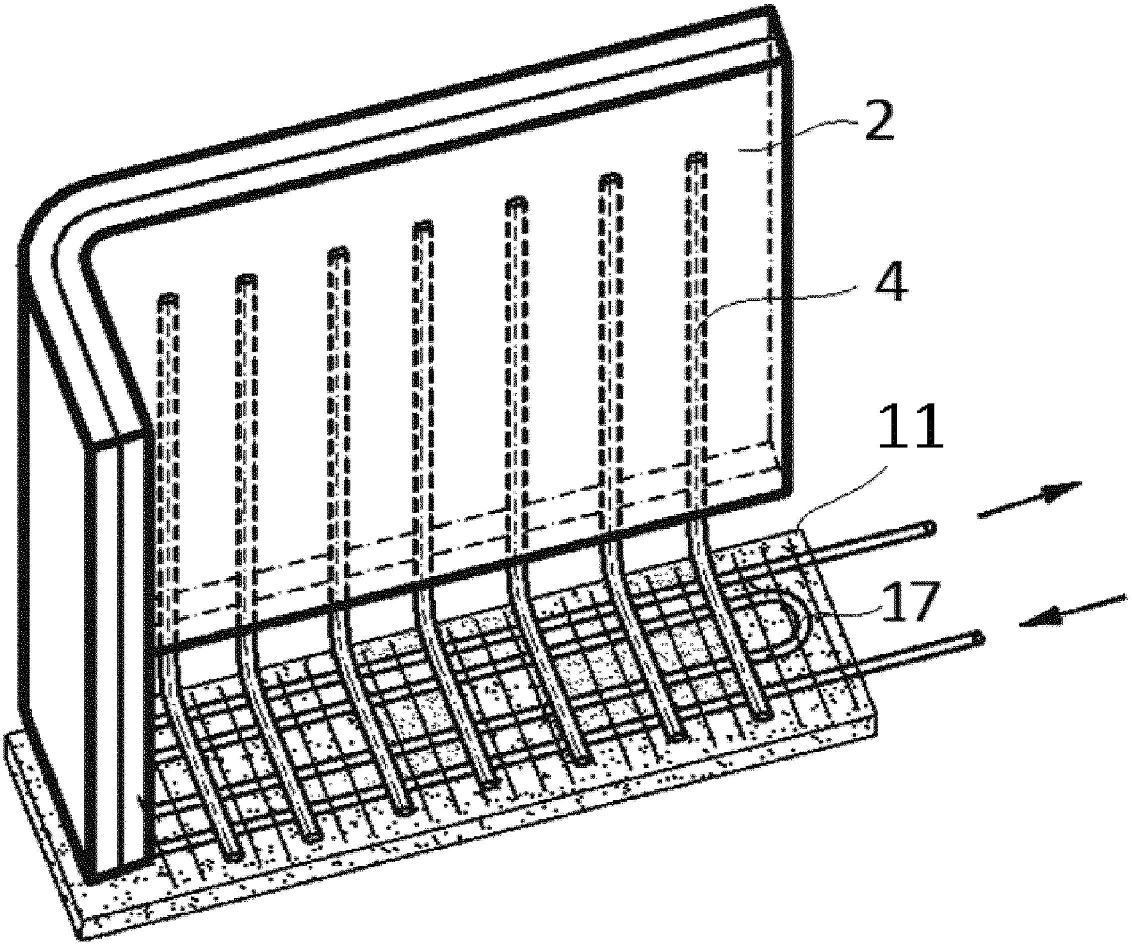


Fig 3

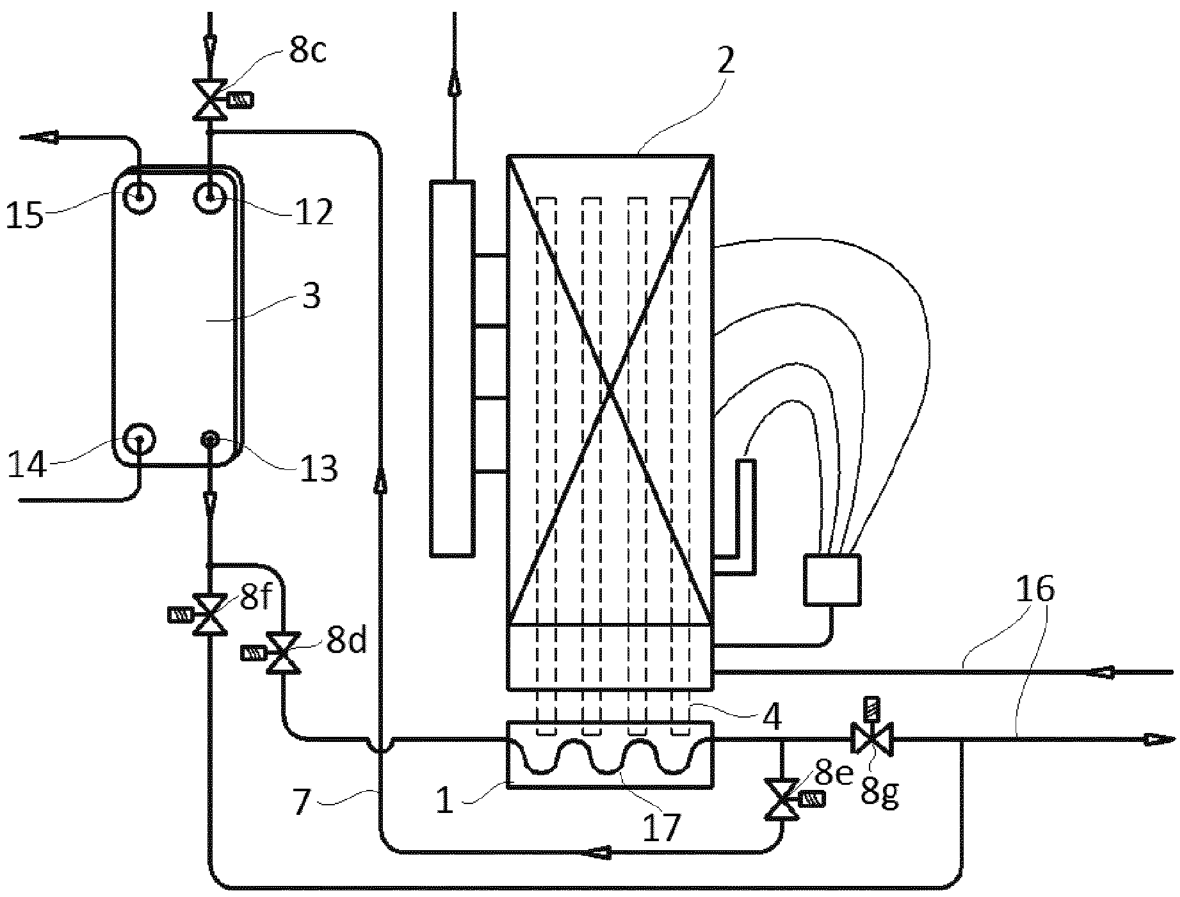


**Fig. 4**

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Application Number
EP 15 19 3581

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