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(54) **A MODULAR DE-SUPERHEATER AND WATER HEATER SYSTEM**

(57) A modular de-superheater and water heater system (100). The system comprises a refrigerant-to-water, RW, heat exchanger (102) comprising a first coil (104), and a second coil (106) in thermal communication with each other. A first end (104-1) of the first coil is connected to a first port (110-1) of a heat pump (108) and a second end (104-2) of the first coil is connected to an inlet (114-1) of an indoor fan coil unit (112). A first end (106-1) of the second coil is connected to an outlet

(116-1) of a domestic hot water, DHW, tank (116) and a second end (106-2) of the second coil is connected to an inlet (116-2) of the DHW tank. The system further comprises a solenoid valve (118) connected between an outlet (114-2) of the fan coil unit and a second port (110-2) of the heat pump, and an electronic expansion valve (120) connected between the second port of the heat pump and the second end of the first coil.

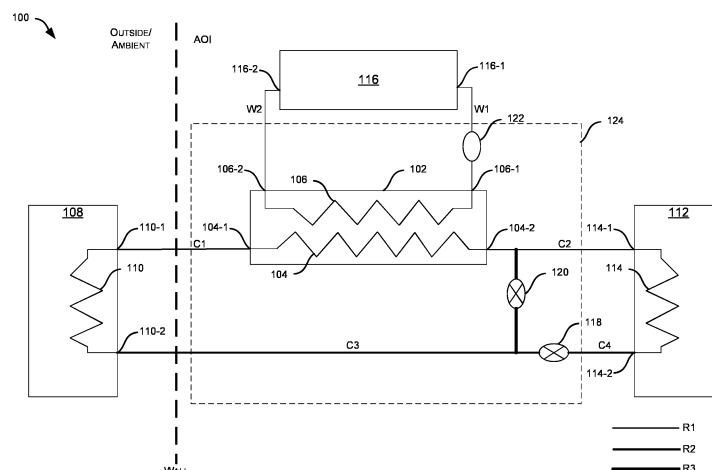


FIG. 1

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Description

BACKGROUND

[0001] This invention relates to the field of de-superheaters and domestic water heating systems, and more particularly, to a modular de-superheater and water heater system.

SUMMARY

[0002] According to a first aspect of the invention there is provided a modular de-superheater and water heater system. The system comprises a refrigerant-to-water (RW) heat exchanger comprising a first coil, and a second coil in thermal communication with the first coil to facilitate heat exchange therebetween, wherein a first end of the first coil is configured to be fluidically connected to a first port of a heat pump associated with an outdoor unit and a second end of the first coil is configured to be fluidically connected to an inlet of an indoor fan coil unit associated with an area of interest (AOI), and wherein a first end of the second coil is configured to be fluidically connected to an outlet of a domestic hot water (DHW) tank associated with the AOI and a second end of the second coil is configured to be fluidically connected to an inlet of the DHW tank. The system further comprises a solenoid valve configured to be fluidically connected between an outlet of the fan coil unit and a second port of the heat pump, and an electronic expansion valve (EXV) configured to be fluidically connected between the second port of the heat pump and the second end of the first coil of the RW heat exchanger.

[0003] Optionally, the system comprises a water pump configured to be fluidically connected between the first end of the second coil and an outlet of the DHW tank to control flow of water between the DHW tank and the RW heat exchanger.

[0004] Optionally, the water pump is a variable-speed water pump.

[0005] Optionally, the heat pump is a variable-speed heat pump.

[0006] Optionally, in a de-superheating mode, the system is configured to close the EXV, open the solenoid valve, and operate the heat pump to enable flow of high-temperature, high-pressure vapor phase of the refrigerant from the first port of the heat pump through the first coil of the RW heat exchanger, and further actuate the water pump to enable flow of the water from the DHW tank through the second coil of the RW heat exchanger, wherein the RW heat exchanger facilitates heat exchange between the vapor phase of the refrigerant and the water while flowing therethrough to de-super heat the vapor and further heat the water.

[0007] Optionally, the system is configured to supply the heated water into the DHW tank and the de-superheated vapor into the heat pump via the fan coil unit and the solenoid valve.

[0008] Optionally, when the heat pump is operated in a defrost mode, the system is configured to close the solenoid valve, open the EXV, and operate the heat pump to enable flow of the refrigerant from the second port of the heat pump into the first coil of the RW heat exchanger via the EXV while restricting flow of the refrigerant into the fan coil unit, and further actuate the water pump to enable flow of hot water from the DHW tank through the second coil of the RW heat exchanger, wherein the RW heat exchanger facilitates heat exchange between the refrigerant and the hot water while flowing therethrough to heat the refrigerant.

[0009] Optionally, the system is configured to supply the heated refrigerant into the heat pump via the first port of the heat pump to defrost an outdoor coil associated with the outdoor unit.

[0010] Optionally, when the water in the DHW tank is to be heated in a cooling dominant season or in between heating cycles, the system is configured to close the solenoid valve, open the EXV, and operate the heat pump to enable flow of the refrigerant from the first port of the heat pump through the first coil of the RW heat exchanger while restricting flow of the refrigerant into the fan coil unit, and further actuate the water pump to enable flow of water from the DHW tank through the second coil of the RW heat exchanger, wherein the RW heat exchanger facilitates heat exchange between the refrigerant and the hot water while flowing therethrough to heat the water being supplied back into the DHW tank.

[0011] Optionally, when the water in the DHW tank is to be heated in the cooling dominant season or in between heating cycles, the system can be configured to operate the water pump to supply the water from the DHW tank through the second coil of the RW heat exchanger at a maximum flow rate and the heat pump is operated at a minimum heating capacity.

[0012] Optionally, when the AOI is to be cooled, the system is configured to open the solenoid valve, close the EXV, and operate the heat pump to enable flow of the refrigerant from the first port of the heat pump into the inlet of the fan coil unit and further back into the heat pump via the outlet of the fan coil unit, wherein the flow of refrigerant through the fan coil unit facilitates absorption of heat from the AOI to cool the AOI.

[0013] Optionally, the system comprises a first refrigerant line extending from the first end and the second end of the RW heat exchanger, wherein a first end of the first refrigerant line is configured to be fluidically connected to the first port of the heat pump and a second end of the first refrigerant line is configured to be fluidically connected to the inlet of the fan coil unit, a second refrigerant line extending from an inlet and an outlet of the solenoid valve, wherein a first end of the second refrigerant line is configured to be fluidically connected to the second port of the heat pump and a second end of the second refrigerant line is configured to be fluidically connected to the outlet of the fan coil unit, and a third refrigerant line fluidically connecting the EXV to the first refrigerant line.

and the second refrigerant line.

[0014] Optionally, the system comprises a first water line having a first end fluidically connected to the second end of the second coil via the water pump and a second end configured to be fluidically connected to the outlet of the DHW tank, and a second water line having a first end fluidically connected to the first end of the second coil and a second end configured to be fluidically connected to the inlet of DHW tank.

[0015] Optionally, the RW heat exchanger, the water pump, the solenoid valve, and the EXV are enclosed within a housing, such that corresponding ends of the first and second refrigeration lines, and the first and second water lines extend out of the housing to facilitate fluidic coupling of the system to the heat pump, the fan coil unit, and the DHW tank.

[0016] Optionally, the first and second refrigeration lines, and the first and second water lines comprise a set of conduits.

[0017] Optionally, the system comprises a control unit in communication with a controller associated with one or more of the heat pump, the water pump, the solenoid valve, and the EXV via a network, wherein the control unit comprises one or more processor coupled to a memory storing instructions executable by the processors, which causes the control unit to: actuate one or more of the heat pump, the water pump, the solenoid valve, and the EXV to control de-superheating of the refrigerant, adjust the temperature of the AOI at a first predefined temperature, heat the water of the DHW tank to a second predefined temperature, and/or control defrosting of the outdoor coil associated with the outdoor unit.

