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Dorna et al.

(54) **MODULAR HVAC-SHW SYSTEM AND A METHOD OF INTEGRATING THEREOF**

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F24H 7/02	(2006.01)

(52) **U.S. Cl.**

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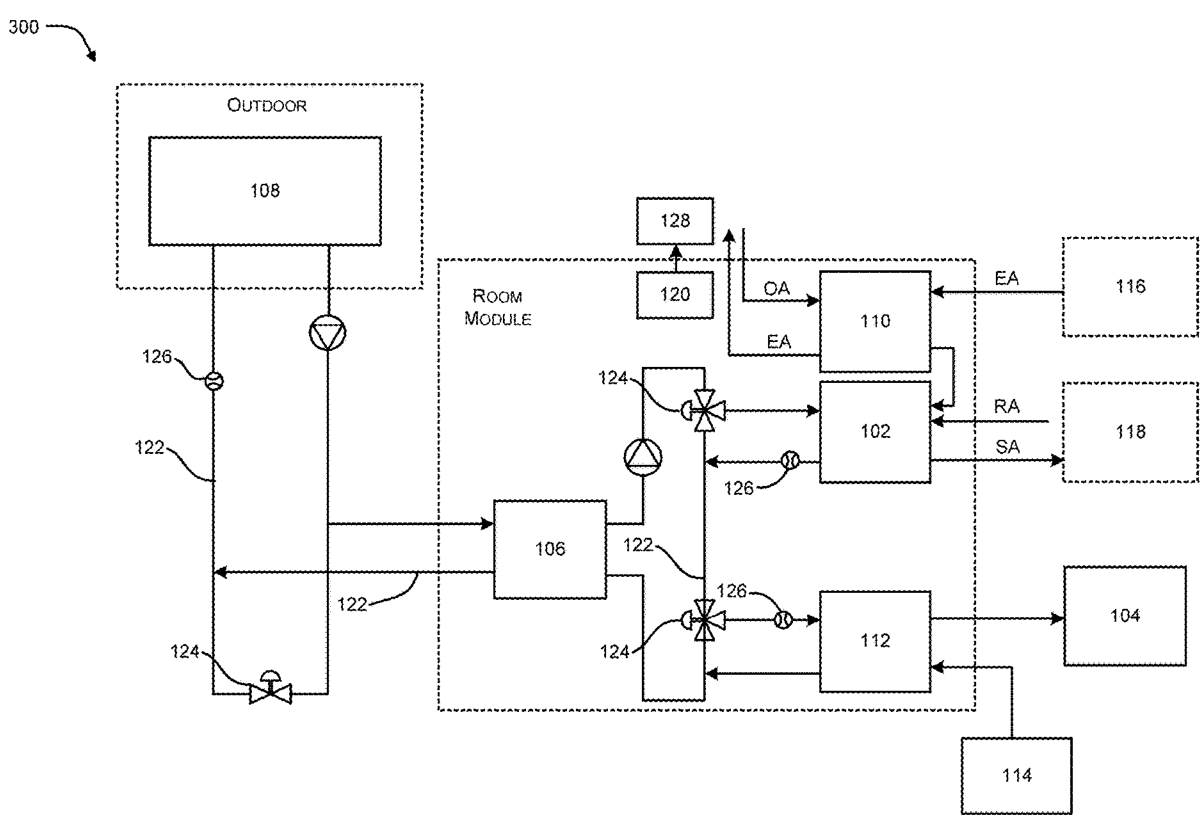
(57) **ABSTRACT**

A modular HVAC-SHW/DHW system that provides comfort conditioning, sanitary hot water, and ventilation in the buildings is disclosed. The system includes HVAC units, SHW/DHW units, and one or more air-to-water heat pump (AWHP) units fluidically connected to the HVAC units and the SHW/DHW units through at least one water-to-water heat pump (WWHPs). The AWHP units are configured to enable the exchange of heat between the environment and the WWHPs, and the WWHP is configured to enable the exchange of rejected heat between any of the AWHP units, the HVAC units, and the SHW/DHW units. The system is designed in a packaged form factor or modular design, where the components/units of the system are configured within a housing that is easily installable at the desired locations in the building.



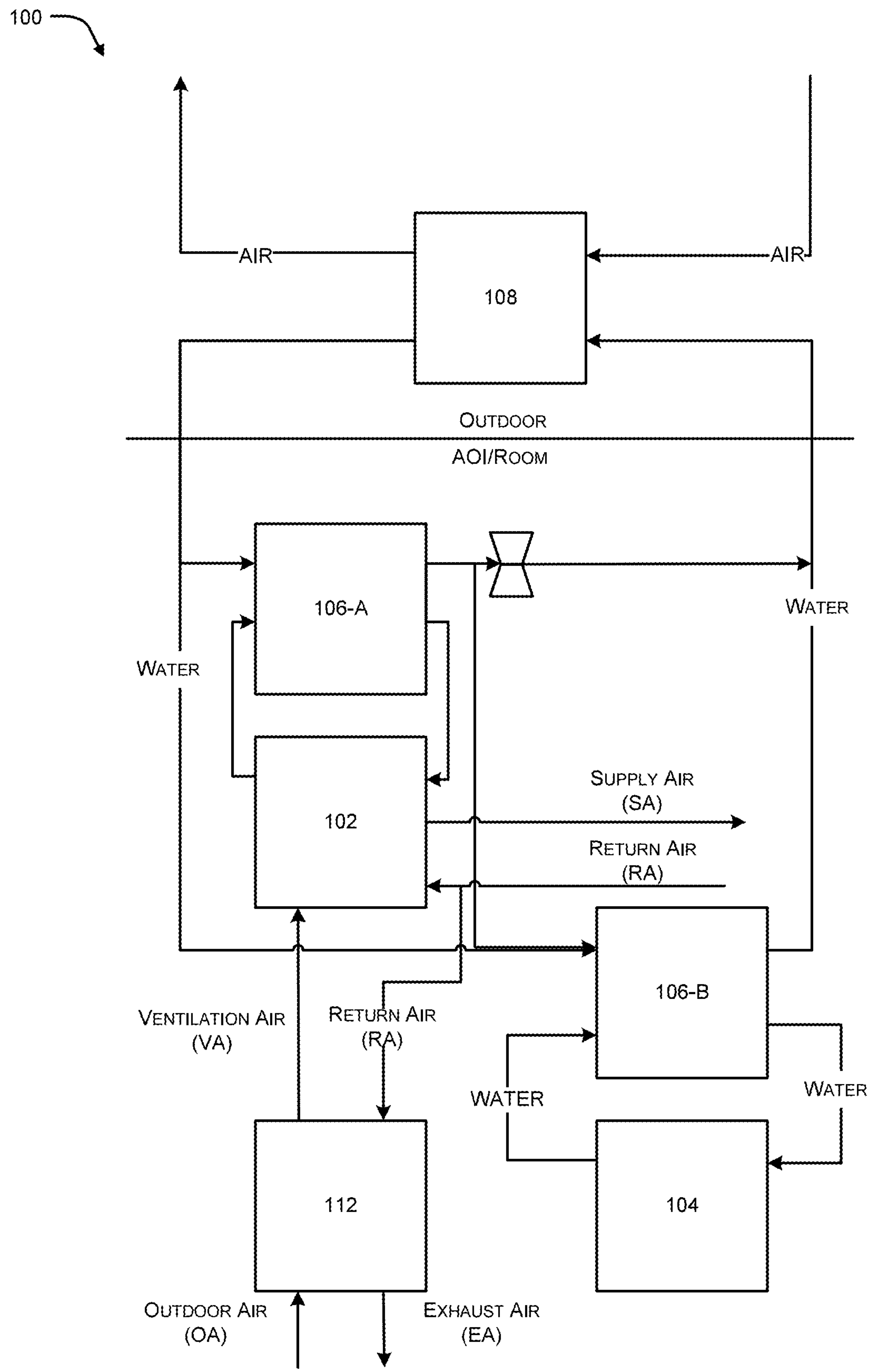

100
AIR
AIR
108
OUTDOOR
AOI/ROOM
106-A
WATER
WATER
102
SUPPLY AIR
(SA)
RETURN AIR
(RA)
106-B
VENTILATION AIR
(VA)
RETURN AIR
(RA)
WATER
WATER
112
104
OUTDOOR AIR
(OA)
EXHAUST AIR
(EA)

FIG. 1A

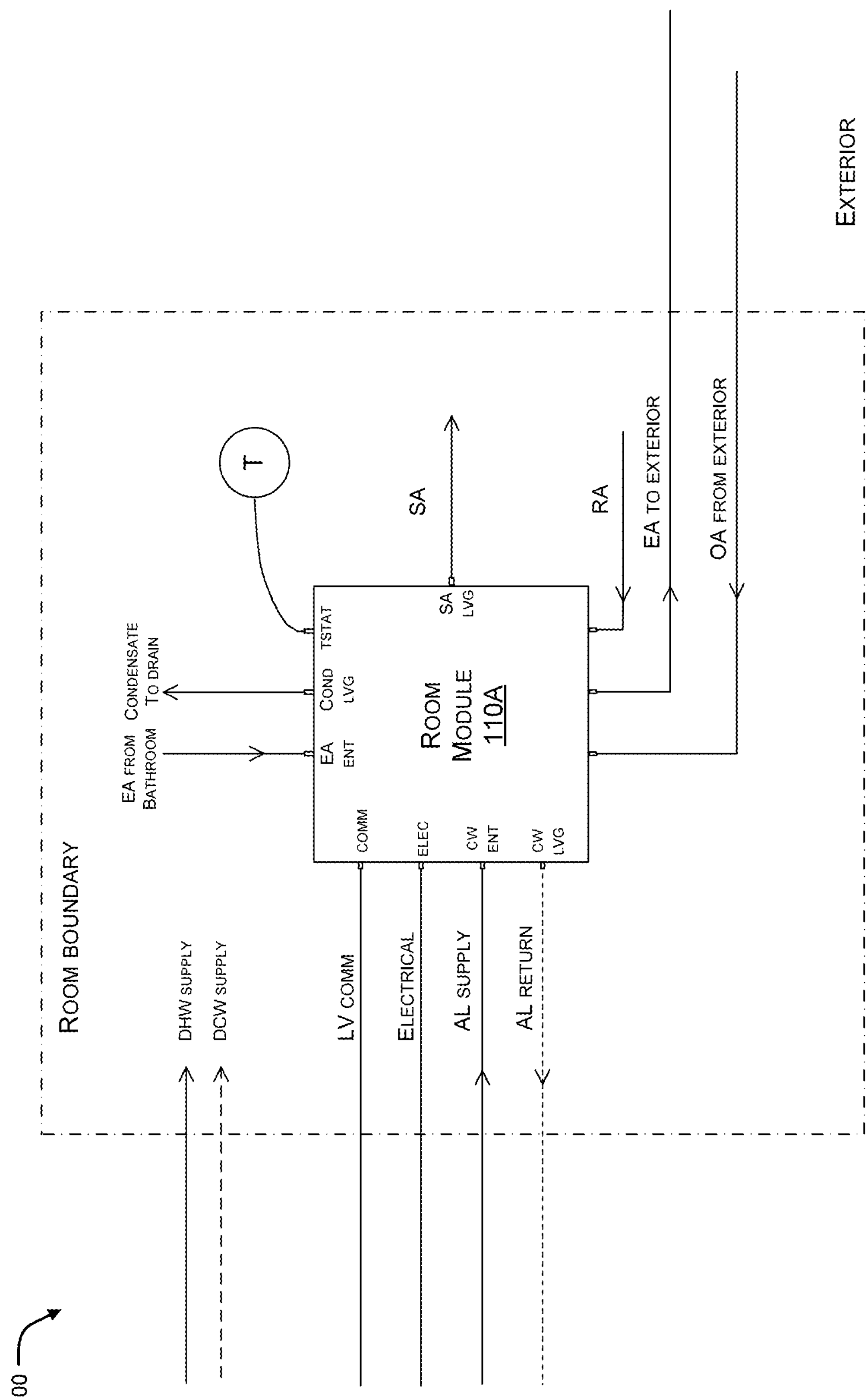

100
ROOM BOUNDARY
DHW SUPPLY
DCW SUPPLY
LV COMM
ELECTRICAL
AL SUPPLY
AL RETURN
EA FROM BATHROOM
CONDENSATE TO DRAIN
T
TSTAT
COND LVG
EA ENT
ROOM MODULE 110A
COMM
ELEC
CW ENT
CW LVG
SA LVG
SA
RA
EA TO EXTERIOR
OA FROM EXTERIOR
EXTERIOR

