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METHOD AND SYSTEM FOR TRIGGERING DEFROST
- (57)

A method for determining when to initiate a defrost mode of a heat pump (20) includes monitoring a heating capacity of a heat exchanger of the heat pump during operation of the heat pump in a heating mode, initiating the defrost mode when the heating capacity of the heat exchanger is less than or equal to a reduced

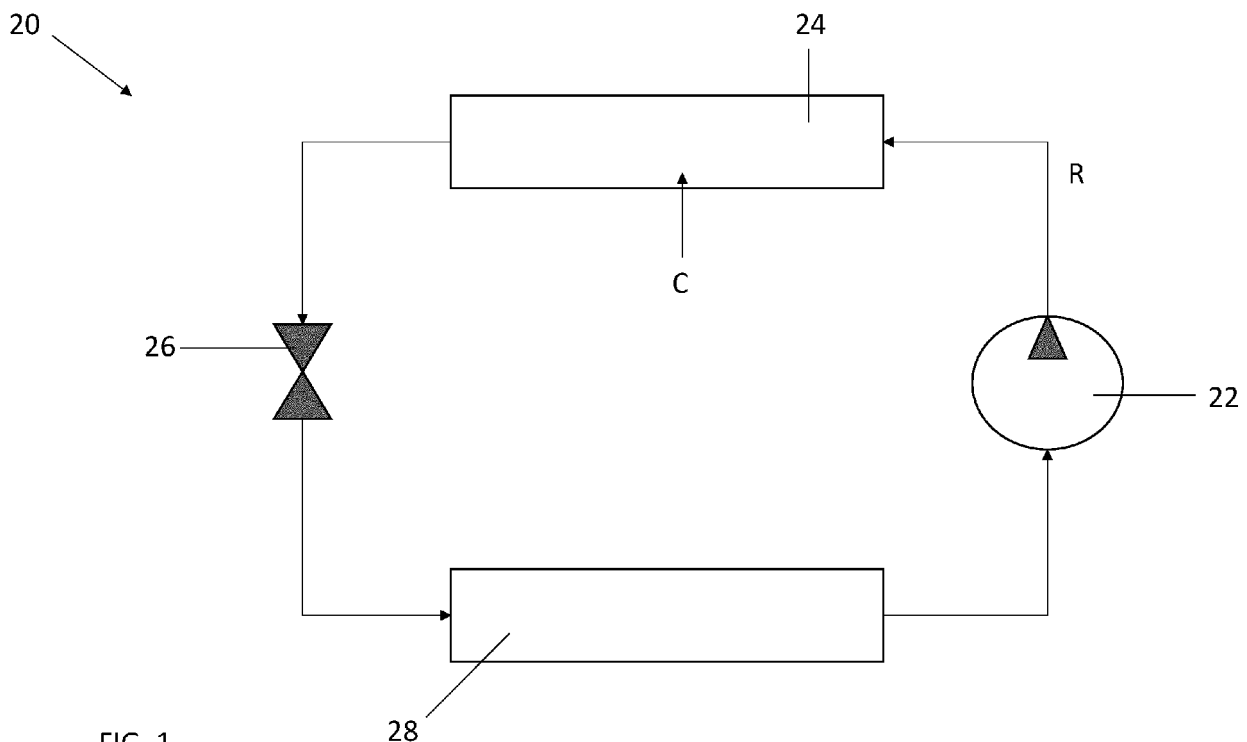
defrost threshold when a capacity demand of the heat exchanger is less than a maximum capacity demand, and initiating the defrost mode when the heating capacity of the heat exchanger is less than or equal to a maximum defrost threshold when the capacity demand of the heat exchanger is equal to the maximum capacity demand.
- 

FIG. 1
- EP 4 450 899 A1
- Processed by Luminess, 75001 PARIS (FR)

Description

BACKGROUND

[0001] The present disclosure pertains to the art of heating, ventilation, and air conditioning (HVAC) systems, and more particularly, to a defrost cycle of an HVAC system.

[0002] Heat pumps are used in a variety of settings, for example, in heating, ventilation, and air conditioning (HVAC) systems that provide a desired air temperature in a facility. Such heat pumps commonly include a compressor, evaporator, expansion device, and condenser. The heat pumps input work to the refrigerant, e.g., by driving the compressor, thereby enabling the refrigerant to move heat from a colder heat reservoir to a warmer heat sink.

[0003] Some heat pumps are provided as "split" systems, having a first heat exchanger arranged inside of the building to be conditioned and a second heat exchanger located outside of the building to be conditioned. When such a heat pump operates in a heating mode, the second heat exchanger operating as an evaporator is disposed outside the building. "Frosting" of the evaporator is a common problem seen in such heat pump split systems. Frosting is caused by moisture accumulation on the evaporator when the evaporator temperature is at or below freezing, for example, at or below 0°C. Accumulation of frost obstructs the flow of air through the evaporator and reduces heat transfer between the evaporator and the air flowing through, both of which reduce operating efficiency.

[0004] Frost may be removed by performing periodic defrost cycles. A defrost cycle typically proceeds by reversing the flow of the refrigerant in the heat pump, such that the condenser and evaporator conceptually exchange roles. The result is that the refrigerant warms the evaporator, thereby eliminating, or at least reducing, any accumulated frost.

[0005] Existing heat pumps typically perform a defrost cycle in response to a transition decision based on one or more control parameters. This transition decision may be based on the capacity of the evaporator, which typically reduces as frost accumulates thereon. Once the requested capacity of the evaporator is maximized, an auxiliary heater is typically relied upon to compensate for lost heat pump capacity.

BRIEF DESCRIPTION

[0006] According to a first aspect of the invention, a method for determining when to initiate a defrost mode of a heat pump includes monitoring a heating capacity of a heat exchanger of the heat pump during operation of the heat pump in a heating mode, initiating the defrost mode when the heating capacity of the heat exchanger is less than or equal to a reduced defrost threshold when a capacity demand of the heat exchanger is less than a

maximum capacity demand, and initiating the defrost mode when the heating capacity of the heat exchanger is less than or equal to a maximum defrost threshold when the capacity demand of the heat exchanger is equal to the maximum capacity demand.

[0007] Optionally, monitoring the heating capacity of the heat exchanger further comprises monitoring at least one parameter or operating condition of the heat pump associated with the heating capacity.

[0008] Optionally, the at least one parameter or operating condition is a refrigerant mass flow.

[0009] Optionally, the at least one parameter or operating condition comprises a temperature of an air discharged from the heat exchanger.

[0010] Optionally, the at least one parameter or operating condition comprises at least one of a pressure at an outlet of the heat exchanger, a pressure at an inlet of a compressor arranged directly downstream from the heat exchanger relative to a fluid flow through the heat pump in the heating mode, and a pressure between the outlet of the heat exchanger and the inlet of the compressor.

[0011] Optionally, the at least one parameter or operating condition comprises at least one of a pressure at an inlet of the heat exchanger, a pressure at an outlet of an expansion device, the expansion device being arranged directly upstream from the heat exchanger relative to a fluid flow through the heat pump in the heating mode, and a pressure between the outlet of the expansion device and the inlet of the heat exchanger.