[0018] Optionally, the control unit is configured to close the EXV, open the solenoid valve, and actuate the heat pump to adjust the heating capacity of the heat pump and/or flow rate of the refrigerant supplied by the heat pump to the RW heat exchanger, and further actuate the water pump to adjust flow rate of the water supplied by the DHW tank to the RW heat exchanger, to de-super heat the refrigerant and further heat the water at the second predefined temperature.

[0019] Optionally, the control unit is configured to open the EXV, close the solenoid valve, and actuate the heat pump to adjust the heating capacity of the heat pump and/or flow rate of the refrigerant supplied by the heat pump to the RW heat exchanger, and further actuate the water pump to adjust flow rate of the hot water supplied by the DHW tank to the RW heat exchanger, to heat the refrigerant and further supply the heated refrigerant to the heat pump to defrost the outdoor coil, while restricting flow of the refrigerant into the fan coil unit.

[0020] Optionally, when the water in the DHW tank is to be heated in a cooling dominant season or in between heating cycles, the control unit is configured to close the solenoid valve, open the EXV, and actuate the heat pump to adjust the heating capacity of the heat pump and/or flow rate of the refrigerant supplied by the heat pump to the RW heat exchanger, and further actuate the water

pump to enable flow of water from the DHW tank through the second coil of the RW heat exchanger, to heat the water and further supply the heated water back into the DHW tank.

[0021] Optionally, when the water in the DHW tank is to be heated in the cooling dominant season or in between heating cycles, the control unit is configured to actuate the water pump to supply the water at a maximum flow rate from the DHW tank into the RW heat exchanger and further actuate the heat pump to operate at a minimum heating capacity.

[0022] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, features, and techniques of the invention will become more apparent from the following description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The accompanying drawings are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification. The drawings illustrate exemplary embodiments of the invention and, together with the description, serve to explain the principles of the invention.

[0024] In the drawings, similar components and/or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label with a second label that distinguishes among the similar components. If only the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label.

FIG. 1 illustrates an exemplary representation of a modular de-superheater and water heater system.

FIG. 2 illustrates an exemplary control system implemented in the modular de-superheater and water heater system of FIG. 1.

FIGs. 3A and 3B illustrate exemplary plots depicting the psychometric capacity and mass-flow capacity measured during a standard defrosting cycle in a psychometric room to determine the amount of heat absorbed from the psychometric room for the defrosting.

DETAILED DESCRIPTION

[0025] The following is a detailed description of embodiments of the invention depicted in the accompanying drawings. The embodiments are in such detail as to clearly communicate the invention. However, the amount of detail offered is not intended to limit the anticipated variations of embodiments; on the contrary, the intention is to cover all modifications, equivalents, and alternatives

falling within the scope of the invention as defined by the appended claims.

[0026] Various terms are used herein. To the extent a term used in a claim is not defined below, it should be given the broadest definition persons in the pertinent art have given that term as reflected in printed publications and issued patents at the time of filing.

[0027] In the specification, reference may be made to the spatial relationships between various components and to the spatial orientation of various aspects of components as the devices are depicted in the attached drawings. However, as will be recognized by those skilled in the art after a complete reading of the specification, the components of the invention described herein may be positioned in any desired orientation. Thus, the use of terms such as "above," "below," "upper," "lower," "first," "second" or other like terms to describe a spatial relationship between various components or to describe the spatial orientation of aspects of such components should be understood to describe a relative relationship between the components or a spatial orientation of aspects of such components, respectively, described herein may be oriented in any desired direction.

[0028] In a designated space, a heating, ventilation, and air conditioning (HVAC) system may be installed which may comprise an outdoor heat pump unit and an indoor fan coil unit installed within the space, configured to deliver warm or conditioned air based on occupants' comfort. Additionally, a domestic hot water (DHW) unit may also be integrated to provide hot or warm water within the same space. Notably, the existing systems are engineered to configure the heat pump with both the fan coil unit and the DHW unit, allowing the heat pump to either actively heat the DHW or heat the cooler space at a time. However, the existing configuration restricts the heat pump from concurrently performing both functions.

[0029] Furthermore, the heat pump of existing systems lacks provisions for defrosting, a common issue addressed by conventional systems through the application of electric heaters during defrost cycles or by pulling heat from the space for defrosting. However, the use of resistance heat during these defrosting processes may be expensive and inefficient and may also lead to penalization, adversely affecting the system's overall efficiency. Moreover, pulling heat from the space for defrosting the outdoor coils may make the space cooler or uncomfortable for the occupants. There is therefore a need to overcome the above-mentioned drawbacks, limitations, and shortcomings associated with existing integrated HVAC-DHW systems.

[0030] This invention provides a simple, effective, and efficient solution in the form of a modular de-superheater and water heater system or package that utilizes de-superheated heat generated during the heating process to facilitate the warming of domestic water. The de-superheating also makes the fan coil unit's heat exchanger more effective because the system can begin conden-

sing the refrigerant as soon as it gets to the fan coil unit. In addition, in instances where the system is not engaged in high-capacity heating or lacks adequate de-superheating heat to fully warm the domestic water, the system functions as a dedicated water heating heat pump, actively raising the temperature of the water without concurrently cooling or providing heating to the indoor environment. Furthermore, the heated water resulting from this process serves a dual purpose by also being employed in the defrosting mechanism. This approach eliminates the necessity to extract heat from the indoor environment during defrost cycles, allowing for the utilization of the heat sourced from the domestic water instead, thereby making the overall system efficient and cost-effective.

[0031] Referring to FIG. 1, a modular de-superheater and water heater system 100 (also referred to as modular system 100 or system 100, herein) is disclosed. The system 100 can be configured to be connected between a heat pump 108 associated with an outdoor unit and an indoor fan coil unit 112 associated with an area of interest (AOI). In one or more embodiments, the heat pump 108 can be a heat exchanger comprising an outdoor coil 110 having a first port 110-1 at one end and a second port 110-2 at another end. The outdoor coil 110 of the heat pump 108 may be in thermal communication with an ambient to facilitate heat exchange between a refrigerant flowing through the heat pump 108 and the ambient. Further, the fan coil unit 112 can also be a heat exchanger comprising an indoor coil 114 having an inlet 114-1 and an outlet 114-2. The indoor coil 114 of the fan coil unit 112 may be in thermal communication with an indoor space associated with the AOI where the fan coil unit 112 is installed to facilitate heat exchange between the refrigerant flowing through the fan coil unit 112 and the indoor space. In addition, the modular system 100 can also be configured to be connected to a domestic hot water (DHW) tank 116 associated with the AOI.

[0032] In one or more embodiments, the modular system 100 can include a refrigerant-to-water (RW) heat exchanger 102 comprising a first coil 104, and a second coil 106 in thermal communication with the first coil 104 to facilitate heat exchange therebetween. A first end 104-1 of the first coil 104 of the RW heat exchanger 102 can be configured to be fluidically connected to the first port 110-1 and a second end 104-2 of the first coil 104 can be configured to be fluidically connected to the inlet 114-1 of the indoor fan coil unit 112. Further, a first end 106-1 of the second coil 106 of the RW heat exchanger 102 can be configured to be fluidically connected to an outlet 116-1 of the DHW tank 116 and a second end 106-2 of the second coil 106 can be configured to be fluidically connected to an inlet 116-2 of the DHW tank 116 to enable flow of the water between the DHW tank 116 and the second coil 106 of the RW heat exchanger 102.