FIG. 1B

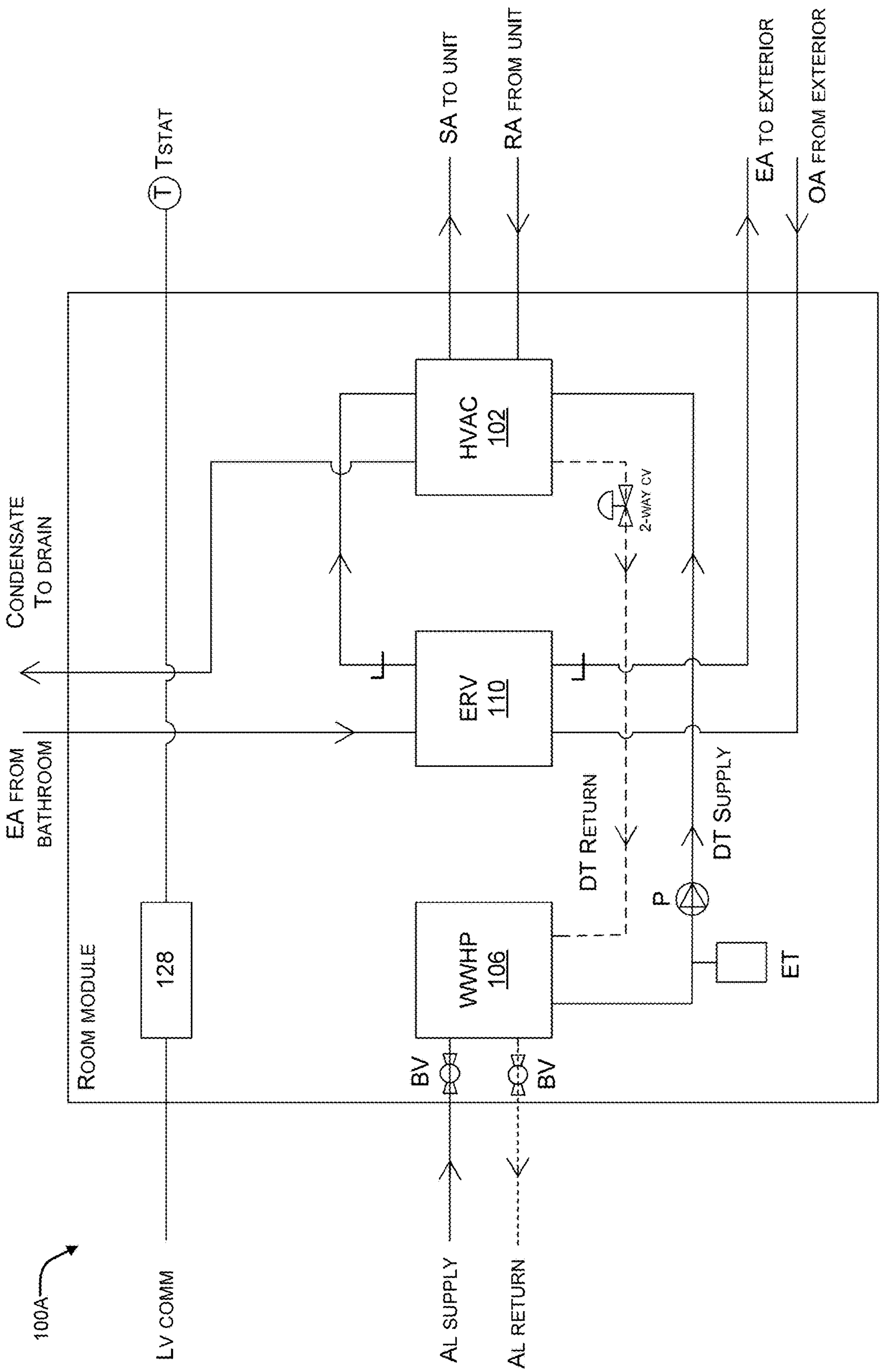

100A
LV COMM
AL SUPPLY
AL RETURN
ROOM MODULE
128
BV
BV
WWHP
106
ET
P
DT RETURN
DT SUPPLY
ERV
110
HVAC
102
2-WAY CV
EA FROM
BATHROOM
CONDENSATE
TO DRAIN
T
TSTAT
SA TO UNIT
RA FROM UNIT
EA TO EXTERIOR
OA FROM EXTERIOR

FIG. 1C

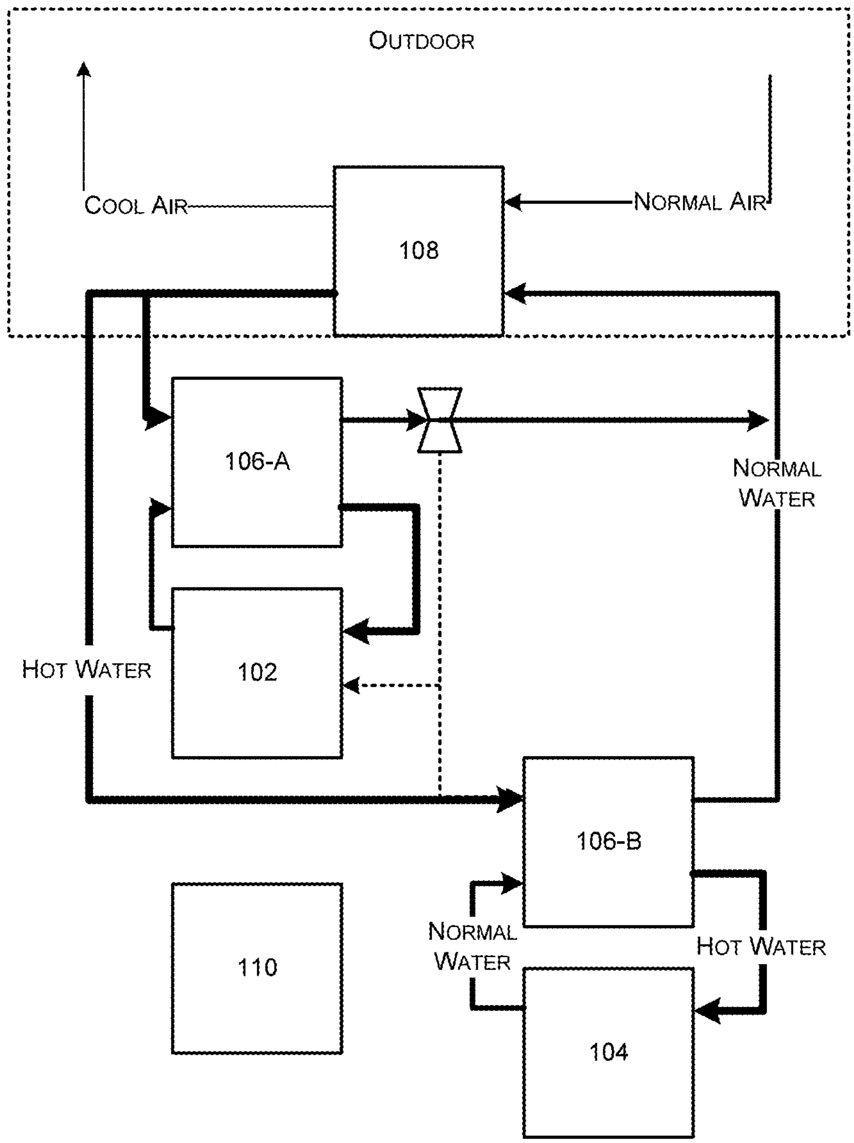

OUTDOOR
COOL AIR
NORMAL AIR
108
106-A
NORMAL WATER
HOT WATER
102
106-B
NORMAL WATER
HOT WATER
110
104

FIG. 2A

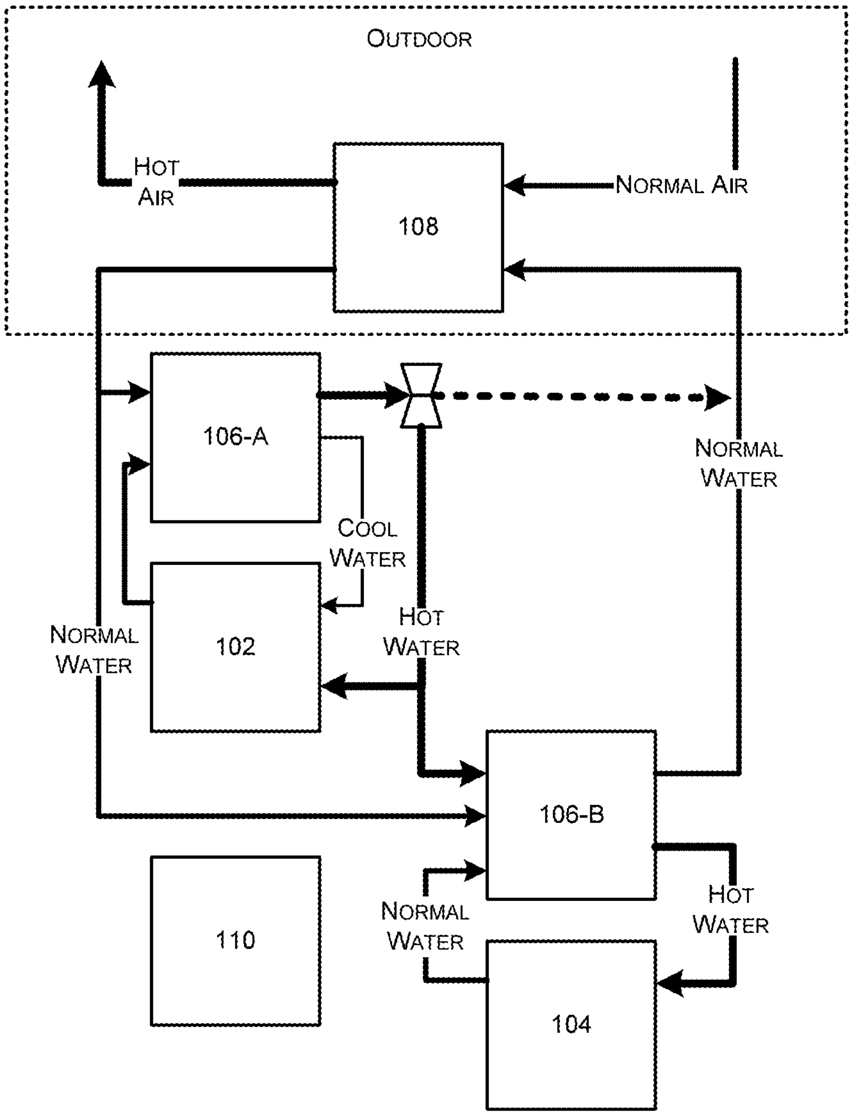

OUTDOOR
HOT AIR
108
NORMAL AIR
106-A
NORMAL WATER
COOL WATER
102
HOT WATER
NORMAL WATER
106-B
HOT WATER
110
NORMAL WATER
104