[0012] Optionally, the at least one parameter or operating condition comprises a temperature at an inlet of the heat exchanger, at an outlet of an expansion device, the expansion device being arranged directly upstream from the heat exchanger relative to a fluid flow through the heat pump in the heating mode, or between the outlet of the expansion device and the inlet of the heat exchanger.

[0013] According to a second aspect of the invention, a system for conditioning air includes a refrigeration circuit including a compressor, and expansion valve, and a heat exchanger. A controller is configured to transition the refrigeration circuit between operation in a heating mode and a defrost mode. The controller is configured to transition the refrigeration circuit from the heating mode to the defrost mode in response to a heating capacity of the heat exchanger reaching a first defrost threshold when the capacity demand of the heat exchanger is less than the maximum capacity demand. The controller is also configured to transition the refrigeration circuit from the heating mode to the defrost mode in response to the heating capacity of the heat exchanger reaching a second defrost threshold when the capacity demand of the heat exchanger is equal to the maximum capacity demand.

[0014] Optionally, at least one sensor is operably coupled to the controller, the at least one sensor is configured to monitor at least one parameter or operating condition of the system associated with the heating capacity.

[0015] Optionally, the at least one parameter or operating condition is a refrigerant mass flow.

[0016] Optionally, the at least one parameter or operating condition comprises a temperature of an air discharged from the heat exchanger.

[0017] Optionally, the at least one parameter or operating condition comprises at least one of a pressure at an outlet of the heat exchanger, a pressure at an inlet of the compressor arranged directly downstream from the heat exchanger relative to a fluid flow through the system in the heating mode, and a pressure between the outlet of the heat exchanger and the inlet of the compressor.

[0018] Optionally, the at least one parameter or operating condition comprises at least one of a pressure at an inlet of the heat exchanger, a pressure at an outlet of an expansion device, the expansion device being arranged directly upstream from the heat exchanger relative to a fluid flow through the system in the heating mode, and a pressure between the outlet of the expansion device and the inlet of the heat exchanger.

[0019] Optionally, the at least one parameter or operating condition comprises a temperature at an inlet of the heat exchanger, at an outlet of an expansion device, the expansion device being arranged directly upstream from the heat exchanger relative to a fluid flow through the heat pump in the heating mode, or between the outlet of the expansion device and the inlet of the heat exchanger.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] The following descriptions should not be considered limiting in any way; rather, the scope of protection is defined by the appended claims. With reference to the accompanying drawings, in which like elements are numbered alike:

FIG. 1 is a schematic diagram of an exemplary heat pump;

FIG. 2A is a schematic diagram of an exemplary heat pump in a first mode;

FIG. 2B is a schematic diagram of an exemplary heat pump in a second mode;

FIG. 3 is a schematic diagram of a control system of a heat pump;

FIG. 4 is a graphic representation of the capacity of the second heat exchanger over time relative to a reduced demand threshold and a maximum demand threshold; and

FIG. 5 is a flow diagram of a method of determining when to initiate operation of the heat pump in a defrost cycle.

DETAILED DESCRIPTION

[0021] A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

[0022] With reference now to FIG. 1, a schematic diagram of an example of a basic vapor compression cycle of an air conditioning system 20 is illustrated. The vapor compression cycle includes one or more compressors 22, a first heat exchanger 24, an expansion device 26, and a second heat exchanger 28. A fluid, such as a refrigerant for example, is configured to circulate through the vapor compression cycle, such as in a counterclockwise direction for example.

[0023] In operation, the compressor 22 receives a refrigerant vapor from the second heat exchanger 28 and compresses it to a high temperature and pressure. The relatively hot refrigerant vapor is then delivered to the first heat exchanger 24 where it is cooled and condensed to a liquid state via heat exchange relationship with a cooling medium C, such as air or water. Accordingly, when the first heat exchanger 24 receives the refrigerant output from the compressor 22, the first heat exchanger functions as a condenser. The cooled liquid refrigerant flows from the first heat exchanger 24 to the expansion device 26, such as an expansion valve for example, in which the refrigerant is expanded to a lower pressure where the temperature is reduced and the refrigerant may exist in a two-phase liquid/vapor state. From the expansion device 26, the refrigerant is provided to the second heat exchanger 28. Because heat is transferred from a secondary medium, such as air for example, to the refrigerant within the second heat exchanger 28, causing any refrigerant in the liquid phase to vaporize, the second heat exchanger 28 functions as an evaporator. From the second heat exchanger 28, the low-pressure vapor refrigerant returns to the compressor 22 so that the cycle may be repeated.

[0024] In embodiments where the air conditioning system 20 is a heat pump, the flow of refrigerant within the vapor compression cycle may be reversed. In such embodiments, the refrigerant may flow clockwise from the compressor 22 to the second heat exchanger 28, the expansion device 26, and the first heat exchanger 24 sequentially. In such instances, the refrigerant within the second heat exchanger 28 is cooled and condensed to a liquid state and the refrigerant within the first heat exchanger is heated to form a low-pressure vapor. Accordingly, when operating in this reverse flow direction, the second heat exchanger 28 functions as the condenser and the first heat exchanger 24 functions as the evaporator of the vapor compression cycle.

[0025] With reference now to FIGS. 2A-2B, a schematic diagram of an air conditioning system, such as a heat pump for example, is shown. In the illustrated, non-limiting embodiment, the heat pump 20 includes a first or indoor portion 30 positioned inside a building to be con-

ditioned and a second or outdoor portion 32 positioned outside of the building. It should be understood that embodiments where the heat pump 20 is installed in a single casing located partially or completely inside or outside of the building are also within the scope of the disclosure.

[0026] As shown, the at least one compressor 22 is located within the outdoor portion 32. The one or more compressors 22 may be any suitable single or multistage compressor, including, but not limited to a screw compressor, reciprocating compressor, centrifugal compressor, scroll compressor, rotary compressor or axial-flow compressor. The compressor(s) 22 may be driven by an electrically powered motor, or another suitable energy source.

[0027] The first heat exchanger 24 is also arranged within the first or indoor portion 30 and is directly or indirectly fluidly coupled to the one or more compressors 22. The first heat exchanger 24 may be any suitable type of heat exchanger configured to transfer heat between a refrigerant and air or another medium. For example, the first heat exchanger 24 may include one or more coils of thermally conductive material, such as copper, aluminum, alloys thereof, or combinations thereof. In other embodiments, the first heat exchanger 24 may be a shell-and-tube heat exchanger, a printed circuit heat exchanger, a plate-fin heat exchanger, or any combination thereof. In the illustrated, non-limiting embodiment, the air or other medium is moved (drawn or blown) over the first heat exchanger 24 via a first movement mechanism 34, such as a fan for example.