[0033] In addition, in one or more embodiments, the modular system 100 can include a solenoid valve 118 configured to be fluidically connected between the outlet

114-2 of the fan coil unit 112 and the second port 110-2 of the heat pump 108. Further, the modular system 100 can also include an electronic expansion valve (EXV) 120 that can be configured to be fluidically connected between the second port 110-2 of the heat pump 108 and the second end 104-2 of the first coil 104 of the RW heat exchanger 102.

[0034] In one or more embodiments, the modular system 100 can further include a water pump 122 configured to be fluidically connected between the first end 106-1 of the second coil 106 and the outlet 116-1 of the DHW tank 116 to control the flow of water between the DHW tank 116 and the RW heat exchanger 102. The water pump 122 may be a variable-speed water pump 122; however, the water pump 122 may also be a fixed-speed pump.

[0035] In one or more embodiments, a first refrigerant line R1 comprising a first set of conduits C1, C2 can extend from the first end 104-1 and the second end 104-2 of first coil 104 of the RW heat exchanger 102, where a first end of the first refrigerant line R1 can be configured to be fluidically connected to the first port 110-1 of the heat pump 108 by a conduit C1 and a second end of the first refrigerant line R1 can be configured to be fluidically connected to the inlet 114-1 of the fan coil unit 112 by another conduit C2. Further, a second refrigerant line R2 comprising a second set of conduits C3, C4 can extend from an inlet and an outlet of the solenoid valve 118, where a first end of the second refrigerant line R2 can be configured to be fluidically connected to the second port 110-2 of the heat pump 108 by a conduit C3 and a second end of the second refrigerant line R2 can be configured to be fluidically connected to the outlet 114-2 of the fan coil unit 112 by another conduit C4. In addition, a third refrigerant line R3 comprising a third set of conduits (not designated) can be used to fluidically connect the EXV 120 to the first refrigerant line R1 and the second refrigerant line R2.

[0036] In one or more embodiments, a first water line W1 and a second water line W2 can fluidically connect the DHW tank 116 to the second coil 106 of the RW heat exchanger 102. A first end of the first water line W1 can be fluidically connected to the second end 106-2 of the second coil 106 via the water pump 122 and a second end of the first water line W1 can be configured to be fluidically connected to the outlet 116-1 of the DHW tank 116. Further, a first end of the second water line W2 can be fluidically connected to the first end of the second coil 106 and a second end of the second water line W2 can be configured to be fluidically connected to the inlet 116-2 of the DHW tank 116.

[0037] In one or more embodiments, the RW heat exchanger 102, the water pump 122, the solenoid valve 118, and the EXV 120 associated with the system 100 can be enclosed or packaged within a housing 124 to form a modular structure, such that corresponding ends of the first and second refrigeration lines R1, R2, and the first and second water lines W1, W2 extend out of the housing 124 to facilitate fluidic coupling of the system 100 to the

heat pump 108, the fan coil unit 112, and the DHW tank 116.

[0038] The housing 124 or the modular system 100 can be adapted to be installed at a predefined position within the AOI in a horizontal or vertical configuration. The system 100 is designed in a packaged form factor or modular design, where the components/units of the system 100 are configured within the housing that is compact and easily installable at a desired location in the AOI/-building. The locations can be but are not limited to rooms, entry halls, above doors, below a floor, on the floor, ceiling, walls, corridors, staircases, basement, and storage spaces associated with the building. For instance, the packaged system 100/housing 124 can be designed in a horizontal orientation/configuration on each floor above the door in the entry hall or in the corridors, and/or designed in a vertical orientation/configuration in wet chase risers or at exterior walls, and/or designed to be horizontally or vertically fitted in a closet, and/or configured vertically against the outer wall, but not limited to the like.

[0039] In one or more embodiments, in a de-superheating mode, the system 100 can be configured to close the EXV 120, open the solenoid valve 118, and then operate the heat pump 108 to enable the flow of high-temperature, high-pressure vapor phase of the refrigerant from the first port 110-1 of the heat pump 108 through the first coil 104 of the RW heat exchanger 102 via the refrigerant line R1. The system 100 can further actuate the water pump 122 to enable the flow of water from the DHW tank 116 through the second coil 106 of the RW heat exchanger 102 via the water line W1. Accordingly, the RW heat exchanger 102 can facilitate heat exchange between the vapor phase of the refrigerant and the water while flowing therethrough to de-superheat the vapor and further heat the water. In one or more embodiments, the system 100 can be configured to actuate the water pump 122 to enable the supply of the heated water back into the DHW tank 116 through the water line W2 and further supply the de-superheated vapor back to the heat pump 108 via the fan coil unit 112 and the solenoid valve 118 through the refrigerant line R2.

[0040] In one or more embodiments, when the heat pump 108 is operated in a defrost mode, the system 100 can be configured to close the solenoid valve 118, open the EXV 120, and then operate the heat pump 108 to enable the flow of the refrigerant from the second port 110-2 of the heat pump 108 into the first coil 104 of the RW heat exchanger 102 via the EXV 120 through refrigerant line R2 (conduit C3) and R3 while restricting the flow of the refrigerant into the fan coil unit 112 (or through conduit C4) as the solenoid valve 118 is closed. The EXV 120 can enable the expansion of the refrigerant into the RW heat exchanger 102. The system 100 can further actuate the water pump 122 to enable the flow of hot water from the DHW tank 116 through the second coil 106 of the RW heat exchanger 102 via the water line W1. Accordingly, the RW heat exchanger can facilitate heat exchange

between the refrigerant flowing through the first coil 104 and the hot water while flowing through the second coil 106 of the RW heat exchanger 102 to heat the refrigerant. This heated refrigerant can then be supplied into the heat pump 108 via the first port 110-1 of the heat pump 108 through the conduit C 1 to defrost the outdoor coil 110 associated with the outdoor unit, without using any electric heating or without pulling heat from the indoor space of the AOI.

[0041] Referring to FIGs. 3A and 3B, exemplary plots depicting the psychometric capacity and mass-flow capacity measured during a standard defrosting cycle in a psychometric room (indoor space of the AOI) to determine the amount of heat (in BTU) extracted/absorbed by a typical heat pump (without the modular system 100) from the psychometric room for the defrosting. Further, the calculated amount of heat was observed to calculate the amount of heat that the defrost cycle may draw from the domestic water tank and the drop in temperature in the domestic hot water tank, and further determine how long a de-superheater may take to reheat the water.

[0042] In one or more embodiments, when the water in the DHW tank 116 is to be heated in a cooling dominant season or in between heating cycles, the system 100 can be configured to close the solenoid valve 118, open the EXV 120, and then operate the heat pump 108 to enable flow of the refrigerant from the first port 110-1 of the heat pump 108 through the first coil 104 of the RW heat exchanger 102 through conduit C1 while restricting flow of the refrigerant into the fan coil unit 112 (or through conduit C2) as the solenoid valve 118 is closed. The system 100 can further actuate the water pump 122 to enable the flow of water from the DHW tank 116 through the second coil 106 of the RW heat exchanger 102 via the water line W1. Accordingly, the RW heat exchanger 102 can facilitate heat exchange between the refrigerant flowing through the first coil 104 and the hot water while flowing through the second coil 106 of the RW heat exchanger 102 to heat the water that can be supplied back into the DHW tank 116 via the water line W2. The refrigerant can then be supplied back to the heat pump 108 via the refrigerant line R3 and conduit C3.