FIG. 2B

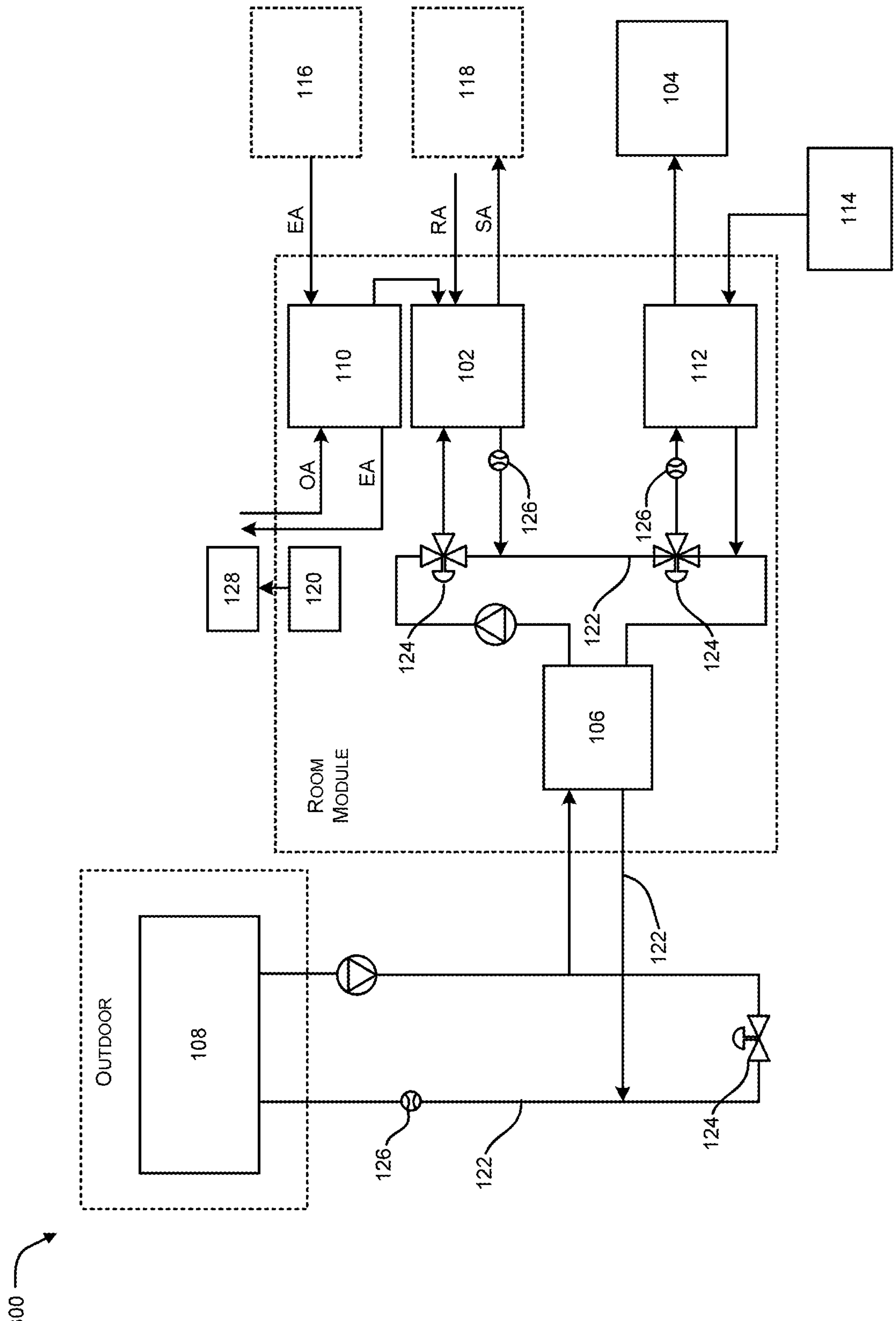

116
118
104
114
EA
RA
SA
110
102
112
OA
EA
126
126
128
120
124
122
124
106
Room Module
Outdoor
108
122
126
122
124
300

FIG. 3

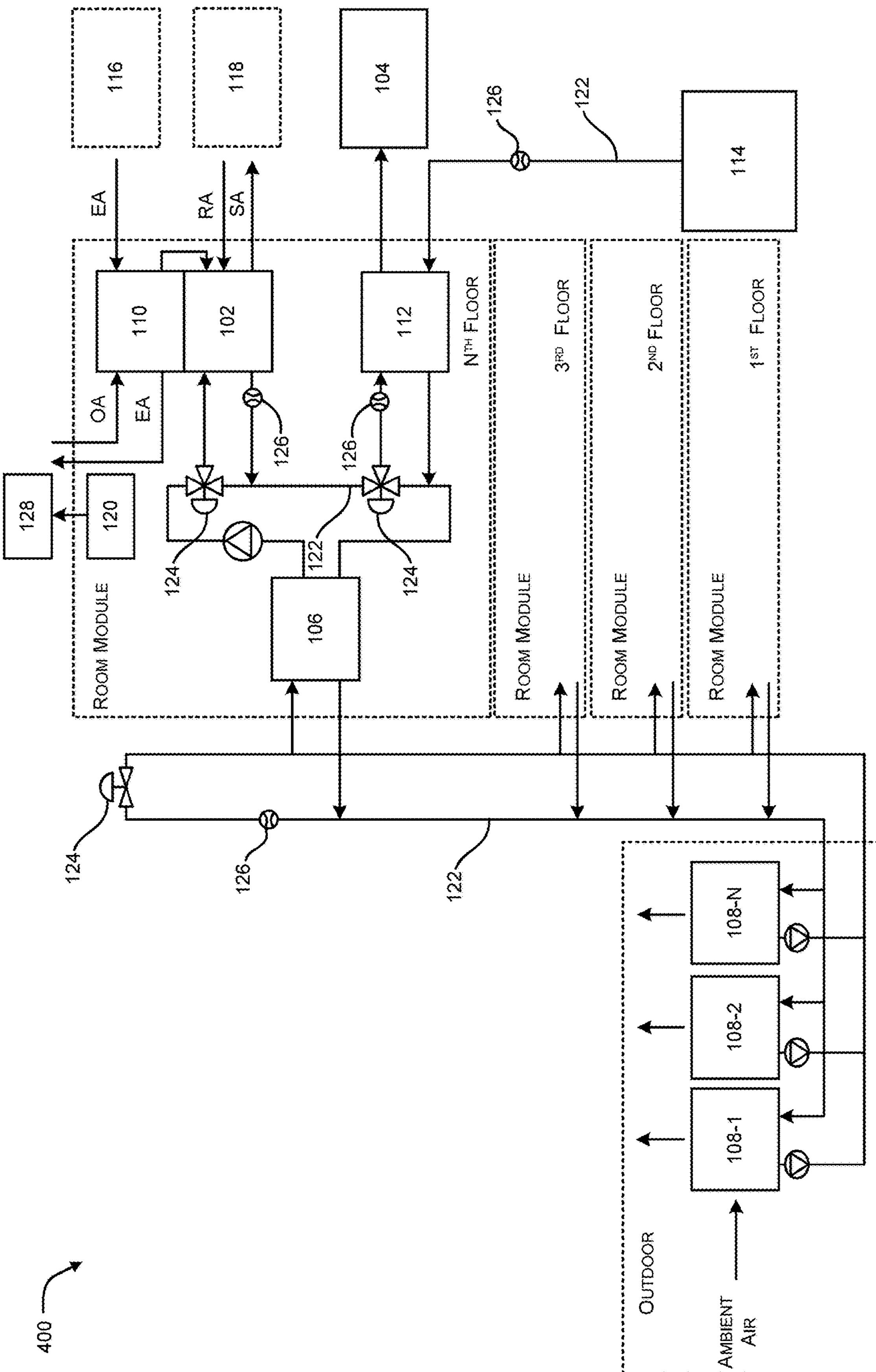

116
118
104
EA
RA
SA
126
122
114
110
102
112
OA
EA
128
120
124
122
126
124
106
Room Module
Nth Floor
3rd Floor
2nd Floor
1st Floor
Room Module
Room Module
Room Module
124
126
122
108-N
108-2
108-1
Low Temp Loop
Outdoor
Ambient Air
400

FIG. 4

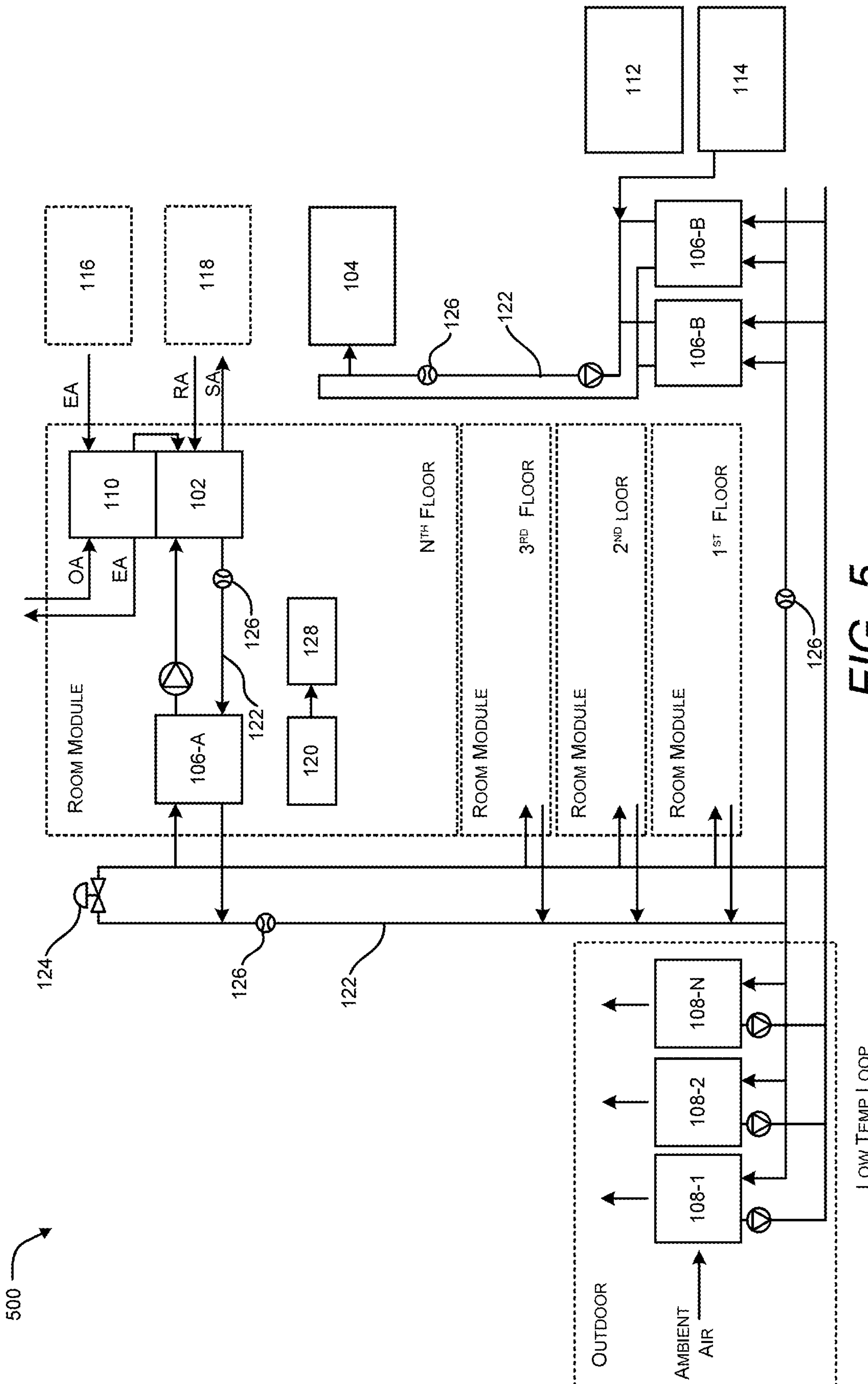

500
112
114
116
118
104
106-B
106-B
126
122
EA
RA
SA
OA
EA
110
102
126
122
106-A
128
120
ROOM MODULE
NTH FLOOR
ROOM MODULE
3RD FLOOR
ROOM MODULE
2ND LOOR
ROOM MODULE
1ST FLOOR
126
124
126
122
108-N
108-2
108-1
OUTDOOR
AMBIENT AIR
LOW TEMP LOOP