[0028] The heat pump 20 includes at least one expansion device 26. Although a single expansion device 26 is illustrated, it should be understood that embodiments having a separate indoor expansion device positioned within the indoor portion and an outdoor expansion device positioned within the outdoor portion are also contemplated herein. The first heat exchanger 24 is fluidly coupled to the expansion device 26.

[0029] The second heat exchanger 28 is arranged within the second or outdoor portion 32 of the heat pump 20 and is also fluidly coupled to the expansion device 26. In embodiments including a separate indoor expansion device and outdoor expansion device 26, the first heat exchanger 24 is fluidly coupled to a first (indoor) expansion device and the second heat exchanger 28 is fluidly coupled to a second (outdoor) expansion device. In such embodiments, refrigerant is only configured to flow through one of the expansion devices in each direction of flow through the refrigeration circuit.

[0030] Similar to the first heat exchanger 24, the second heat exchanger 28 may be any suitable type of heat exchanger configured to transfer heat between a refrigerant and air or another medium. In the illustrated, non-limiting embodiment, the second heat exchanger 28 is disposed about the outer extent of the outdoor portion 32. However, embodiments where the second heat exchanger 28 is arranged at another location, such as within or proximal to the outdoor portion 32 are also contemplated herein.

plated herein.

[0031] The second heat exchanger 28 may have any suitable configuration. For example, the second heat exchanger 28 may include one or more coils of thermally conductive material, such as copper, aluminum, alloys thereof, or combinations thereof. In other embodiments, the second heat exchanger 28 may be a shell-and-tube heat exchanger, a printed circuit heat exchanger, a plate-fin heat exchanger, or any combination thereof.

[0032] In the illustrated, non-limiting embodiment, the outdoor portion 32 includes a second movement mechanism 36, such as a fan assembly for example, to move air or another medium over the second heat exchanger 28. The second movement mechanism 36 may be arranged adjacent a top 38 of the outdoor portion 32, as shown, or may be positioned near a bottom 40 of the outdoor portion, or at any point between the top 38 and the bottom 40 to push or pull air through the outdoor portion.

[0033] The heat pump 20 additionally includes a reversing valve 42 configured to redirect the flow of refrigerant R therein. In the illustrated embodiment, the reversing valve 42 is arranged within the outdoor portion 32 and includes a fluidly separate first flow path and second flow path. In a first state, as shown in FIG. 2A, the first flow path fluidly connects an outlet of the one or more compressors 22 to the first heat exchanger 24, and the second flow path fluidly connects the second heat exchanger 28 to an inlet of the one or more compressors 22. In a second state, the first flow path fluidly connects the outlet of the one or more compressors 22 to the second heat exchanger 28 and the second flow path fluidly connects the first heat exchanger 24 to the inlet of the one or more compressors 22 (FIG. 2B). It should be understood that the heat pump 20 illustrated and described herein is intended as an example only and that a heat pump having another configuration and/or additional components arranged along the fluid flow path are also within the scope of the disclosure.

[0034] During normal operation of the heat pump 20, the heat pump is operable in a "heating" mode (FIG. 2A). When the reversing valve 42 is in the first state, refrigerant is configured to flow through the closed refrigeration circuit from the compressor 22 to the first heat exchanger 24 acting as a condenser. Within the first heat exchanger 24, heat is transferred from the refrigerant to the air moving across the first heat exchanger 24 by the first movement mechanism 34. This warmed air may be used to heat one or more areas to be conditioned within the building. The partially or fully condensed liquid refrigerant is provided from the first heat exchanger 24 to the expansion device 26 where the pressure is reduced causing the refrigerant to be expanded and cooled to a temperature below the ambient temperature. Within the second heat exchanger 28, heat is transferred to the refrigerant from the air moving across the second heat exchanger 28 by the second movement mechanism 36. This heat causes the liquid portions of the refrigerant to evaporate

to a gaseous phase. From the second heat exchanger 28, the refrigerant is returned to the compressor 22 via the reversing valve 42.

[0035] During normal operation of the heat pump 20, frost can accumulate on the second heat exchanger 28. When frost accumulates on the second heat exchanger 28, the frost impedes heat transfer from the air to the heat exchanger and therefore provides undesirable insulating properties to the heat exchanger. The undesirable insulating properties result in an increase in the temperature difference between the temperature of the air and the temperature of the heat exchanger. As the extent and thickness of frost increases, the degree of insulating properties of the frost increases. Accordingly, the temperature of the second heat exchanger 28 will continue to decrease indefinitely as frost continues to accumulate.

[0036] As frost accumulates on the second heat exchanger 28 and the operating temperature of the second heat exchanger 28 decreases, the operating temperature of the refrigerant within the second heat exchanger 28 decreases as a result. Given a fixed amount of superheat, the density of the refrigerant vapor leaving the second heat exchanger 28 decreases as the temperature of the vapor decreases. Decreasing vapor density for a given volume flow results in decreasing refrigerant mass flow, and the heating capacity of the refrigerant system decreases. Therefore, the extent and thickness of the presence of frost will directly relate to a decrease in mass flow and heating capacity.

[0037] To eliminate, or at least mitigate, this frost, the heat pump 20 may transition to a defrost mode, such as by switching the reversing valve 42 to the second state. With the reversing valve 42 in the second state, shown in FIG. 2B, the direction of flow of refrigerant through the closed refrigerant circuit is reversed. Accordingly, the warm, high pressure refrigerant output from the at least one compressor 22 is routed to the second heat exchanger 28 such that the second heat exchanger 28 functions as a condenser rather than as an evaporator. In the defrost mode, the second movement mechanism 36 may be disabled to prevent air movement through the second heat exchanger 28, thus enabling the temperature of the second heat exchanger 28 to increase to a greater degree above the ambient air temperature. From the second heat exchanger 28, the refrigerant is expanded in an expansion device 26, such as the indoor expansion device (not shown), and then is delivered to the first heat exchanger 24, which is configured to operate as an evaporator. Within the first heat exchanger 24, the refrigerant can absorb heat from the medium moving across the first heat exchanger 24 via the first movement mechanism 34. In an embodiment, the heat pump 20 includes an auxiliary heater 44 configured to heat the cool air output from the first heat exchanger 24 during a defrost cycle to meet the heating demands of the area being conditioned. From the first heat exchanger 24, the refrigerant is returned to the compressor 22 via the reversing valve 42.

[0038] With reference to FIG. 3, in an embodiment, the heat pump 20 includes a control system 50 configured to monitor one or more operating conditions of the heat pump 20 during the heating mode. With reference to FIG. 3, the control system 50 of the heat pump 20 includes a controller 52 having one or more of a microprocessor, microcontroller, application specific integrated circuit (ASIC), or any other form of electronic controller known in the art. The controller 52 is operably coupled to the compressor 22, the first and second movement mechanisms 34, 36, the reversing valve 42, and any other suitable components. In an embodiment, the control system 50 additionally includes at least one sensor S operable to monitor one or more operating parameters or operating conditions (referred to collectively herein as parameters) of the heat pump 20 that correlate to or are associated with determining the heating capacity of the second heat exchanger 28. The at least one sensor S may be configured to continuously monitor and communicate a respective parameter to the controller, or alternatively, may be configured to intermittently monitor and communicate a respective parameter to the controller 52.