[0043] In one or more embodiments, when the water in the DHW tank 116 is to be heated in the cooling dominant season or in between heating cycles, the system 100 can be configured to operate the water pump 122 to supply the water from the DHW tank 116 through the second coil 106 of the RW heat exchanger 102 at a maximum flow rate and further operate the heat pump 108 at a minimum (or reduced) heating capacity if the refrigerant is to be fully condensed.

[0044] In one or more embodiments, when the AOI is to be cooled, the system 100 can be configured to open the solenoid valve 118, close the EXV 120, and then operate the heat pump 108 to enable flow of the refrigerant from the first port 110-1 of the heat pump 108 into the inlet 114-1 of the fan coil unit 112 via the refrigerant line R1 (conduit C1 and C2) and further back into the heat pump

108 via the outlet 114-2 of the fan coil unit 112 via the refrigerant line R2 (conduit C3 and C4). Accordingly, the flow of refrigerant through the fan coil unit 112 can facilitate the absorption of heat from the AOI to cool the AOI.

[0045] Accordingly, during periods of elevated heating demand, the process of de-superheating becomes an effective and efficient solution to rapidly reheat DHW (water) following a defrost of the outdoor coil, which may be accomplished within an hour or less. This efficient reheat capability enhances the overall responsiveness of the modular system 100. Further, in instances where the demand for heating or cooling the DHW is relatively lower, the system 100 provides a proactive solution by actively heating the water during off-cycles. As a result, even when the primary demand for heating or cooling at the AOI is reduced, the system 100 remains dynamically engaged in the optimization of the DHW temperature. Furthermore, the system 100 can extend the duration of the on-cycle, thereby creating a predetermined interval for an off-cycle. By increasing the heating or cooling capacity during specific periods, the system 100 effectively manages to generate surplus heat energy that can be harnessed during subsequent off-cycles, contributing to enhanced overall efficiency and performance of the modular system 100 and the associated heat pump 108 and fan coil unit 112.

[0046] Referring to FIG. 2, the system 100 can include a control unit 202 that can be in communication with a controller associated with one or more of the heat pump 108, the water pump 122, the solenoid valve 118, and the EXV 120 via a secured network. In one or more embodiments, the control unit 202 can comprise one or more processors 202-1 coupled to a memory 202-2 storing instructions executable by the processors 202-1, which can cause the control unit 202 to perform one or more designated operations. In one or more embodiments, the control unit 202 can actuate one or more of the heat pump 108, the water pump 122, the solenoid valve 118, and the EXV 120 to control the de-superheating of the refrigerant, adjust the temperature of the AOI at a first predefined temperature, heat the water of the DHW tank 116 to a second predefined temperature, and/or control defrosting of the outdoor coil associated with the outdoor unit.

[0047] In one or more embodiments, the system 100 may further include a thermostat 204 positioned within the AOI. The thermostat 204 and/or mobile devices of occupants of the AOI may be in communication with the control unit 202 via the network, which may be configured to enable the occupants of the AOI to set one or more of the first predefined temperature to be maintained within the space of the AOI based on the occupant's comfort and further set the second predefined temperature for the water to be supplied within the AOI by the DHW tank 116. In one or more embodiments, the thermostat 204 and/or mobile devices of occupants may further allow the occupants to operate the heat pump 108 in the de-superheating mode, and/or the defrost mode. However, the system 100 can be configured to automatically operate

the heat pump 108 in the defrost mode when the system 100 detects an event of frost formation in/on the outdoor coil.

[0048] In one or more embodiments, the control unit 202 can be configured to close the EXV 120, open the solenoid valve 118, and actuate the heat pump 108 to adjust the heating capacity of the heat pump 108 and/or flow rate of the refrigerant supplied by the heat pump 108 to the RW heat exchanger 102, and further actuate the water pump 122 to adjust flow rate of the water supplied by the DHW tank 116 to the RW heat exchanger 102, to de-super heat the refrigerant and further heat the water at the second predefined temperature.

[0049] In one or more embodiments, the control unit 202 can be configured to open the EXV 120, close the solenoid valve 118, and actuate the heat pump 108 to adjust the heating capacity of the heat pump 108 and/or flow rate of the refrigerant supplied by the heat pump 108 to the RW heat exchanger 102, and further actuate the water pump 122 to adjust the flow rate of the hot water supplied by the DHW tank 116 to the RW heat exchanger 102, to heat the refrigerant and further supply the heated refrigerant to the heat pump 108 to defrost the outdoor coil 110, while restricting the flow of the refrigerant into the fan coil unit 112.

[0050] In one or more embodiments, when the water in the DHW tank 116 is to be heated in a cooling dominant season or in between heating cycles, the control unit 202 can be configured to close the solenoid valve 118, open the EXV 120, and actuate the heat pump 108 to adjust the heating capacity of the heat pump 108 and/or flow rate of the refrigerant supplied by the heat pump 108 to the RW heat exchanger 102, and further actuate the water pump 122 to enable flow of water from the DHW tank 116 through the second coil 106 of the RW heat exchanger 102, to heat the water and further supply the heated water back into the DHW tank 116.

[0051] In one or more embodiments, when the water in the DHW tank 116 is to be heated in the cooling dominant season or in between heating cycles, the control unit 202 can be configured to actuate the water pump 122 to supply the water at a maximum flow rate from the DHW tank 116 into the RW heat exchanger 102 and further actuate the heat pump 108 to operate at a minimum heating capacity to fully condense the refrigerant.

[0052] In one or more embodiments, wherein when the AOI is to be cooled or maintained at the first predefined temperature, the control unit 202 can be configured to open the solenoid valve 118, close the EXV 120, and operate the heat pump 108 to enable the flow of the refrigerant from the first port 110-1 of the heat pump 108 into the inlet 114-1 of the fan coil unit 112 and further back into the heat pump 108 via the outlet 114-2 of the fan coil unit 112. Accordingly, the flow of refrigerant through the fan coil unit 112 can facilitate the absorption of heat from the AOI to cool and maintain the AOI at the first predefined temperature.

[0053] It is to be appreciated by a person skilled in the

art that the modular system utilizes de-superheated heat generated during the heating process to facilitate the warming of the domestic water, which (de-superheating) also makes the fan coil unit's heat exchanger more effective because the system can begin condensing the refrigerant as soon as it gets to the fan coil unit. In addition, in instances where the system is not engaged in high-capacity heating or lacks adequate de-superheating heat to fully warm the domestic water, the heat pump functions as a dedicated water heating heat pump that actively raises the temperature of the water without concurrently cooling or providing heating to the indoor environment. In addition, the heated water resulting from this process serves a dual purpose by being employed as the domestic hot water and also being employed in the defrosting of the outdoor coil. This solution eliminates the need to extract heat from the indoor space of the AOI during defrost cycles, allowing for the utilization of the heat sourced from the domestic water instead, thereby making the overall system efficient and cost-effective.

[0054] Thus, this invention overcomes the drawbacks of existing integrated HVAC-DHW systems, by providing a simple, effective, and efficient solution in the form of the modular de-superheater and water heater system.

[0055] While the invention has been described with reference to exemplary 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 invention as defined by the appended claims. Modifications may be made to adopt a particular situation or material to the teachings of the invention without departing from the scope thereof as defined by the appended claims. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed, but that the invention includes all embodiments falling within the scope of the invention as defined by the appended claims.

[0056] In interpreting the specification, all terms should be interpreted in the broadest possible manner consistent with the context. In particular, the terms "comprises" and "comprising" should be interpreted as referring to elements, components, or steps in a non-exclusive manner, indicating that the referenced elements, components, or steps may be present, or utilized, or combined with other elements, components, or steps that are not expressly referenced. Where the specification claims refer to at least one of something selected from the group consisting of A, B, Cand N, the text should be interpreted as requiring only one element from the group, not A plus N, or B plus N, etc.