FIG. 5

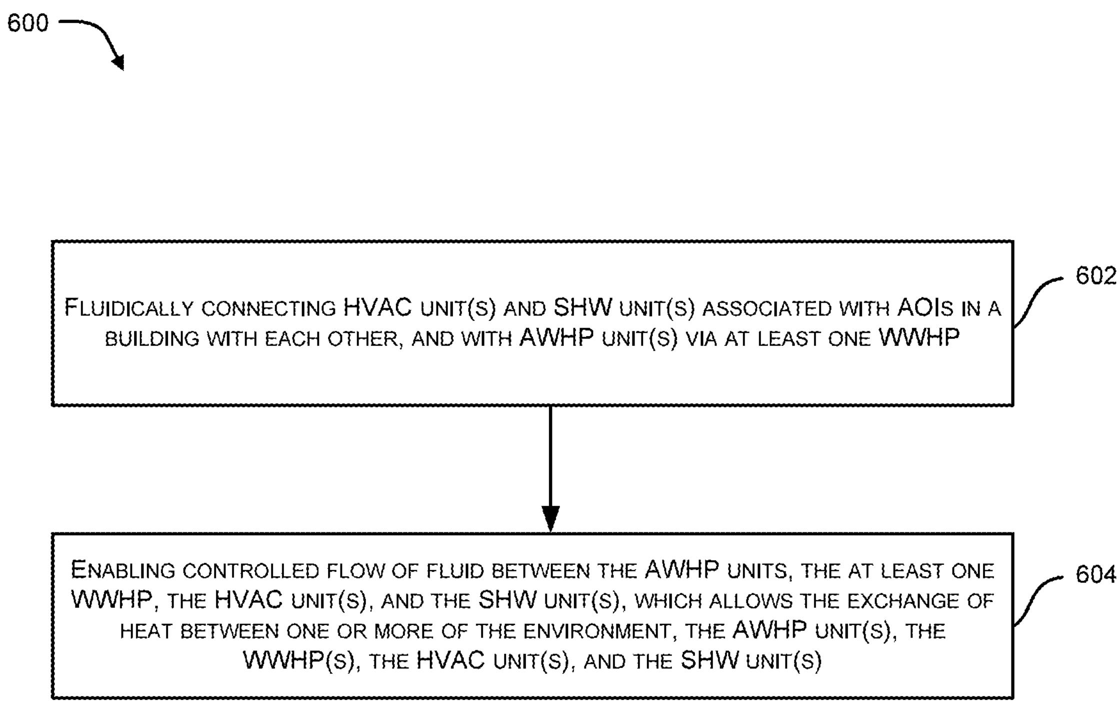
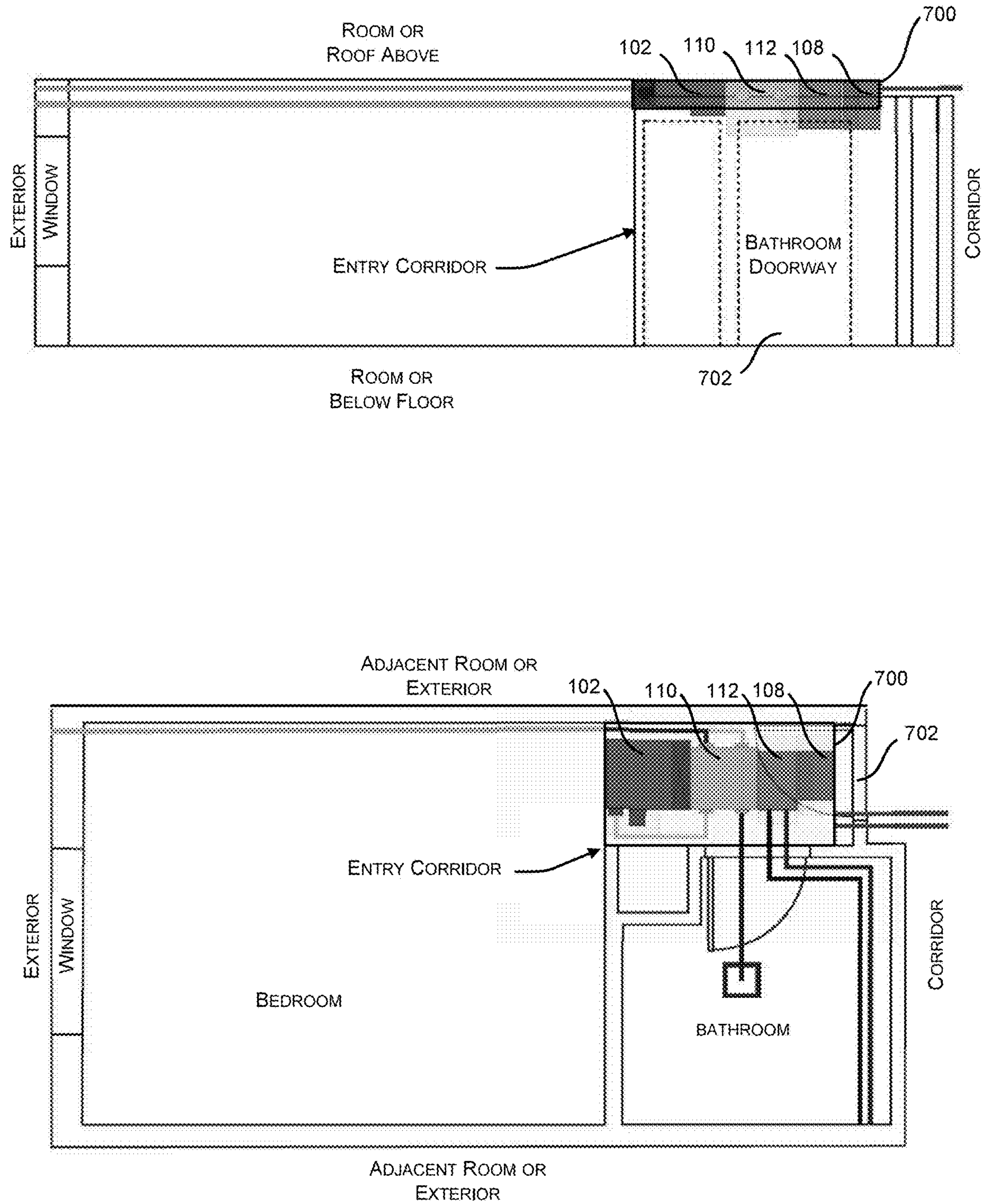
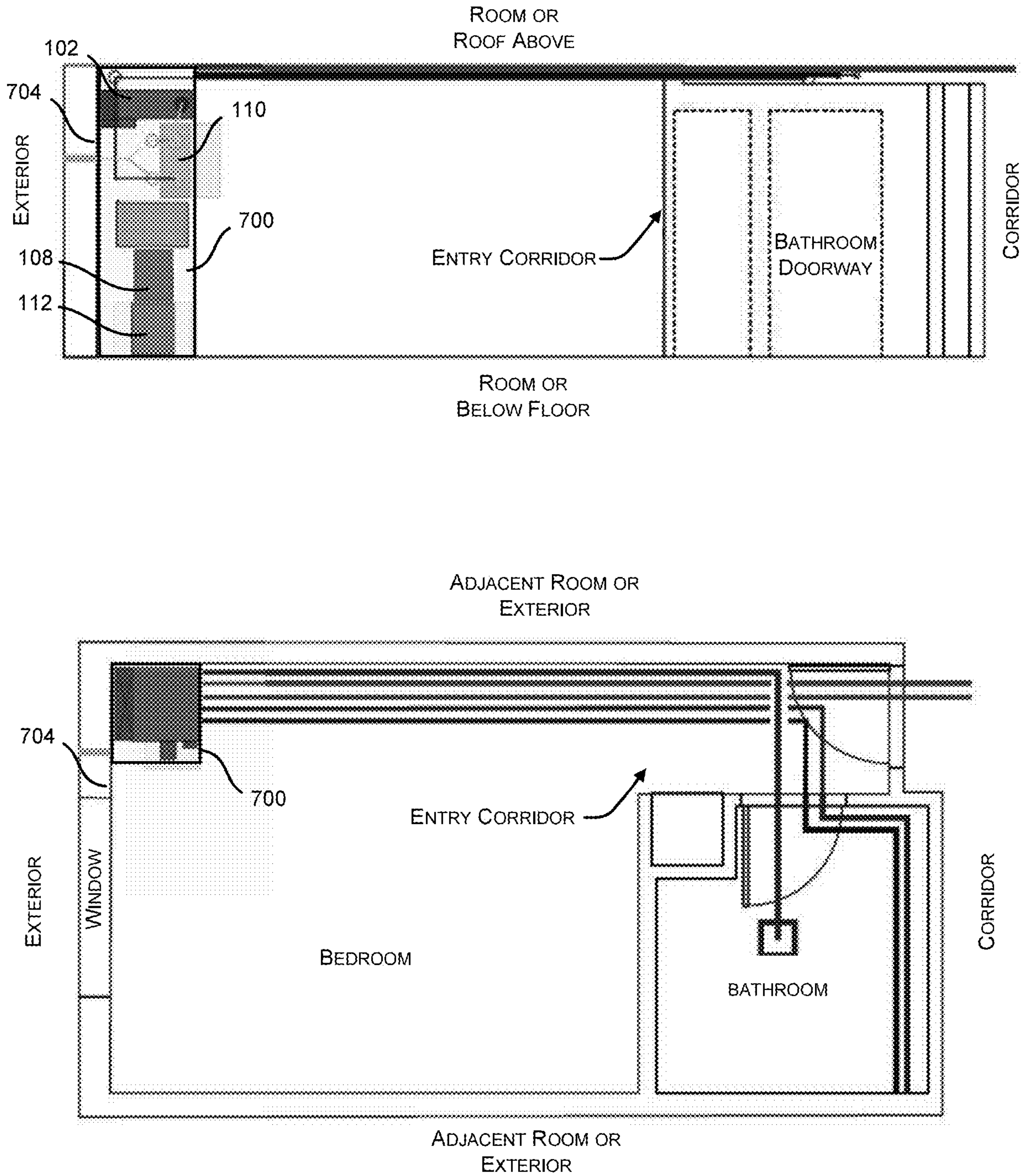