[0039] Existing heat pumps 20 typically transition between a heating mode in which the reversing valve 42 is in the first state and a defrost mode in which the reversing valve 42 is in the second state upon determining that the capacity of the second heat exchanger 28 is reduced. This transition, however, may result in the use of the auxiliary heater 44 before the capacity of the second heat exchanger is reduced to less than or equal to a primary or minimum defrost threshold.

[0040] To optimize the run time of the heat pump in a heating mode, the heating capacity of the second heat exchanger 28 can be monitored (directly or indirectly) during a heating cycle. A comparison of the heating capacity of the second heat exchanger 28 during operation of the heating cycle and the heating capacity of the second heat exchanger 28 when no frost is present will indicate the reduction in heating capacity due to frost accumulation on the second heat exchanger 28. The control system 50 may be operable to monitor any of the parameters associated with a reduction in capacity of the heat exchanger as described in U.S. Provisional Patent Application Serial No. 63/288896, filed on December 13, 2021, the entire contents of which are incorporated herein by reference. Examples of the parameters that may be monitored include, but are not limited to, a temperature of an air discharged from the second heat exchanger 28, at least one of a pressure at an outlet of the second heat exchanger 28, a pressure at an inlet of a compressor 22 arranged directly downstream from the second heat exchanger 28 relative to a fluid flow through the heat pump 20 in the heating mode, and a pressure between the outlet of the second heat exchanger 28 and the inlet of the compressor 22, at least one of a pressure at an inlet of the second heat exchanger 28, a pressure at an outlet of an expansion device 26 arranged directly upstream from the second heat exchanger 28 relative to a fluid flow

through the heat pump 20 in the heating mode, and a pressure between an outlet of the expansion device 26 and the inlet of the second heat exchanger 28, and a temperature at an outlet of an expansion device 26 arranged directly upstream from the second heat exchanger 28 relative to a fluid flow through the heat pump 20 in the heating mode.

[0041] The controller 52 is configured to evaluate the available heating capacity of the second heat exchanger 28 from the monitored parameter. With reference to FIG. 4, when the current capacity demand on the second heat exchanger 28 is less than a maximum capacity demand, in an embodiment, the controller 52 will compare the heating capacity to a first or primary defrost threshold (labeled "Lower Demand Threshold") to determine when to initiate or trigger operation in the defrost mode. As used herein, the term "monitored parameter" is intended to include parameters or operating conditions that are measured via one or more sensors S, or alternatively, parameters or operating conditions that are calculated using the monitored parameters or operating conditions. In an embodiment, the controller 52 is configured to transition the heat pump 20 from the heating mode to the defrost mode automatically in response to the heating capacity crossing the first or primary defrost threshold (also referred to herein as the reduced demand threshold) indicative that the capacity of the heat exchanger is below an acceptable level. In another embodiment, the defrost mode is initiated when the heating capacity crosses the reduced demand threshold and remains less than or equal to the reduced demand threshold for a minimum period of time. Examples of a minimum period of time include anywhere from about zero minutes to about ten minutes. The minimum period of time may vary based on the parameter being monitored, such as pressure or temperature for example.

[0042] To further improve the operation of the heat pump and reduce the use of an auxiliary heat source such as auxiliary heater 44, in an embodiment, the control system 50 is configured to implement another or secondary defrost trigger threshold (labeled "Upper Demand Threshold" in FIG. 4) based on to the capacity demand on the system. In an embodiment, implementation of the secondary defrost trigger is conditional on the demand on the system being at a maximum capacity demand. In such embodiments, when the current capacity demand of the second heat exchanger 28 is equal to the maximum capacity demand, the controller 52 is configured to compare the heating capacity of the second heat exchanger 28 to the second defrost threshold (also referred to herein as a maximum demand threshold) to determine when to initiate or trigger operation in the defrost mode. As shown, the maximum demand threshold is increased relative to the first capacity threshold. It should be understood that although the thresholds are referred to herein as a first or reduced demand threshold and a second or maximum demand threshold, the capacity of the heat exchanger is configured to cross the maximum demand threshold be-

fore the reduced demand threshold as the capacity reduces.

[0043] With reference now to FIG. 5, a flow diagram 100 of a method of determining whether to transition the heat pump from a heating cycle to a defrost cycle is illustrated. As shown in block 102, the controller 52 will determine a heating capacity of the second heat exchanger 28 using the one or more monitored parameters previously described herein. The controller 52 will then, in block 104, determine if the capacity demand is equal to a maximum capacity demand. If the capacity demand is less than the maximum capacity demand, the method will proceed to block 106, where the heating capacity is compared to the reduced demand threshold. If the heating capacity is less than or equal to the reduced demand threshold, the controller 52 will transition the heat pump 20 from a heating mode to a defrost mode, as shown in block 108. However, if the heating capacity of the second heat exchanger 28 is greater than the reduced demand threshold, the method will return to block 102.

[0044] If at block 106, the capacity demand is determined to be equal to the maximum capacity demand, the method will proceed to block 110, where the heating capacity is compared to the maximum demand threshold. If the heating capacity is less than or equal to the maximum demand threshold, the controller 52 will transition the heat pump 20 from a heating mode to a defrost mode, as shown in block 112. However, if the heating capacity of the second heat exchanger 28 is greater than the maximum demand threshold, the method will return to block 102.

[0045] A heat pump or air conditioning system 20 as described herein allows for the use of a first, reduced defrost threshold as a defrost trigger when the full capacity of the heat pump is not required to meet the capacity demand on the system. However, by including a second, maximum demand threshold associated with the maximum capacity demand, the heat pump 20 is able to perform more frequent defrost cycles when the capacity demand on the heat pump 20 is high. More frequent defrost cycles reduces the need to use the auxiliary heating methods, thereby improving the overall system efficiency.

[0046] The term "about" is intended to include the degree of error associated with measurement of the particular quantity based upon the equipment available at the time of filing the application.

[0047] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present disclosure. As used herein, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, oper-

ations, element components, and/or groups thereof.

[0048] While the present disclosure has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the appended claims. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from the scope of the appended claims. Therefore, it is intended that the present disclosure not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this present disclosure, but that the present disclosure will include all embodiments falling within the scope of the claims.

Claims

1. A method for determining when to initiate a defrost mode of a heat pump (20), the method comprising:

monitoring (102) a heating capacity of a heat exchanger (28) of the heat pump during operation of the heat pump in a heating mode; initiating (108) the defrost mode when the heating capacity of the heat exchanger is less than or equal to a reduced defrost threshold when a capacity demand of the heat exchanger is less than a maximum capacity demand; and initiating (112) the defrost mode when the heating capacity of the heat exchanger is less than or equal to a maximum defrost threshold when the capacity demand of the heat exchanger is equal to the maximum capacity demand.