[0057] The following clauses set out features of the invention which may not presently be claimed in this application, but which may form the basis for future amendment and/or a divisional application.

1. A modular de-superheater and water heater system, the system comprising:

a refrigerant-to-water (RW) heat exchanger comprising a first coil, and a second coil in thermal communication with the first coil to facilitate heat exchange therebetween, wherein a first end of the first coil is configured to be fluidically connected to a first port of a heat pump associated with an outdoor unit and a second end of the first coil is configured to be fluidically connected to an inlet of an indoor fan coil unit associated with an area of interest (AOI), and wherein a first end of the second coil is configured to be fluidically connected to an outlet of a domestic hot water (DHW) tank associated with the AOI and a second end of the second coil is configured to be fluidically connected to an inlet of the DHW tank; a solenoid valve configured to be fluidically connected between an outlet of the fan coil unit and a second port of the heat pump; and an electronic expansion valve (EXV) configured to be fluidically connected between the second port of the heat pump and the second end of the first coil of the RW heat exchanger.

2. The system of clause 1, wherein the system comprises a water pump configured to be fluidically connected between the first end of the second coil and an outlet of the DHW tank to control flow of water between the DHW tank and the RW heat exchanger.

3. The system of clause 2, wherein the water pump is a variable-speed water pump.

4. The system of any one of clauses 1 to 3, wherein the heat pump is a variable-speed heat pump.

5. The system of any one of clauses 1 to 4, wherein in a de-superheating mode, the system is configured to close the EXV, open the solenoid valve, and operate the heat pump to enable flow of high-temperature, high-pressure vapor phase of the refrigerant from the first port of the heat pump through the first coil of the RW heat exchanger, and further actuate the water pump to enable flow of water from the DHW tank through the second coil of the RW heat exchanger, wherein the RW heat exchanger facilitates heat exchange between the vapor phase of the refrigerant and the water while flowing therethrough to de-super heat the vapor and further heat the water.

6. The system of clause 5, wherein the system is configured to supply the heated water into the DHW tank and the de-superheated vapor into the heat pump via the fan coil unit and the solenoid valve.

7. The system of any one of clauses 1 to 4, wherein when the heat pump is operated in a defrost mode, the system is configured to close the solenoid valve, open the EXV, and operate the heat pump to enable flow of the refrigerant from the second port of the heat pump into the first coil of the RW heat exchanger via the EXV while restricting flow of the refrigerant into

the fan coil unit, and further actuate the water pump to enable flow of hot water from the DHW tank through the second coil of the RW heat exchanger, wherein the RW heat exchanger facilitates heat exchange between the refrigerant and the hot water while flowing therethrough to heat the refrigerant.

8. The system of clause 7, wherein the system is configured to supply the heated refrigerant into the heat pump via the first port of the heat pump to defrost an outdoor coil associated with the outdoor unit.

9. The system of any one of clauses 1 to 4, wherein when the water in the DHW tank is to be heated in a cooling dominant season or in between heating cycles, the system is configured to close the solenoid valve, open the EXV, and operate the heat pump to enable flow of the refrigerant from the first port of the heat pump through the first coil of the RW heat exchanger while restricting flow of the refrigerant into the fan coil unit, and further actuate the water pump to enable flow of water from the DHW tank through the second coil of the RW heat exchanger, wherein the RW heat exchanger facilitates heat exchange between the refrigerant and the hot water while flowing therethrough to heat the water being supplied back into the DHW tank.

10. The system of clause 9, wherein when the water in the DHW tank is to be heated in the cooling dominant season or in between heating cycles, the system can be configured to operate the water pump to supply the water from the DHW tank through the second coil of the RW heat exchanger at a maximum flow rate and the heat pump is operated at a minimum heating capacity.

11. The system of any one of clauses 1 to 4, wherein when the AOI is to be cooled, the system is configured to open the solenoid valve, close the EXV, and operate the heat pump to enable flow of the refrigerant from the first port of the heat pump into the inlet of the fan coil unit and further back into the heat pump via the outlet of the fan coil unit, wherein the flow of refrigerant through the fan coil unit facilitates absorption of heat from the AOI to cool the AOI.

12. The system of any one of clauses 1 to 11, wherein the system comprises:

a first refrigerant line extending from the first end and the second end of the RW heat exchanger, wherein a first end of the first refrigerant line is configured to be fluidically connected to the first port of the heat pump and a second end of the first refrigerant line is configured to be fluidically connected to the inlet of the fan coil unit;

a second refrigerant line extending from an inlet and an outlet of the solenoid valve, wherein a first end of the second refrigerant line is configured to be fluidically connected to the second port of the heat pump and a second end of the

second refrigerant line is configured to be fluidically connected to the outlet of the fan coil unit; and
 a third refrigerant line fluidically connecting the EXV to the first refrigerant line and the second refrigerant line;

13. The system of any one of clauses 1 to 12, wherein the system comprises:

a first water line having a first end fluidically connected to the second end of the second coil via the water pump and a second end configured to be fluidically connected to the outlet of the DHW tank; and
 a second water line having a first end fluidically connected to the first end of the second coil and a second end configured to be fluidically connected to the inlet of DHW tank.

14. The system of any one of clauses 1 to 13, wherein the RW heat exchanger, the water pump, the solenoid valve, and the EXV are enclosed within a housing, such that corresponding ends of the first and second refrigeration lines, and the first and second water lines extend out of the housing to facilitate fluidic coupling of the system to the heat pump, the fan coil unit, and the DHW tank.

15. The system of any one of clauses 12 and 13, wherein the first and second refrigeration lines, and the first and second water lines comprise a set of conduits.

16. The system of any one of clauses 1 to 15, wherein the system comprises a control unit in communication with a controller associated with one or more of the heat pump, the water pump, the solenoid valve, and the EXV via a network, wherein the control unit comprises one or more processor coupled to a memory storing instructions executable by the processors, which causes the control unit to:

actuate one or more of the heat pump, the water pump, the solenoid valve, and the EXV to control the de-superheating of the refrigerant, adjust the temperature of the AOI at a first predefined temperature, heat the water of the DHW tank to a second predefined temperature, and/or control defrosting of the outdoor coil associated with the outdoor unit.

17. The system of clause 16, wherein the control unit is configured to close the EXV, open the solenoid valve, and actuate the heat pump to adjust the heating capacity of the heat pump and/or flow rate of the refrigerant supplied by the heat pump to the RW heat exchanger, and further actuate the water pump to adjust flow rate of the water supplied by the DHW tank to the RW heat exchanger, to de-super heat the refrigerant and further heat the water at the second predefined temperature.

18. The system of clause 16, wherein the control unit

is configured to open the EXV, close the solenoid valve, and actuate the heat pump to adjust the heating capacity of the heat pump and/or flow rate of the refrigerant supplied by the heat pump to the RW heat exchanger, and further actuate the water pump to adjust flow rate of the hot water supplied by the DHW tank to the RW heat exchanger, to heat the refrigerant and further supply the heated refrigerant to the heat pump to defrost the outdoor coil, while restricting flow of the refrigerant into the fan coil unit.

19. The system of clause 16, wherein when the water in the DHW tank is to be heated in a cooling dominant season or in between heating cycles, the control unit is configured to close the solenoid valve, open the EXV, and actuate the heat pump to adjust the heating capacity of the heat pump and/or flow rate of the refrigerant supplied by the heat pump to the RW heat exchanger, and further actuate the water pump to enable flow of water from the DHW tank through the second coil of the RW heat exchanger, to heat the water and further supply the heated water back into the DHW tank.