600
FLUIDICALLY CONNECTING HVAC UNIT(S) AND SHW UNIT(S) ASSOCIATED WITH AOIS IN A BUILDING WITH EACH OTHER, AND WITH AWHP UNIT(S) VIA AT LEAST ONE WWHP
602
ENABLING CONTROLLED FLOW OF FLUID BETWEEN THE AWHP UNITS, THE AT LEAST ONE WWHP, THE HVAC UNIT(S), AND THE SHW UNIT(S), WHICH ALLOWS THE EXCHANGE OF HEAT BETWEEN ONE OR MORE OF THE ENVIRONMENT, THE AWHP UNIT(S), THE WWHP(S), THE HVAC UNIT(S), AND THE SHW UNIT(S)
604

FIG. 6



ROOM OR
ROOF ABOVE
102
110
112
108
700
EXTERIOR
WINDOW
ENTRY CORRIDOR
BATHROOM
DOORWAY
CORRIDOR
ROOM OR
BELOW FLOOR
702
ADJACENT ROOM OR
EXTERIOR
102
110
112
108
700
702
ENTRY CORRIDOR
EXTERIOR
WINDOW
BEDROOM
BATHROOM
CORRIDOR
ADJACENT ROOM OR
EXTERIOR

FIG. 7A



ROOM OR
ROOF ABOVE
102
704
110
EXTERIOR
700
108
ENTRY CORRIDOR
BATHROOM
DOORWAY
CORRIDOR
112
ROOM OR
BELOW FLOOR
ADJACENT ROOM OR
EXTERIOR
704
700
ENTRY CORRIDOR
EXTERIOR
WINDOW
BEDROOM
BATHROOM
CORRIDOR
ADJACENT ROOM OR
EXTERIOR

FIG. 7B

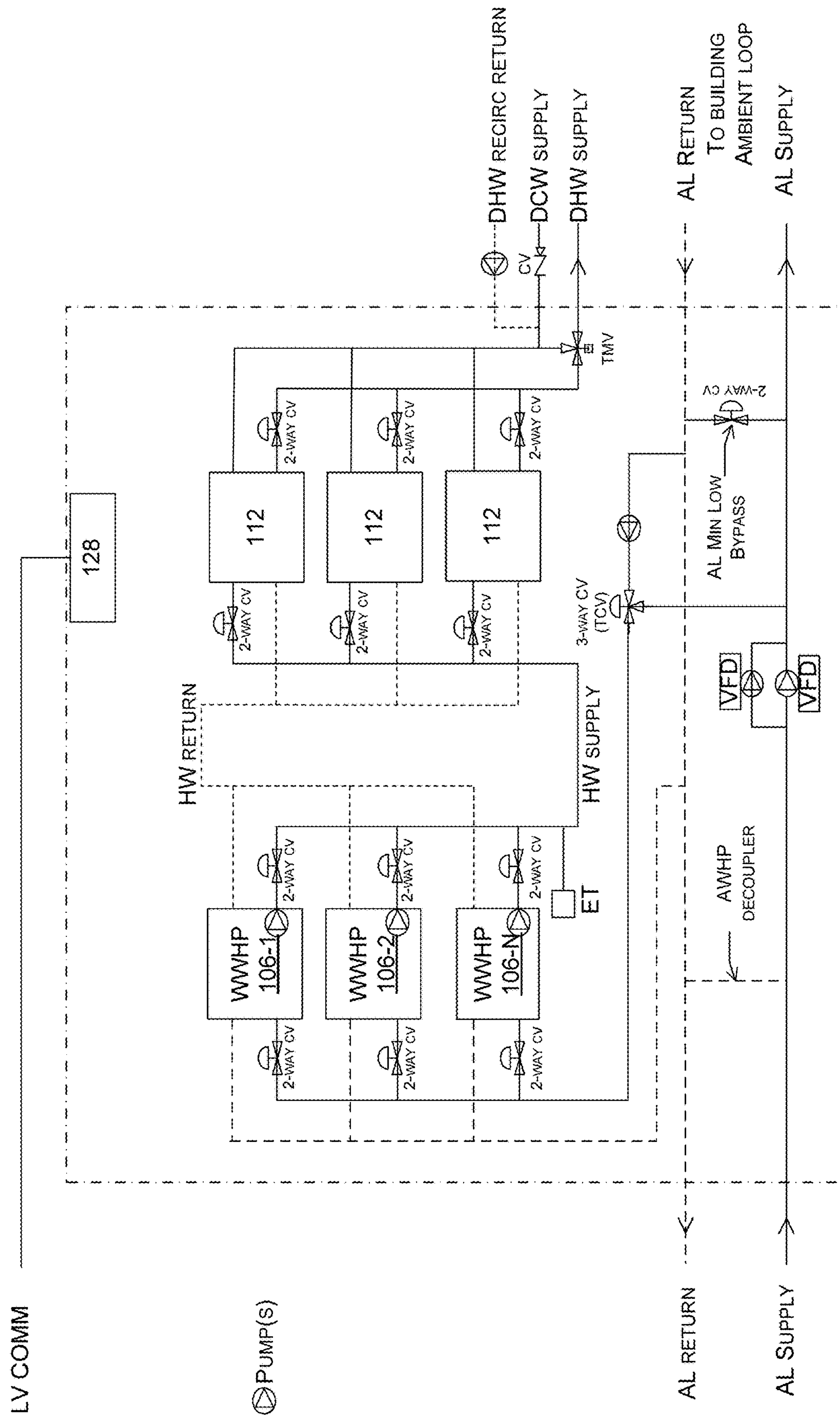

LV COMM
PUMP(S)
AL RETURN
AL SUPPLY
128
112
112
112
WWHP
106-1
WWHP
106-2
WWHP
106-N
2-WAY CV
HW RETURN
HW SUPPLY
ET
3-WAY CV
(TCV)
AL MIN LOW
BYPASS
2-WAY CV
TMV
CV
DHW RECIRC RETURN
DCW SUPPLY
DHW SUPPLY
AL RETURN
TO BUILDING
AMBIENT LOOP
AL SUPPLY
VFD
VFD
AWHP
DECOUPLER

FIG. 8

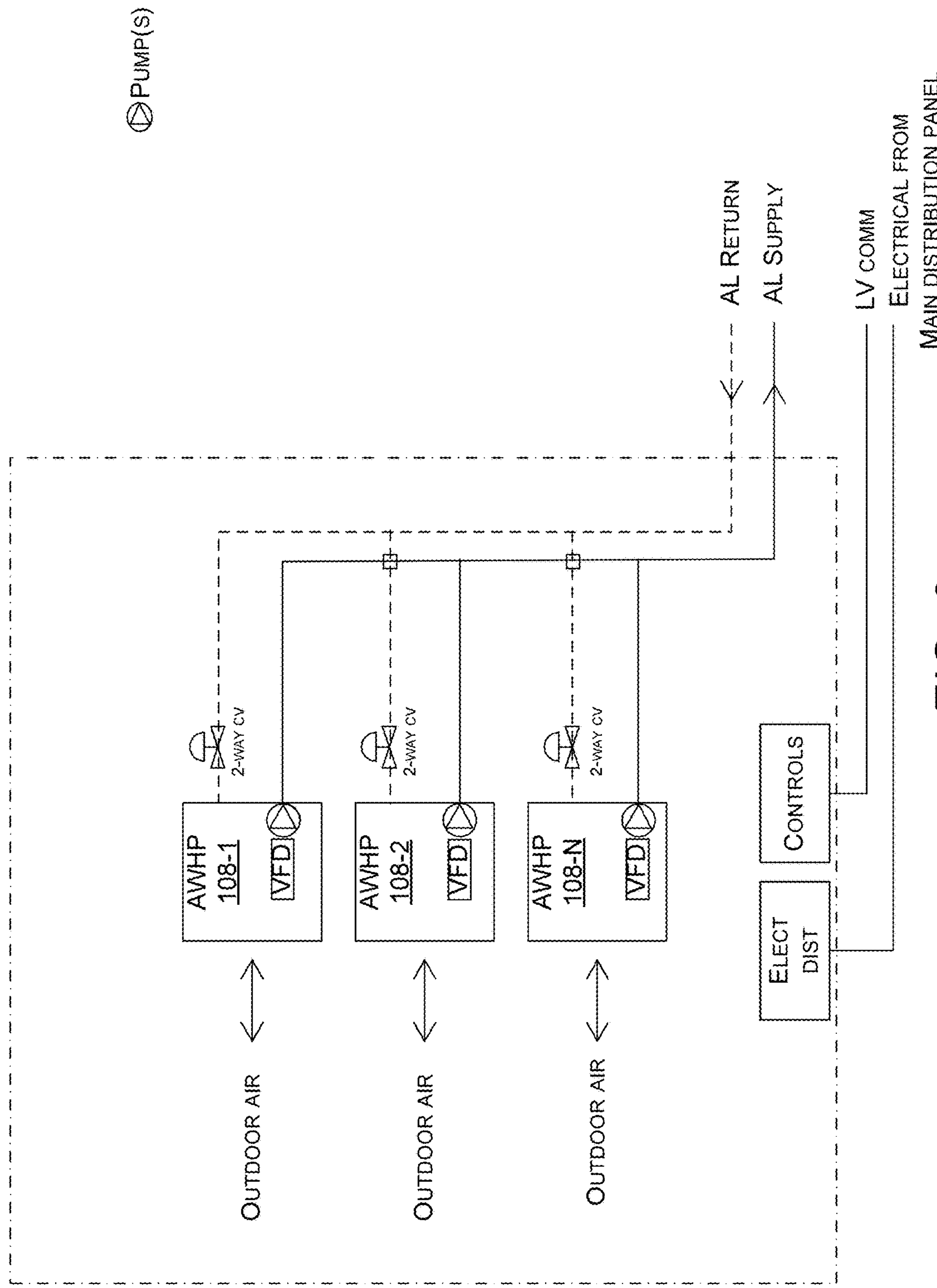

PUMP(S)
AL RETURN
AL SUPPLY
LV COMM
ELECTRICAL FROM
MAIN DISTRIBUTION PANEL
2-WAY CV
2-WAY CV
2-WAY CV
AWHP
108-1
VFD
AWHP
108-2
VFD
AWHP
108-N
VFD
CONTROLS
ELECT
DIST
OUTDOOR AIR
OUTDOOR AIR
OUTDOOR AIR

FIG. 9

MODULAR HVAC-SHW SYSTEM AND A METHOD OF INTEGRATING THEREOF

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This patent application claims the benefit of U.S. Provisional Patent Application No. 63/384,515, filed on Nov. 21, 2022, which is incorporated by reference herein in its entirety.

BACKGROUND

[0002] This invention relates to the field of heating, ventilation, and air conditioning (HVAC) systems and sanitary or domestic hot water (SHW/DHW) systems, and more particularly, a modular HVAC-SHW/DHW system for buildings and a method of integrating existing HVAC and SHW/DHW systems of buildings.

[0003] Mid-scale buildings such as hotels, motels, housing facilities, hospitals, condominiums, apartment buildings, add-on rooms, and sunrooms, are traditionally installed with packaged terminal air conditioners (PTACs) to cool the rooms of the building. These PTACs may be ductless, through-the-wall HVAC systems, however, there is lack of energy recovery in PTACs. In addition, sanitary or domestic hot water (SHW/DHW) systems are also installed in the buildings to provide hot water, but SHW/DHW systems are typically fossil fuel-based gas boilers that may not align with customer sustainable goals.