2. The method of claim 1, wherein monitoring the heating capacity of the heat exchanger further comprises monitoring at least one parameter or operating condition of the heat pump associated with the heating capacity.
3. The method of claim 2, wherein the at least one parameter or operating condition is a refrigerant mass flow.
4. The method of claim either claim 2 or claim 3, wherein the at least one parameter or operating condition comprises a temperature of an air discharged from the heat exchanger.
5. The method of any of claims 2-4, wherein the at least one parameter or operating condition comprises at least one of a pressure at an outlet of the heat exchanger, a pressure at an inlet of a compressor (22) arranged directly downstream from the heat exchanger relative to a fluid flow through the heat pump

in the heating mode, and a pressure between the outlet of the heat exchanger and the inlet of the compressor.

6. The method of any of claims 2-5, wherein the at least one parameter or operating condition comprises at least one of a pressure at an inlet of the heat exchanger, a pressure at an outlet of an expansion device (26), the expansion device being arranged directly upstream from the heat exchanger relative to a fluid flow through the heat pump in the heating mode, and a pressure between the outlet of the expansion device and the inlet of the heat exchanger.
7. The method of any of claims 2-6, wherein the at least one parameter or operating condition comprises a temperature at an inlet of the heat exchanger, at an outlet of an expansion device, the expansion device being arranged directly upstream from the heat exchanger relative to a fluid flow through the heat pump in the heating mode, or between the outlet of the expansion device and the inlet of the heat exchanger.
8. A system (20) for conditioning air comprising:
 - a refrigeration circuit including a compressor (22), and expansion valve (26), and a heat exchanger (28);
 - a controller (52) configured to transition the refrigeration circuit between operation in a heating mode and a defrost mode;
 - wherein the controller is configured to:
 - transition the refrigeration circuit from the heating mode to the defrost mode in response to a heating capacity of the heat exchanger reaching a first defrost threshold when the capacity demand of the heat exchanger is less than the maximum capacity demand; and
 - transition the refrigeration circuit from the heating mode to the defrost mode in response to the heating capacity of the heat exchanger reaching a second defrost threshold when the capacity demand of the heat exchanger is equal to the maximum capacity demand.
9. The system of claim 8, further comprising at least one sensor (S) operably coupled to the controller, the at least one sensor being configured to monitor at least one parameter or operating condition of the system associated with the heating capacity.
10. The system of claim 9, wherein the at least one parameter or operating condition is a refrigerant mass flow.