20. The system of clause 19, wherein when the water in the DHW tank is to be heated in the cooling dominant season or in between heating cycles, the control unit is configured to actuate the water pump to supply the water at a maximum flow rate from the DHW tank into the RW heat exchanger and further actuate the heat pump to operate at a minimum heating capacity.

Claims

1. A modular de-superheater and water heater system (100), the system comprising:
 a refrigerant-to-water, RW, heat exchanger (102) comprising a first coil (104), and a second coil (106) in thermal communication with the first coil to facilitate heat exchange therebetween,

wherein a first end (104-1) of the first coil is configured to be fluidically connected to a first port (110-1) of a heat pump (108) associated with an outdoor unit and a second end (104-2) of the first coil is configured to be fluidically connected to an inlet (114-1) of an indoor fan coil unit (112) associated with an area of interest, AOI, and

wherein a first end (106-1) of the second coil is configured to be fluidically connected to an outlet (116-1) of a domestic hot water, DHW, tank (116) associated with the AOI and a second end (106-2) of the second coil is configured to be fluidically connected to an inlet (116-2) of the DHW tank;

a solenoid valve (118) configured to be fluidically connected between an outlet (114-2) of the fan

- coil unit and a second port (110-2) of the heat pump; and
 an electronic expansion valve, EXV, (120) configured to be fluidically connected between the second port of the heat pump and the second end of the first coil of the RW heat exchanger.
2. The system of claim 1, wherein the heat pump is a variable-speed heat pump.
 3. The system of claim 1 or 2, wherein the system comprises a water pump (122) configured to be fluidically connected between the first end of the second coil and the outlet of the DHW tank to control flow of water between the DHW tank and the RW heat exchanger; optionally, wherein the water pump is a variable-speed water pump.
 4. The system of claim 3, wherein in a de-superheating mode, the system is configured to close the EXV, open the solenoid valve, and operate the heat pump to enable flow of high-temperature, high-pressure vapor phase of the refrigerant from the first port of the heat pump through the first coil of the RW heat exchanger, and further actuate the water pump to enable flow of water from the DHW tank through the second coil of the RW heat exchanger, wherein the RW heat exchanger facilitates heat exchange between the vapor phase of the refrigerant and the water while flowing therethrough to de-super heat the vapor and further heat the water; optionally, wherein the system is configured to supply the heated water into the DHW tank and the de-superheated vapor into the heat pump via the fan coil unit and the solenoid valve.
 5. The system of claim 3 or 4, wherein when the heat pump is operated in a defrost mode, the system is configured to close the solenoid valve, open the EXV, and operate the heat pump to enable flow of the refrigerant from the second port of the heat pump into the first coil of the RW heat exchanger via the EXV while restricting flow of the refrigerant into the fan coil unit, and further actuate the water pump to enable flow of hot water from the DHW tank through the second coil of the RW heat exchanger, wherein the RW heat exchanger facilitates heat exchange between the refrigerant and the hot water while flowing therethrough to heat the refrigerant; optionally, wherein the system is configured to supply the heated refrigerant into the heat pump via the first port of the heat pump to defrost an outdoor coil associated with the outdoor unit.
 6. The system of any of claims 3 to 5, wherein when the water in the DHW tank is to be heated in a cooling dominant season or in between heating cycles, the system is configured to close the solenoid valve, open the EXV, and operate the heat pump to enable flow of the refrigerant from the first port of the heat pump through the first coil of the RW heat exchanger while restricting flow of the refrigerant into the fan coil unit, and further actuate the water pump to enable flow of water from the DHW tank through the second coil of the RW heat exchanger, wherein the RW heat exchanger facilitates heat exchange between the refrigerant and the hot water while flowing therethrough to heat the water being supplied back into the DHW tank; and/or, wherein when the water in the DHW tank is to be heated in the cooling dominant season or in between heating cycles, the system can be configured to operate the water pump to supply the water from the DHW tank through the second coil of the RW heat exchanger at a maximum flow rate and the heat pump is operated at a minimum heating capacity.
 7. The system of any of claims 3 to 6, wherein the system comprises:
 - a first water line (W1) having a first end fluidically connected to the second end of the second coil via the water pump and a second end configured to be fluidically connected to the outlet of the DHW tank; and
 - a second water line (W2) having a first end fluidically connected to the first end of the second coil and a second end configured to be fluidically connected to the inlet of the DHW tank.
 8. The system of any of claims 3 to 7, wherein the system comprises a control unit (202) in communication with a controller associated with one or more of the heat pump, the water pump, the solenoid valve, and the EXV via a network, wherein the control unit comprises one or more processors (202-1) coupled to a memory (202-2) storing instructions executable by the processors, which causes the control unit to:
 - actuate one or more of the heat pump, the water pump, the solenoid valve, and the EXV to control the de-superheating of the refrigerant, adjust the temperature of the AOI at a first predefined temperature, heat the water of the DHW tank to a second predefined temperature, and/or control defrosting of the outdoor coil associated with the outdoor unit.
 9. The system of claim 8, wherein the control unit is configured to close the EXV, open the solenoid valve, and actuate the heat pump to adjust the heating capacity of the heat pump and/or flow rate of the refrigerant supplied by the heat pump to the RW heat exchanger, and further actuate the water pump to adjust flow rate of the water supplied by the DHW

tank to the RW heat exchanger, to de-super heat the refrigerant and further heat the water at the second predefined temperature.

10. The system of claim 8 or 9, wherein the control unit is configured to open the EXV, close the solenoid valve, and actuate the heat pump to adjust the heating capacity of the heat pump and/or flow rate of the refrigerant supplied by the heat pump to the RW heat exchanger, and further actuate the water pump to adjust flow rate of the hot water supplied by the DHW tank to the RW heat exchanger, to heat the refrigerant and further supply the heated refrigerant to the heat pump to defrost the outdoor coil, while restricting flow of the refrigerant into the fan coil unit.
11. The system of any of claims 8 to 10, wherein when the water in the DHW tank is to be heated in a cooling dominant season or in between heating cycles, the control unit is configured to close the solenoid valve, open the EXV, and actuate the heat pump to adjust the heating capacity of the heat pump and/or flow rate of the refrigerant supplied by the heat pump to the RW heat exchanger, and further actuate the water pump to enable flow of water from the DHW tank through the second coil of the RW heat exchanger, to heat the water and further supply the heated water back into the DHW tank;
and/or wherein when the water in the DHW tank is to be heated in the cooling dominant season or in between heating cycles, the control unit is configured to actuate the water pump to supply the water at a maximum flow rate from the DHW tank into the RW heat exchanger and further actuate the heat pump to operate at a minimum heating capacity.
12. The system of any preceding claim, wherein when the AOI is to be cooled, the system is configured to open the solenoid valve, close the EXV, and operate the heat pump to enable flow of the refrigerant from the first port of the heat pump into the inlet of the fan coil unit and further back into the heat pump via the outlet of the fan coil unit, wherein the flow of refrigerant through the fan coil unit facilitates absorption of heat from the AOI to cool the AOI.
13. The system of any preceding claim, wherein the system comprises:

a first refrigerant line extending from the first end and the second end of the RW heat exchanger, wherein a first end of the first refrigerant line is configured to be fluidically connected to the first port of the heat pump and a second end of the first refrigerant line is configured to be fluidically connected to the inlet of the fan coil unit;
a second refrigerant line extending from an inlet and an outlet of the solenoid valve, wherein a

first end of the second refrigerant line is configured to be fluidically connected to the second port of the heat pump and a second end of the second refrigerant line is configured to be fluidically connected to the outlet of the fan coil unit;
and
a third refrigerant line fluidically connecting the EXV to the first refrigerant line and the second refrigerant line.