[0004] Owners of such buildings may face retrofitting their existing building stack to meet internal sustainability targets, code-driven ventilation requirements, and growing restrictions on the use of fossil fuel-based heating. Centralized dedicated outdoor air systems (DOAS) may also be employed as HVAC systems in the buildings, but they are expensive to retrofit in the building. This fragmented design of HVAC systems and SHW/DHW systems in buildings does not align with sustainability goals or construction efficiencies.

SUMMARY

[0005] Described herein is a modular HVAC-SHW/DHW system ("system") with integrated ventilation for buildings, which provides comfort conditioning, sanitary hot water, and ventilation in the building, and enables the exchange of recovered heat between HVAC and SHW/DHW loads (units) and is also capable of being easily and economically retrofitted in the buildings. The system comprises a heating, ventilation and air conditioning (HVAC) unit configured in an area of interest (AOI), a sanitary or domestic hot water (SHW/DHW) unit configured in the AOI; and an air-to-water heat pump (AWHP) unit fluidically connected to the HVAC unit and the SHW/DHW unit through a water-to-water heat pump (WWHP), wherein the AWHP unit is configured to enable the exchange of heat between environment and the WWHP, and the WWHP is configured to enable the exchange of heat between any of the AWHP unit, the HVAC unit, and the SHW/DHW unit.

[0006] In one or more embodiments, the system comprises a heat storage unit configured between the WWHP and the SHW/DHW unit, wherein the heat storage unit comprises one or more of a phase-changing material, and a water tank that is adapted to store heat provided by the WWHP and transfer the stored heat to the SHW/DHW unit.

[0007] In one or more embodiments, the system comprises a set of conduits connected between the AWHP unit and the WWHP, the WWHP and the HVAC unit, the WWHP and the SHW/DHW unit, and the ERV and the HVAC unit, to fluidically and thermally connect the AWHP unit with the WWHP, the WWHP with the HVAC unit, the WWHP with the SHW/DHW unit, and the ERV with the HVAC unit.

[0008] In one or more embodiments, the system comprises a set of valves configured in the set of conduits to control the flow rate and direction of fluid between the AWHP unit and the WWHP, the WWHP and the HVAC unit, the WWHP and the SHW/DHW unit, and the ERV and the HVAC unit.

[0009] In one or more embodiments, the system comprises a set of temperature sensors configured with the AWHP unit, the WWHP, the HVAC unit, the SHW/DHW unit, and the thermal storage unit to monitor the temperature of the fluid across the system and monitor the temperature of the AOI, and a set of flow meters to monitor the flow rate and the direction of the fluid through the set of conduits.

[0010] In one or more embodiments, the system comprises a controller in communication with the set of temperature sensors, and relative humidity sensors, wherein the controller is configured to actuate at least one of the valves to enable the exchange of heat between one or more of the environments, the HVAC unit, and the SHW/DHW unit, to facilitate maintaining predefined temperatures in the room, and of the water supplied by the SHW/DHW unit.

[0011] In one or more embodiments, the system comprises an energy recovery ventilator (ERV) or a heat recovery ventilator (HRV) configured with the HVAC unit, where the ERV or HRV is operable to provide pre-conditioned ventilated air to the HVAC unit to keep the AOI pressurized at a predefined pressure.

[0012] In one or more embodiments, one or more components of the system comprising the HVAC unit, the SHW/DHW unit, the WWHP unit, the thermal storage unit, and the ERV or HRV are packaged within a single housing, and wherein the housing is adapted to be installed at a predefined position at the AOI, and wherein the AWHP unit is outside the AOI.

[0013] In one or more embodiments, the predefined position comprises one or more of: above a door in the AOI, wherein the packaged system is in a horizontal configuration, and against a wall in the AOI, wherein the packaged system is in a vertical configuration.

[0014] In one or more embodiments, the system comprises an occupancy sensor positioned in the AOI and configured to detect the presence of occupants in the AOI, wherein the ERV or HRV is operatively coupled to the occupancy sensor and the controller, wherein upon detection of the presence of occupants in the AOI, the controller operates the ERV or HRV to supply pre-conditioned ventilated air to the HVAC unit.

[0015] In one or more embodiments, the heat rejected by the HVAC unit into the WWHP unit is supplied to the SHW/DHW unit or is supplied back to the HVAC unit to provide reheat for the HVAC unit.

[0016] In one or more embodiments, the system comprises a heat storage unit adapted to store heat or cold water provided by the WWHP unit and transfer the stored heat or cold water to the HVAC unit based on the cooling and heating requirement of the HVAC unit.

[0017] In one or more embodiments, the system comprises a three-way control valve configured between the WWHP unit, an ambient loop (AL) return line, and AL supply line, wherein the AL supply line and the AL return line are fluidically connected between the AWHP unit and an ambient water flow of the AOI, wherein, the three-way control valve is actuated to select source water from the AL supply line or the AL return line based on temperatures to produce optimum operational efficiency.

[0018] Also described herein is a modular HVAC-SHW/DHW system comprising one or more heating, ventilation, and air conditioning (HVAC) units configured in one or more areas of interest (AOI). The system further comprises a first set of water-to-water heat pumps (WWHP) fluidically connected to each of the HVAC units, such that there being at least one of the first WWHP fluidically connected to one of the HVAC units. The system further comprises one or more sanitary or domestic hot water (SHW/DHW) units configured in the one or more AOI; a second set of WWHPs fluidically connected to each of the SHW/DHW units, such that there being at least one of the second WWHP fluidically connected to one of the SHW/DHW units. Each of the second WWHPs is further fluidically connected to each of the first WWHPs, which allows the exchange of heat between the first set of WWHPs and the second set of WWHPs. Further, the system comprises one or more air-to-water heat (AWHP) units, each fluidically connected to the first set of WWHPs and the second set of WWHPs, wherein the AWHP units are configured to enable the exchange of heat between environment and one or more of the first set of WWHPs and the second set of WWHPs to enable the exchange of heat between one or more of the environments, the one or more HVAC units, and the one or more SHW/DHW units.

[0019] In one or more embodiments, the system comprises an energy recovery ventilator (ERV) or a heat recovery ventilator (HRV) configured with each of the HVAC units, where the ERV or HRV is operable to provide pre-conditioned ventilated air to each of the HVAC units to keep the one or more AOI pressurized at a predefined pressure.

[0020] In one or more embodiments, the ERV or HRV supplies pre-conditioned ventilated air to the rooms in which occupants are present and restrict the supply of pre-conditioned ventilated air to the rooms in which occupants are not present.

[0021] In one or more embodiments, the heat rejected by the HVAC units into the corresponding first WWHP units is supplied to the one or more SHW/DHW units or to the one or more HVAC units to provide reheat for the corresponding HVAC units.

[0022] In one or more embodiments, the HVAC unit, the SHW/DHW unit, the WWHP unit, the thermal storage unit, and the ERV or HRV associated with each of the one or more AOI are packaged within a single housing, wherein the each of the housing is adapted to be installed at predefined positions in horizontal or vertical configuration in the one or more AOI selected from rooms, above doors, below a floor, on the floor, halls, walls, ceiling, corridors, staircases, basement, and storage spaces associated with a building.

[0023] Also described herein is a method of integrating existing or newly installed HVAC and SHW/DHW loads (units) of a building in a modular, efficient, and cost-effective way is disclosed, which provides comfort conditioning, sanitary hot water, and ventilation in the building, and enables the exchange of recovered heat between the HVAC and SHW/DHW loads of the building. The method involves at least one WWHP and one or more AWHP. The method comprises the step of fluidically connecting the one or more HVAC units and the one or more SHW/DHW units associated with the building with each other, and with the one or more AWHP units via at least one WWHP unit. The AWHP units are configured to thermally connect at least one WWHP to the environment. The method further comprises the step of enabling a controlled flow of fluid between the AWHP units, the at least one WWHP, the HVAC units, and the SHW/DHW units, which allows the exchange of heat between one or more of the environments, the AWHP units, the WWHP, the HVAC units, and the SHW/DHW units, thereby facilitating in maintaining predefined temperatures in the one or more AOIs, and of the water supplied by the SHW/DHW units in the one or more AOIs.

[0024] In one or more embodiments, the method comprises the steps of storing the heat provided by the at least one WWHP in a heat storage unit comprising a phase-changing material, and transferring the stored heat to the SHW/DHW units and/or to the HVAC units for reheating the HVAC units.

[0025] In one or more embodiments, the method comprises the steps of storing cold water or heat generated by the WWHP units in a buffer tank, and transferring the stored cool water or stored heat to the HVAC units based on the cooling and heating requirements of the HVAC unit.

[0026] In one or more embodiments, the method comprises the steps of supplying pre-conditioned ventilated air, by an ERV or HRV, to the one or more AOI when at least one occupant is present in the corresponding AOI.

[0027] Accordingly, this invention (system and method) enables the exchange of recovered or rejected heat between HVAC and SHW/DHW units in the building, thereby efficiently utilizing and distributing the recovered or rejected heat in the system and also providing comfort conditioning, sanitary hot water, and ventilation in the building. This makes the invention energy-efficient and reliable, and also reduces carbon footprint.

[0028] The system is designed in a packaged form factor or modular design, where the components/units of the system are configured within a housing that is compact and easily installable at a desired location in the building. The locations can be but are not limited to rooms, entry hall, 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/housing can be designed in a horizontal orientation/configuration on each floor above the door in 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.

[0029] 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

[0030] The accompanying drawings are included to provide a further understanding of the subject disclosure of this invention and are incorporated in and constitute a part of this specification. The drawings illustrate exemplary embodiments of the subject disclosure and, together with the description, serve to explain the principles of the subject disclosure.

[0031] 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.

[0032] FIG. **1**A is a block diagram illustrating an exemplary embodiment of a modular HVAC-SHW/DHW system implemented in a room of a building in accordance with one or more embodiments of the invention.

[0033] FIG. **1**B is a schematic illustrating a room of a building configured with the system of FIG. **1**A, wherein the system is packaged as a room module in accordance with one or more embodiments of the invention.

[0034] FIG. **1**C is a schematic of the room module of FIG. **1**B in accordance with one or more embodiments of the invention.

[0035] FIG. **2**A is a block diagram illustrating the operation of the system of FIG. **1**A in the heating season in accordance with one or more embodiments of the invention.

[0036] FIG. **2**B is a block diagram illustrating the operation of the system of FIG. **1**A in the cooling season in accordance with one or more embodiments of the invention.

[0037] FIG. **3** is a block diagram illustrating another exemplary embodiment of the system involving a heat storage medium at the SHW/DHW end, being implemented in a room of a building in accordance with one or more embodiments of the invention.

[0038] FIG. **4** is a block diagram illustrating an exemplary embodiment of the system implemented in multiple rooms of a building and involving a common heat pump for the HVAC and SHW/DHW units in accordance with one or more embodiments of the invention.

[0039] FIG. **5** is a block diagram illustrating another exemplary embodiment of the system implemented in multiple rooms of a building and involving different heat pumps for the HVAC and SHW/DHW units in accordance with one or more embodiments of the invention.

[0040] FIG. **6** is a flow diagram illustrating an exemplary embodiment of a method of integrating existing HVAC and SHW/DHW units of a building for enabling the exchange of recovered heat between the HVAC and SHW/DHW units of the building in accordance with one or more embodiments of the invention.