11. The system of either claim 9 or claim 10, wherein the at least one parameter or operating condition comprises a temperature of an air discharged from the heat exchanger.
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12. The system of any of claims 9-11, wherein the at least one parameter or operating condition comprises at least one of a pressure at an outlet of the heat exchanger, a pressure at an inlet of the compressor arranged directly downstream from the heat exchanger relative to a fluid flow through the system in the heating mode, and a pressure between the outlet of the heat exchanger and the inlet of the compressor.
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13. The system of any of claims 9-12, wherein the at least one parameter or operating condition comprises at least one of a pressure at an inlet of the heat exchanger, a pressure at an outlet of an expansion device, the expansion device being arranged directly upstream from the heat exchanger relative to a fluid flow through the system in the heating mode, and a pressure between the outlet of the expansion device and the inlet of the heat exchanger.
- 20
- 25
14. The system of any of claims 9-13, wherein the at least one parameter or operating condition comprises a temperature at an inlet of the heat exchanger, at an outlet of an expansion device, the expansion device being arranged directly upstream from the heat exchanger relative to a fluid flow through the heat pump in the heating mode, or between the outlet of the expansion device and the inlet of the heat exchanger.
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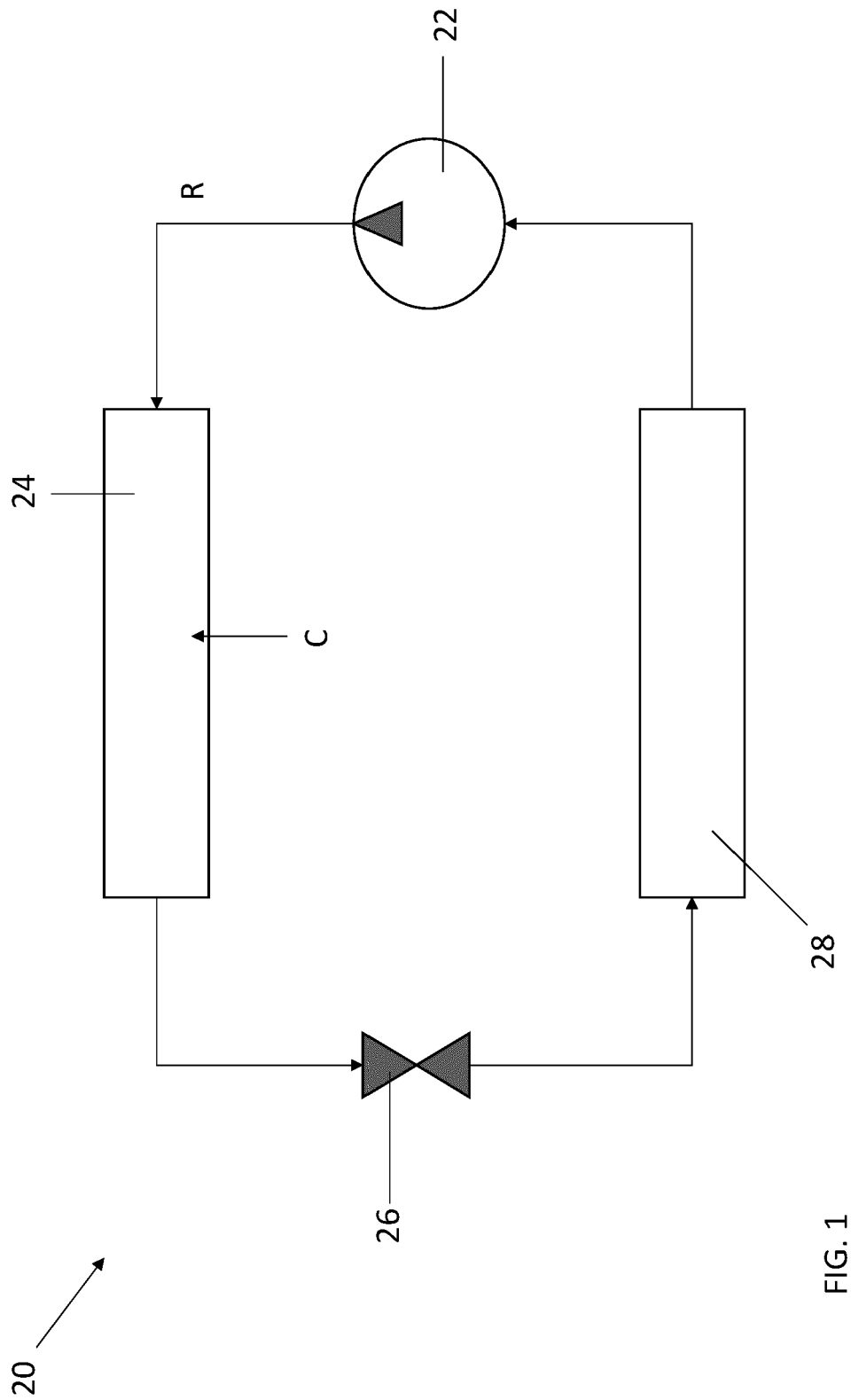
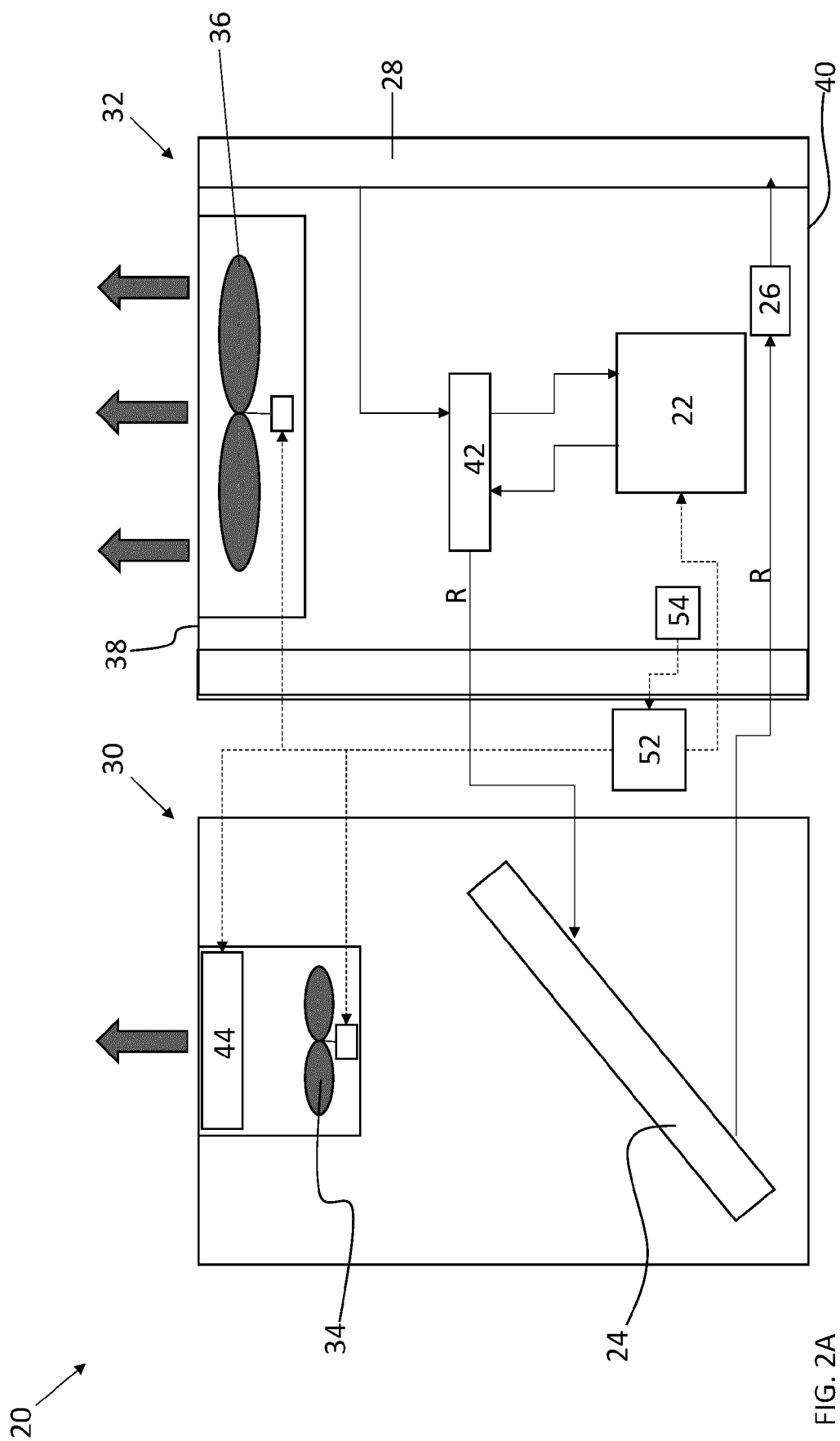
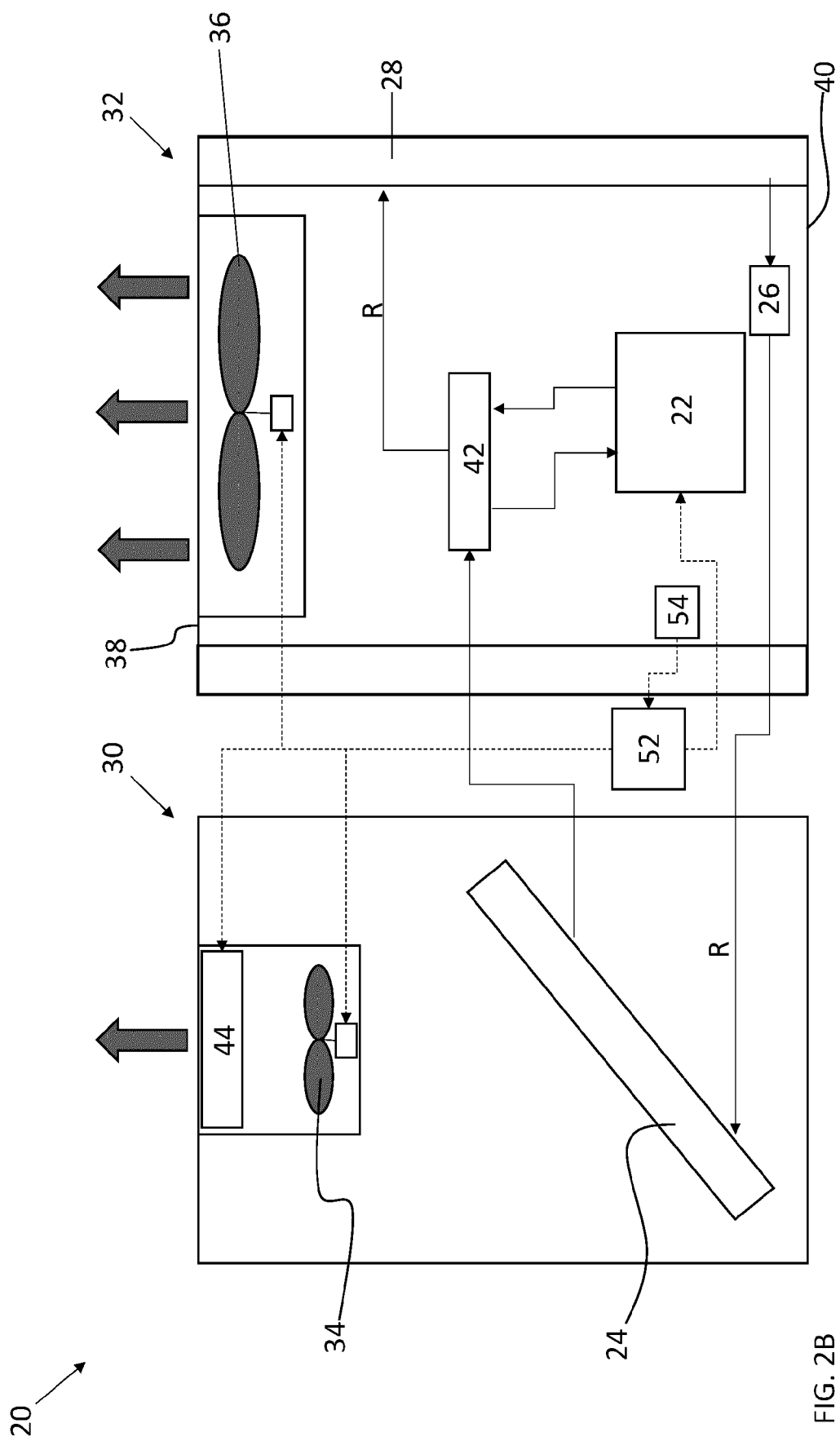