14. The system of claim 13 when dependent on claim 7 or when dependent on any of claims 8 to 12 when dependent on claim 7, wherein the RW heat exchanger, the water pump, the solenoid valve, and the EXV are enclosed within a housing (124), such that corresponding ends of the first and second refrigerant lines, and the first and second water lines extend out of the housing to facilitate fluidic coupling of the system to the heat pump, the fan coil unit, and the DHW tank.
15. The system of claim 13 when dependent on claim 7 or when dependent on any of claims 8 to 12 when dependent on claim 7, or the system of claim 14, wherein the first and second refrigerant lines, and the first and second water lines comprise a set of conduits (C1, C2, C3, C4).

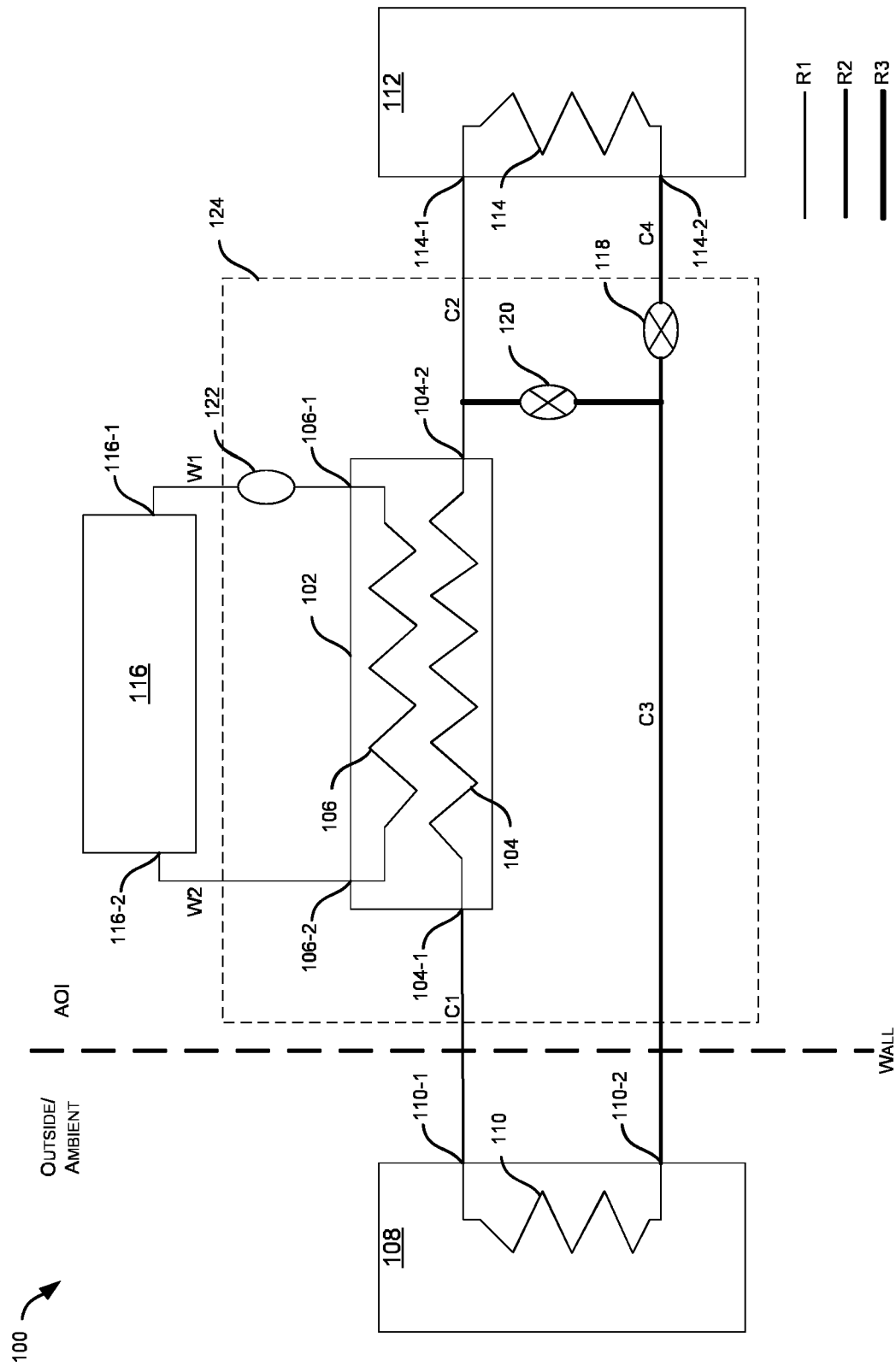


FIG. 1

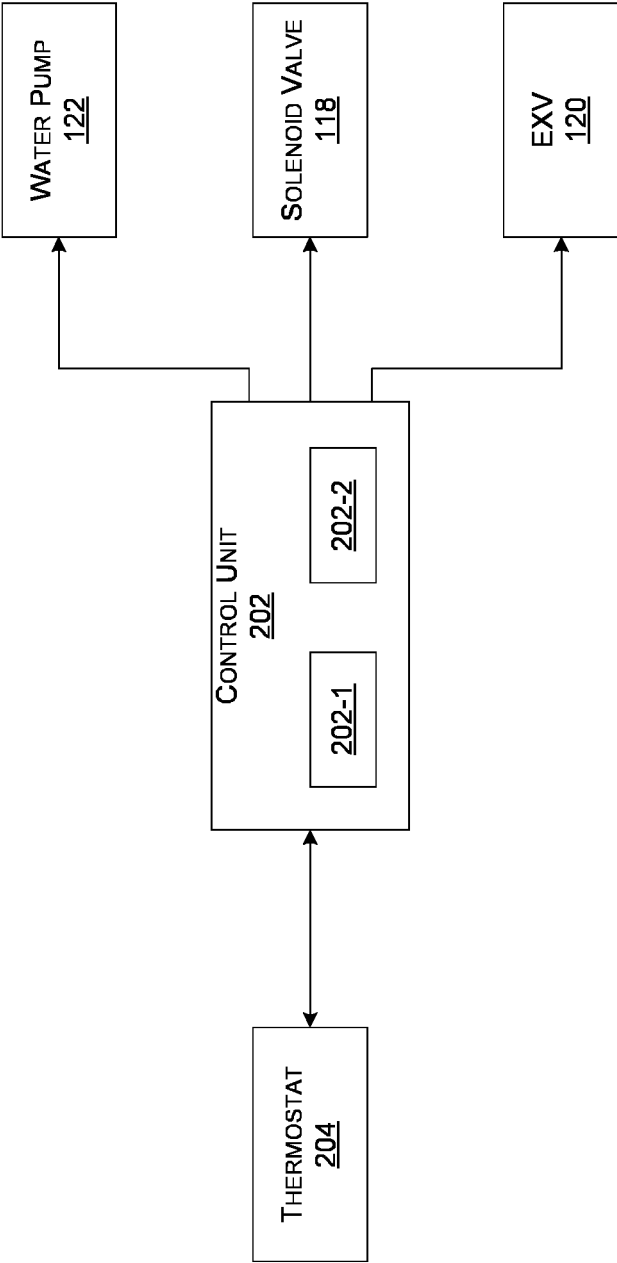


FIG. 2

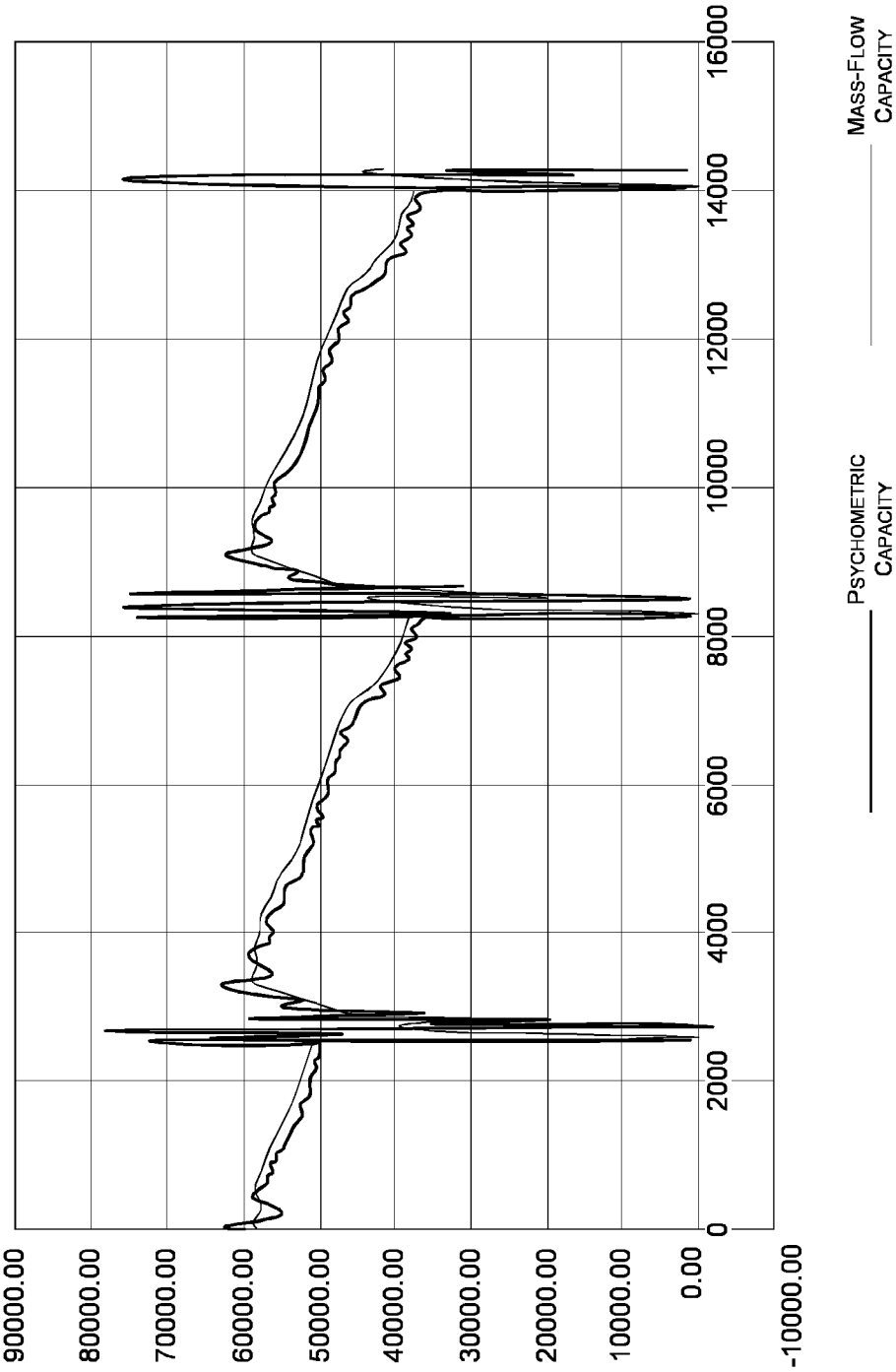


FIG. 3A

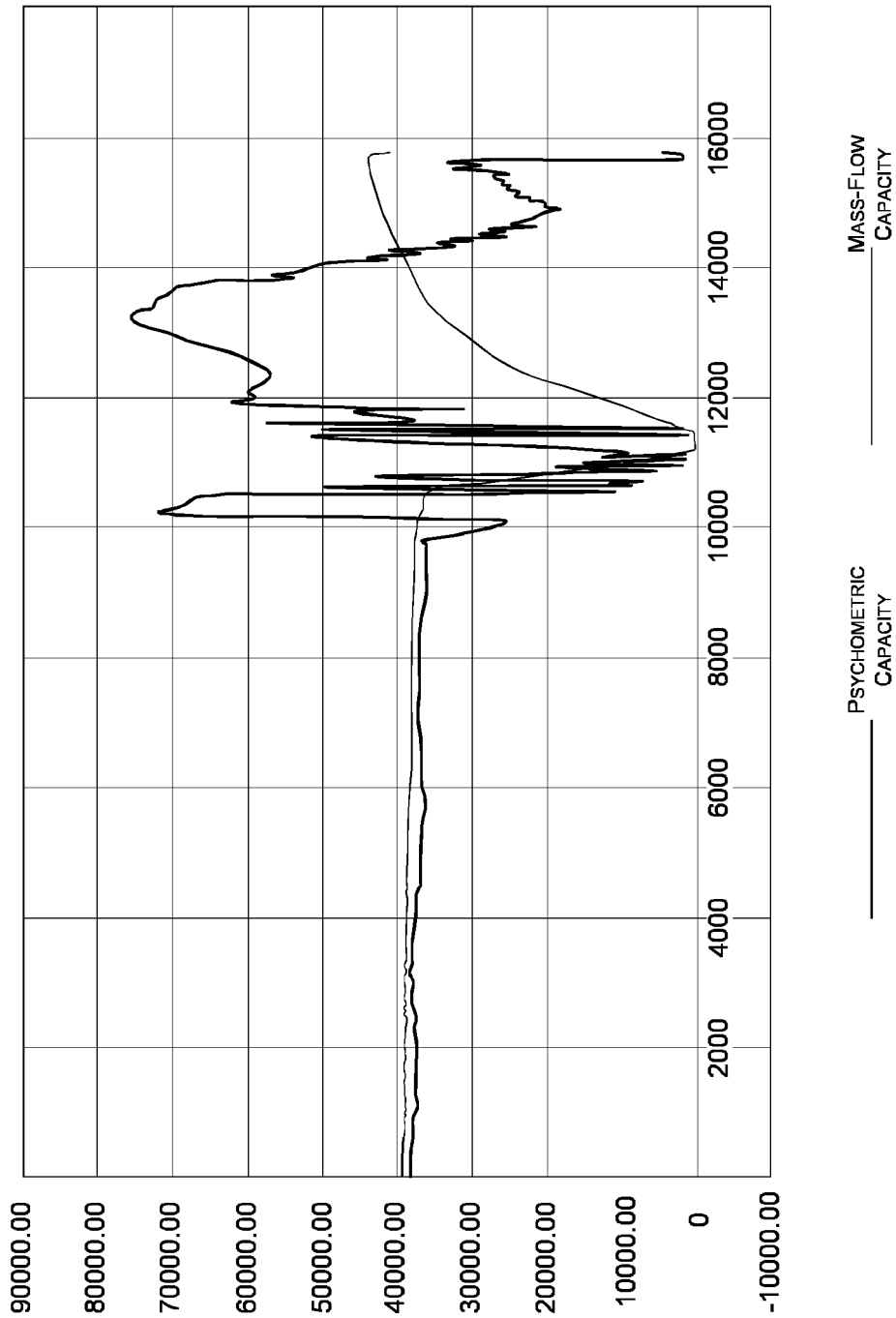


FIG. 3B



EUROPEAN SEARCH REPORT

Application Number

EP 24 21 8486

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Place of search			Examiner
Munich			García Moncayo, O
Date of completion of the search			
2 May 2025			
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