[0041] FIG. **7**A illustrates exemplary views depicting the packaged system being installed horizontally above a door in entry hall in the AOI/room in accordance with one or more embodiments of the invention.

[0042] FIG. **7**B illustrates exemplary views depicting the packaged system being installed vertically against an exterior wall in the AOI/room in accordance with one or more embodiments of the invention.

[0043] FIG. **8** illustrates a schematic of the piping and pumping architecture of the system in accordance with one or more embodiments of the invention.

[0044] FIG. **9** illustrates an AWHP schematic of the system in accordance with one or more embodiments of the invention.

DETAILED DESCRIPTION

[0045] The following is a detailed description of embodiments of the disclosure depicted in the accompanying drawings. The embodiments are in such detail as to clearly communicate the disclosure. 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 spirit and scope of the subject disclosure as defined by the appended claims.

[0046] 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.

[0047] Existing fragmented design of HVAC systems and SHW systems in buildings does not align with sustainability goals or construction efficiencies. Besides, there is no option for heat recovery between the HVAC systems and the SHW systems of the buildings, which generally go unutilized. There is, therefore, a need to provide a modular HVAC-SHW system with integrated ventilation, which provides comfort conditioning, sanitary hot water, and ventilation in the building, enabling the exchange of recovered heat between HVAC and SHW loads, and can be easily and economically retrofitted in the buildings

[0048] Referring to FIGS. **1**A to **5**, the modular HVAC-SHW/DHW system "system" **100** for buildings is disclosed. The system **100** includes one or more HVAC units **102** (collectively referred to as HVAC units **102** and individually referred to as HVAC unit **102**, herein) and one or more sanitary or domestic hot water (SHW/DHW) units **104** (collectively referred to as SHW/DHW units **104** and individually referred to as SHW/DHW unit **104**, herein) configured at predefined positions at one or more locations/areas of interest (AOI) in a building. In some embodiments, the SHW unit **104** of this invention can be a direct consumption fixture such as but not limited to a faucet or shower head as shown in FIGS. **3** to **5**. Further, in other embodiments, the SHW/DHW unit **104** can be an SHW/DHW storage device that can either be a water tank or thermal storage, which can be further fluidically connected to the fixtures as shown in FIGS. **1** to **2**B. The system **100** includes at least one water-to-water heat pump (WWHP) **106**-A, **106**-B (collectively referred to as WWHPs **106** and individually referred to as WWHP **106**, herein) fluidically connected to the HVAC units **102** and/or the SHW/DHW units **104**. For instance, in one embodiment, a first set of WWHPs **106**-A (also referred to as HVAC WWHP **106**-A, herein) can be fluidically connected to each of the HVAC units **102**, such that at least one of the first WWHPs **106**-A remains fluidically connected to one of the HVAC units **102**. Further, a second set of WWHPs **106**-B (also referred to as SHW/DHW WWHP **106**-B) can be fluidically connected to each of the SHW/DHW units **104**, such that at least one of the second WWHPs **106**-B remains fluidically connected to one of the SHW/DHW units **104**. Besides, in another embodiment, a single WWHP **106** can also be employed, which can be fluidically coupled to the HVAC units **102** as well as the SHW/DHW units **104** of the system. The WWHPs **106** can preferably be of identical size to increase modularity and reduce complexity.

[0049] The system **100** further includes one or more air-to-water heat (AWHP) units **108-1** to **108**-N (collectively referred to as AWHP units **108** and individually referred to as AWHP unit **108**, herein). Each AWHP unit **108** is fluidically connected to the first set of WWHPs **106**-A and the second set of WWHPs **106**-B, or the common WWHP **106** based on the requirement. These AWHP units **108** are configured to enable the exchange of heat, via thermally conductive fluid, between the environment and any of the first set of WWHPs **106**-A and/or the second set of WWHPs **106**-B, which correspondingly enables the exchange of rejected or recovered heat between the environment (ambient air), the HVAC units **102**, and/or the SHW/DHW units **104**. In some embodiments, the AWHP units **108** are also used as a WWHP or a ground source heat pump (geothermal heat pump), which enables the exchange of heat between the ground (earth) and any of the first set of WWHPs **106**-A and/or the second set of WWHPs **106**-B, which correspondingly enables the exchange of heat between the ground, the HVAC units **102**, and/or the SHW/DHW units **104**.

[0050] The number of WWHPs and AWHP units involved in this system **100** can be based on the quantity, size, and location of the HVAC units and SHW units used in the building, and based on individual facility requirements, without any limitations, and all such embodiments are well within the scope of this invention.

[0051] System **100** includes a thermal storage unit **112** configured between the WWHPs **106**-B and the SHW/DHW units **104**, and/or between the HVAC WWHP **106**-A and the HVAC unit **102**. In some embodiments, the thermal storage unit **112** includes a phase-changing material (PCM) (also designated as **112**, hereinafter) or water, which is configured between the WWHPs **106**-B and the SHW/DHW units **104**. The PCM **112** is adapted to store heat provided by the WWHP **106**-B and transfer the stored heat to the SHW/DHW unit **104** when required. The system also includes a potable makeup water source **114** fluidically connected to the thermal storage unit to provide additional water to the thermal storage unit **112** when required. The potable makeup water source **114** also provides additional water in the conduits **122** of the system to provide a sufficient amount of water in the SHW/DHW unit **104**.

[0052] In some embodiments, the thermal storage unit **112** includes a buffer tank configured with the HVAC unit **102**. The buffer tank is generally an insulated tank that is being installed right after the HVAC WWHP **106**-A of the HVAC unit **102**. The buffer tank collects the cold water that is produced by the HVAC WWHP **106**-A, in order to pump cool water from the buffer tank to the HVAC unit **106**-A, thereby ensuring a constant and regular flow of cool water to the HVAC unit **106**-A. Besides, the buffer tank is also be used to store the rejected heat of the HVAC unit **102**, which can be later utilized during the heating season. The storage of the buffer tank depends on the total quantity of the circulated water in the system and on the nominal cooling capacity of the system.

[0053] Further, the system **100** includes an energy recovery ventilator (ERV) or heat recovery ventilator (HRV) **110** configured with each of the HVAC units **102** in the rooms/AOI. The ERV/HRV **110** provides pre-conditioned ventilated air to the corresponding HVAC unit **102** to keep the room/AOI positively pressurized at a predefined pressure. In some embodiments, the HVAC unit **102** includes an air terminal that can be fan-powered, or an induction unit driven by the ERV or HRV **110** to increase ventilation, efficiency, and thermal comfort with a reduced noise footprint.

[0054] This system **100** is designed in a packaged form factor or modular design that can be easily retrofitted at desired locations in the building. The locations include but are not limited to rooms, corridors, staircases, basement, and storage spaces associated with the building. For instance, the system can be designed for horizontal distributions on each floor in the corridors. The system can also be designed for vertical distributions in wet chase risers. Further, the system can also be designed to be horizontally or vertically fitted in a closet, and/or configured vertically against the outer wall, but not limited to the like.

[0055] Referring to FIGS. **1**B and **1**C, the system **100** can be packaged in form of a room module **100**A that can be easily retrofitted at desired locations a room. The room module **100**A can include at least the HVAC unit **102**, the WWHP **106**, and the ERV/HRV **110** associated with the system **100**, however, the AWHP unit **108** remains outside of the room module **100**A. The WWHP **106** can be fluidically connected to the outside AWHP **108** using an ambient loop comprising a first set of conduits fitted with a balancing valve (BV). Further, the HVAC unit **102** can be fluidically connected to the WWHP **106** using a dual temperature (DT) loop, where a DT supply line (conduit) can be configured with a pump (P) (configured with a variable frequency drive (VFD)) to supply fluid from the WWHP into the HVAC unit, and a DT return line can be configured with a two-way motorized control valve (CV) to return the fluid back to the WWHP **106**. Any condensate from the HVAC unit **102** can be transferred to a drain outside the room module **100**A. In addition, an expansion tank (ET) can also be configured with the DT supply line. Further, the ERV/HRV **110** can be operable to receive exhaust air (EA) from bathroom and outside air (OA) via a second set of conduits, and accordingly provide pre-conditioned ventilated air to the HVAC unit **102** to keep the room pressurized at a predefined pressure. Furthermore, the room module **100**A can include a thermostat (T) or sensors to monitor the temperature and humidity of the room.

[0056] The components of the system are fluidically connected to one another by a set of conduits (pipes) **122** connected between the AWHP units **108** and the WWHPs **106**, the WWHPs **106**-A and the HVAC units **102**, the WWHPs **106**-B and the SHW units, the ERVs or HRVs **110** and the HVAC units **102**, and the thermal storage unit **112** and the potable makeup water **114**. The conduits **122** can be the existing conduits of the building, which connect the already installed HVAC units **102** and SHW units/DHW **104** of the building. Additionally, additional conduits may also be employed to connect the existing HVAC units and SHW units with the AWHP units and the WWHPs, and to further connect newly installed HVAC units, SHW units, and other components of the system with each other. The system further includes a set of valves **124**, which can be unidirectional or multi-directional configured in the set of conduits **122** to control the flow rate and direction of flow of associated fluid (water or air) between the AWHP units **108** and the WWHPs **106**, the HVAC WWHPs **106**-A and the HVAC units **102**, the SHW/DHW WWHPs **106**-B and the SHW/DHW units **104**, the ERVs or HRVs **110** and the

HVAC units **102**, and/or the thermal storage unit **112** and the potable makeup water source **114**.

[0057] The conduits **122** fluidically and thermally connect the AWHP units **108** with the WWHPs **106**, the WWHPs **106** with the HVAC units **102**, the WWHPs **106** with the SHW/DHW units **104**, the ERVs or HRVs with the HVAC units **102**, and the thermal storage unit **112** and the potable makeup water source **114**. The conduits **122** allow the fluid such as water to flow and transfer heat between the HVAC WWHPs **106**-A and the HVAC units **102**, the SHW/DHW WWHPs **106**-B and the SHW/DHW units **104**, and the AWHP units **108** and the WWHPs **106**-A, **106**-B. Further, the conduits **122** allow the fluid such as air to flow and transfer heat between the environment and the AWHP units **108**, and the ERVs or HRVs **110** and the HVAC units **102**.

[0058] In one or more embodiments, the system may include a set of flow meters **126** connected with the set of conduits **122** of the system to monitor the flow rate and the direction of the fluid through the set of conduits **122**. In addition, in one or more embodiments, the system may include a set of sensors **120** to monitor the temperature and humidity of the rooms/AOI, the temperature of the fluid flowing through the conduits **122**, and detect the presence of occupants in the rooms/AOI. The set of sensors **120** may be positioned at predefined locations comprising one or more of walls, entry hall, ceiling, corridors, staircases, basements, washrooms, toilet, storage spaces, and the like, associated with the rooms/AOI. Further, the sensors **120** may be positioned within components of the system which may include one or more of the set of conduits **122**, the AWHP units **108**, the WWHPs **106**, the HVAC units **102**, the SHW/DHW units **104**, and the thermal storage unit **112**. In one or more embodiments, sensors **120** may include a temperature sensor configured with the set of conduits **122**, the AWHP units **108**, the WWHPs **106**, the HVAC units **102**, the SHW/DHW units **104**, and the thermal storage unit **112**, to monitor the temperature of the fluid across the system and monitor the temperature of the rooms and/or of the water supplied by the SHW/DHW units **104**. Further, in one or more embodiments the set of sensors **120** may include a relative humidity sensor positioned in the AOI/rooms to monitor the humidity of the rooms. Furthermore, in one or more embodiments, the set of sensors **120** may include an occupancy sensor positioned in the rooms/AOI to detect the presence of occupants in the rooms/AOI.