FIG. 1





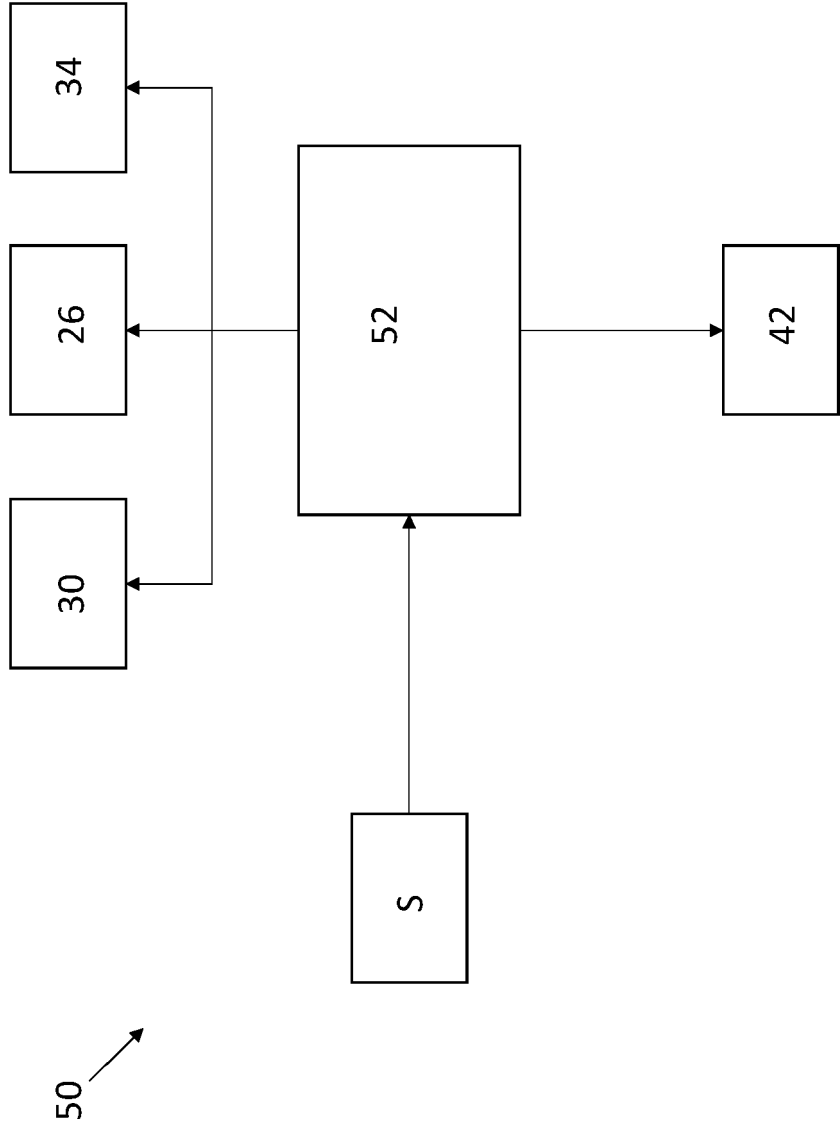


FIG. 3

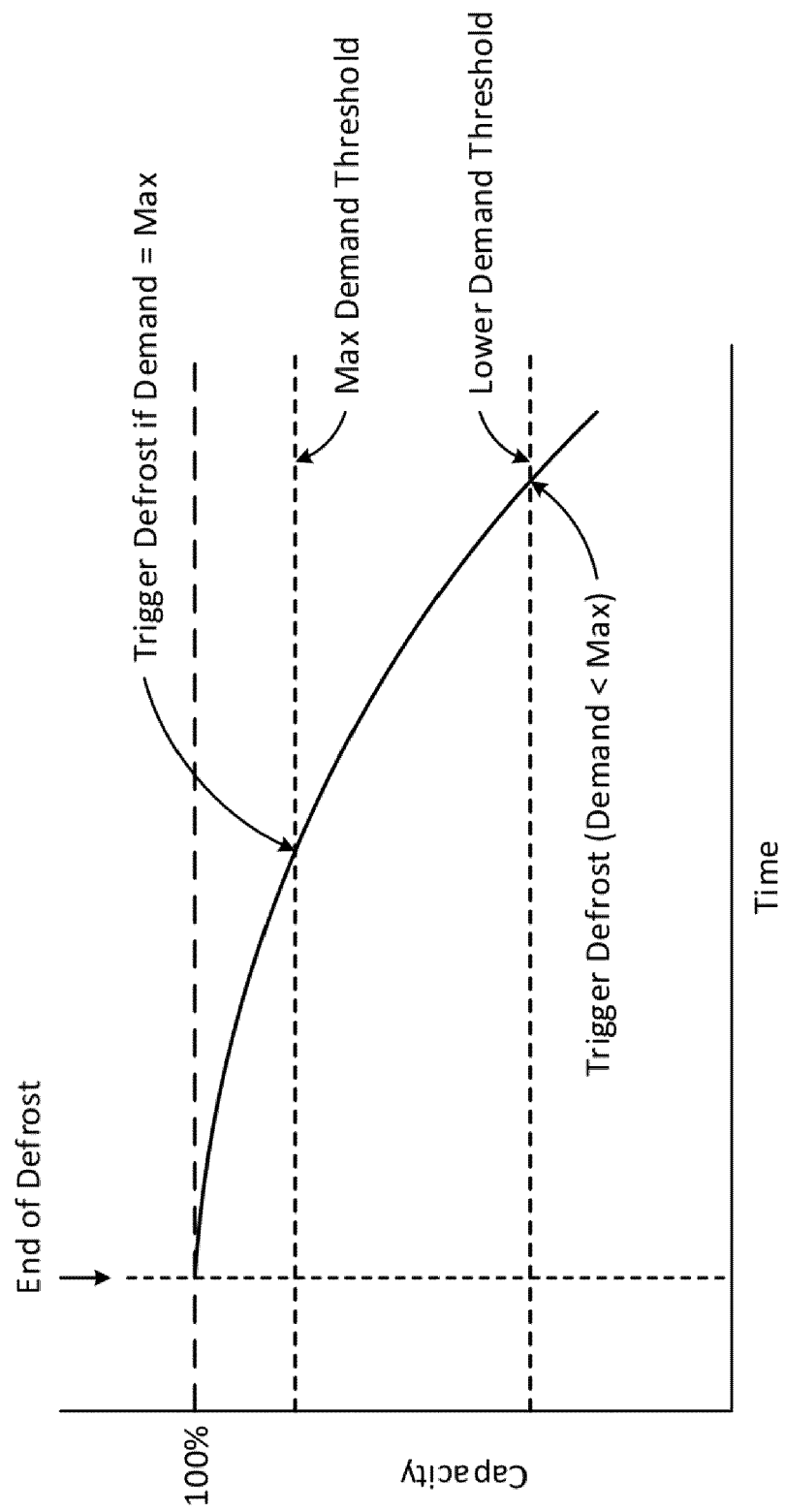


FIG. 4

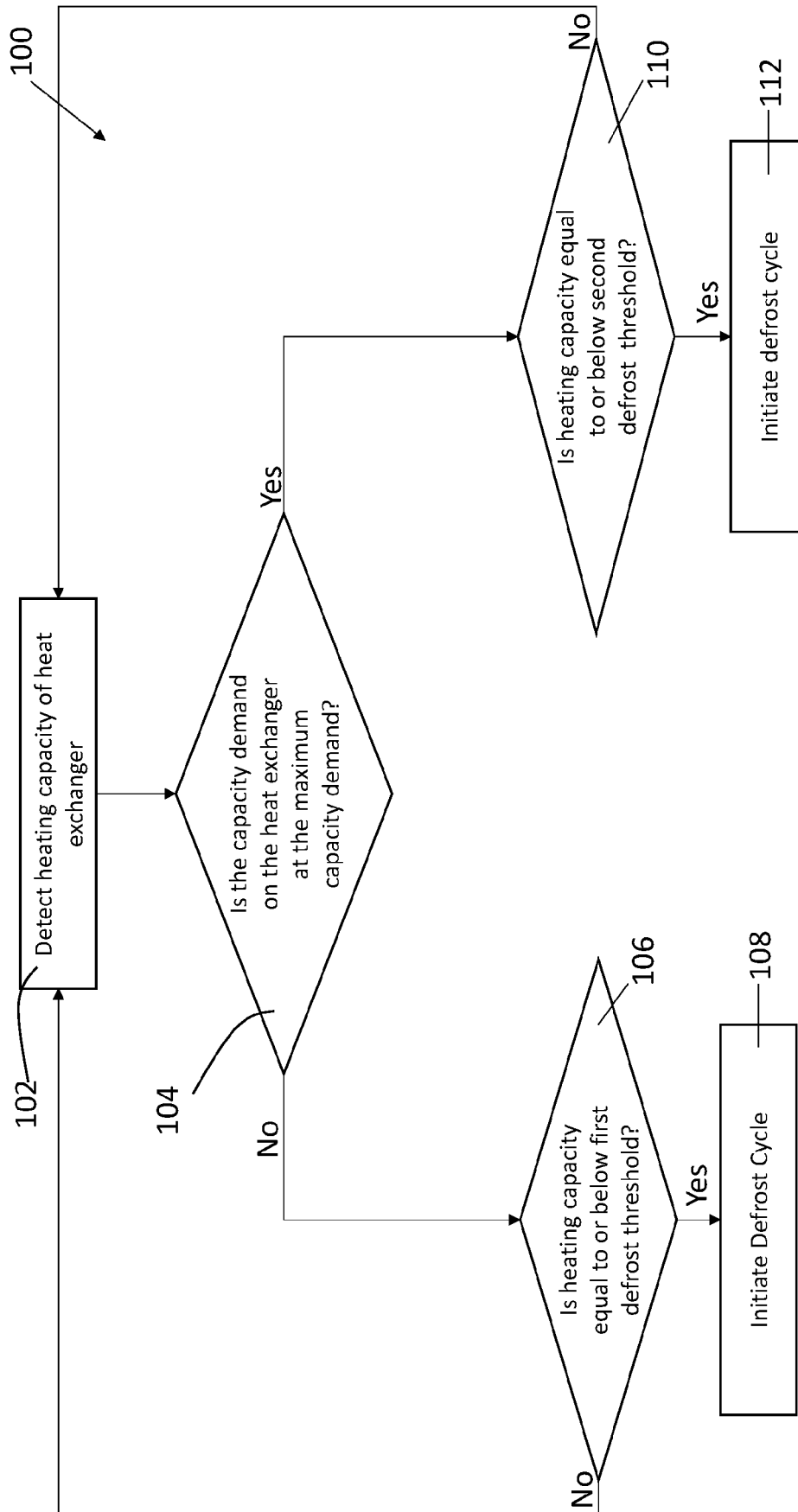


FIG. 5



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EPO FORM 1503 03.82 (P04C01)

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 10 508 826 B2 (MITSUBISHI ELECTRIC CORP [JP]) 17 December 2019 (2019-12-17) * the whole document * -----	1-14	INV. F25B47/02 F25B49/02
A	US 5 319 943 A (BAHEL VIJAY [US] ET AL) 14 June 1994 (1994-06-14) * the whole document * -----	1-14	
A	US 11 029 067 B2 (DAIKIN IND LTD [JP]) 8 June 2021 (2021-06-08) * the whole document * -----	1-14	
			TECHNICAL FIELDS SEARCHED (IPC)
			F25B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 13 September 2024	Examiner Lucic, Anita
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	

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ON EUROPEAN PATENT APPLICATION NO.**

EP 24 16 8835

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.

13 - 09 - 2024

	Patent document cited in search report		Publication date	Patent family member(s)	Publication date	
10	US 10508826	B2	17-12-2019	CN	107110547 A	29-08-2017
EP				3246635 A1	22-11-2017	
JP				6320568 B2	09-05-2018	
JP WO				2016113851 A1	29-06-2017	
US				2017370627 A1	28-12-2017	
WO				2016113851 A1	21-07-2016	
15	-----					
20	US 5319943	A	14-06-1994	CN	1095153 A	16-11-1994
				IL	108213 A	18-06-1996
				JP	H07305925 A	21-11-1995
				US	5319943 A	14-06-1994
25	-----					
30	US 11029067	B2	08-06-2021	AU	2018313510 A1	16-01-2020
				CN	111033152 A	17-04-2020
				EP	3667203 A1	17-06-2020
				ES	2907266 T3	22-04-2022
				JP	6477802 B2	06-03-2019
				JP	2019032110 A	28-02-2019
				US	2020158392 A1	21-05-2020
WO	2019031561 A1	14-02-2019				
35	-----					
40						
45						
50						
55						

ORM P0459

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 63288896 [0040]