[0059] The system includes a controller **128** in communication with the flow meters **126**, and the set of sensors **120** (e.g., the temperature sensors, relative humidity sensors, the occupancy sensors, and/or other sensors). The controller **128** is also operatively coupled to the set of valves **124**, as well as the AWHP units **108**, the WWHPs **106**, the HVAC units **102**, the SHW/DHW units **104**, and the ERVs or HRVs **110**. The controller **128** is configured to receive the data captured by the flow meters **126**, and the set of sensors **120** (temperature sensors, relative humidity sensors, and occupancy sensors). The controller **128** is further configured to actuate at least one of the valves **124** to enable the exchange of heat between any or a combination of the environment, the HVAC units **102**, and the SHW/DHW units **104**, to facilitate maintaining predefined temperatures in the room, and of the water supplied by the SHW/DHW units **104**. In addition, once the occupancy sensor detects the presence of occupants in the room(s)/AOI, the controller **128** operates the ERV or HRV **110** to supply pre-conditioned ventilated air to the HVAC unit. The controller **128** also controls the operation of the AWHP units **108**, the WWHPs **106**, the HVAC units **102**, the SHW/DHW units **104**, and the ERVs or HRVs **110** in the system.

[0060] Referring to FIG. **8**, a schematic of the piping architecture of the system is disclosed. As illustrated, each WWHPs **106** associated with the system **100** can be fluidically connected to SHW/DHW units **104** (as shown in FIGS. **2**A to **5**) of the system using one or more hot water (HW) supply lines and HW return lines. In addition, a thermal storage unit or PCM **112** can also be configured between the WWHPs **106** and the SHW/DHW units **104**, however, the WWHPs **106** can be directly connected to the SHW/DHW unis **104** without the thermal storage **112**. Further, a two-way control valve (CV) and a check valve can be configured in the HW supply lines to facilitate flow of domestic cold water (DCW) from the SHW/DHW units **104** to the WWHPs **106** and further facilitate flow of domestic hot water (DHW) from the WWHPs **106** to the SHW/DHW units **104**. Furthermore, a thermostatic mixing valve (TMV) can also be configured in the DCW line and the DHW line.

[0061] The WWHPs **106** can be fluidically connected to AWHP units **108** that are outside the building/AOI as well as to the ambient water flow that is within the building. An ambient loop (AL) supply line can extend between the AWHP units **108** and the ambient loop water flow of the building to supply water from the AWHP units **108** to the ambient loop water flow within the AOI/building. In addition, an AL return line can supply water from the ambient loop water flow of the building to the AWHP units **108**. Further, a decoupler can be used to fluidically isolate/decouple the AWHP from the ambient loop.

[0062] In addition, a three-way control valve (TCV) can be configured between the AL return line, the AL supply line, and the WWHPs **106** to control the flow of water from the AWHP units and/or the AL water flow of the building to the outdoor coils of the WWHPs **106**. A first port of the TCV can be connected to the AL supply line via a first pump, a second port of the TCV can be connected to the AL return line via a second pump, and a third port of the TCV can be connected to the WWHPs via one or more two-way control valves. In addition, variable frequency drives (VFDs) can be further configured with each of the pumps. Further, the three-way control valve can be actuated to select source water from the AL supply line or the AL return line based on temperatures to produce optimum operational efficiency

[0063] In one or more embodiments, in a cooling dominant mode or season, the TCV can be actuated by the controller to divert warmest possible water from the AL water flow of the building to the WWHPs **106** as the water supplied by the AWHP unit **108** may be much colder compared to the AL water flow of the building. Further, in one or more embodiments, in a heating dominant mode or season, when the AWHP unit **108** is supplying the hottest water to the building, the TCV can be actuated by the controller to first divert the hottest possible water from the AWHP unit **108** to the WWHPs **106** and then from the AL supply of the building. Thus, the selection of the AL supply line or the AL return line based on temperatures during cooling dominant season and heating dominant season can enable the system to achieve optimum operational efficiency.

[0064] Referring to FIG. **9**, an AWHP schematic of the system is disclosed. As illustrated, the AWHP units **108-1** to

108-N can be fluidically connected to the AL return line via a two-way control valve (CV) and to the AL supply line via a pump. Further, the outdoor coils of the AWHP units **108** can be in thermal contact with outside air. The controller can control the actuation of the two-way CV and/or the pumps to control the flow of water between the ambient loop and the AWHP units **108**. In addition, a VFD can be further configured with each of the pumps to adjust the operating speed of the pump. Referring to FIG. **1**A to **1**C, the system **100** implemented in an AOI such as a room of a building is illustrated. System **100** includes an HVAC unit **102** and an SHW/DHW unit **104**, and other units that are efficiently packaged in a single housing forming a 'drop-in' modular system **100** that is easily installable at any position in the AOI/room. This modular system **100** can be installed on the floor, below the floor, wall, closet, ceiling, and the like, without any limitation. However, in some embodiments, the HVAC unit **102** and the SHW unit **104**, and other units that are also configurable separately at predefined positions in a room. For instance, the HVAC unit **102** can be positioned on the floor or wall or closet, or ceiling inside the room, and the SHW/DHW unit **104** can be configured in the bathroom or toilet associated with the room. Similarly, other possible configurations of the SHW/DHW unit **104** and HVAC unit **102** in the room are also possible, without any limitation. The system **100** further includes an AWHP unit **108** configured outside the room, preferably on the roof of the room or building. The AWHP unit **108** can be fluidically connected to the HVAC unit **102** through a first WWHP **106**-A (HVAC WWHP) and the AWHP unit **108** can be fluidically connected to the SHW/DHW unit **104** through a second WWHP **106**-B (HVAC WWHP). The WWHPs **106** can be either positioned in the room/bathrooms/toilet or outside the room. The AWHP unit **108**, the WWHPS **106**, the HVAC unit **102**, and the SHW/DHW unit **104** can be connected through a set of conduits **122**. These conduits **122** can preferably be configured and extended within the walls of the room, however, the conduits **122** may also extend along the inner walls of the room as well. The system further includes an ERV or HRV **110** configured with the HVAC unit **102** and positioned in the room/AOI. The ERV or HRV **110** is also packaged in the same housing of the modular system **100** along with other units. The ERV/HRV **110** provides preconditioned ventilated air to the corresponding HVAC unit **102** to keep the room/AOI positively pressurized at a predefined pressure. The ERV/HRV **110** can receive return air (RA) directly from the room as well as from the HVAC unit **102**, and provide pressurized ventilated air to the HVAC unit **102** later providing supply air (SA) in the room. In an embodiment, the rejected heat from the HVAC heat pump **106**-A may be used for either recovery to the SHW/DHW unit **104** or be piped to provide reheat for the HVAC unit **102**.

[0065] Referring to FIG. **2**A, in HVAC cooling operations, the AWHP unit **108** rejects heat from the common loop into the environmental air, providing a tempered loop for the HVAC WWHP **106**-A to provide cooling capacity to the HVAC unit **102** and the SHW/DHW WWHP **106**-B to provide heating capacity to the SHW/DHW unit **104**. Additionally, the return water from the HVAC WWHP **106**-A can be diverted away from the common loop return stream into the SHW/DHW WWHP **106**-B supply stream so that the rejected HVAC heat can be recovered in the system into the SHW/DHW unit **104**. Further, when no SHW load exists, the return water can be piped and directed back to the common loop through the conduits **122**. Referring to FIG. **2**A, in HVAC heating operations, the AWHP unit **108** pulls heat into the common loop from the environmental air, providing a tempered loop for the HVAC WWHP **106**-A and providing heating capacity to the HVAC unit **102** and the SHW/DHW WWHP **106**-B heating to the SHW/DHW unit **104**. Further, the HVAC WWHP **106**-A and the SHW/DHW WWHP **106**-B can be sequenced to operate non-coincidentally when the AWHP unit **108** cannot provide sufficient capacity to serve both loads simultaneously. Further, in some embodiments, as shown in FIG. **3**, if additional SHW thermal storage is desired, a thermal storage buffer tank **112** (thermal storage unit), either water or phase change material, can be included in the system **100**.

[0066] Referring to FIG. **3**, in one or more embodiments of this invention, the two separate WWHPs **106** i.e., the HVAC WWHP **106**-A and SHW/DHW WWHP **106**-B of FIG. **1**A can be replaced with a single WWHP **106**. One side of the common WWHP **106** can be fluidically connected to the HVAC **102** unit as well as the thermal storage unit **112**, and the other side of the common WWHP **106** can be fluidically connected to the AWHP unit **108**. The WWHP **106** can be a mini heat pump that can be integrated with the HVAC unit **102** and the thermal storage unit **112** to provide a 'drop-in' modular system **300** that can be easily configured within the room. Additionally, the ERV/HRV unit **110** can be configured with the HVAC unit **102**, which can also be integrated with the modular design of system **300**. Further, the thermal storage unit **112** includes a phase-changing material or a buffer tank, configured between the common WWHP **106** and the SHW/DHW unit **104**, and/or the common WWHP **106** and the HVAC unit **102**. The SHW unit **104** of FIG. **3** is a direct consumption fixture such as but not limited to a faucet or shower head (also referred to as SHW fixtures **104**, herein) that is adapted to be fluidically coupled to the thermal storage unit **112** of the system **300**. The thermal storage unit **112** is adapted to store heat or cold water provided by any of the WWHP **106**, and the HVAC unit **102** and later supply the stored heat or cold water back to any of the HVAC unit **102** and/or to the SHW fixtures **104** when required. Further, the thermal storage unit **112** additionally includes a potable makeup water source fluidically connected to the phase changing material (PCM) **112** to provide additional water to the heat storage unit when required. The potable makeup water source **114** can also provide additional water in the conduits **122** of system **300** to maintain a sufficient amount of water as required in the system **300**. Further, the ERV or HRV **110** can be connected to an exhaust fan **116** provided in the toilet or bathroom. Referring to FIGS. **4** and **5**, the system **400**, **500** implemented in multiple rooms of a building is illustrated. The system **400**, **500** includes one HVAC unit **102** configured at predefined positions in each room of the building. The system **400**, **500** further includes at least one WWHP **106** fluidically connected the HVAC unit **102**, which is also provided as a part of the modular package of the system in each room of the building. For instance, in one embodiment, as shown in FIG. **4**, a single WWHP **106** can also be employed in each room, which can be fluidically coupled to the HVAC unit **102** of the corresponding room. In another embodiment, as shown in FIG. **5**, one WWHP **106**-A (HVAC WWHP) can be fluidically connected to the HVAC unit **102** in each room, and one or more SHW heat pumps **106**-B can be fluidically connected to the SHW fixtures (faucet or shower head) **104** provided for the corresponding room. The WWHPs **106**-A, **106**-B can preferably be of identical size to increase modularity and reduce complexity.

[0067] The system **400**, **500** further includes one or more AWHP units **108-1** to **108**-N fluidically connected to the HVAC WWHPs **106**-A and the SHW/DHW WWHPs **106**-B of each room of the building as shown in FIG. **5**, or to the common WWHP **106** of each room of the building as shown in FIG. **4**. These AWHP units **108** are configured to enable the exchange of heat between the environment and any of the HVAC WWHPs **106**-A, the SWH/DHW WWHPs **106**-B, and the common WWHP **106**. In some embodiments, as shown in FIG. **5**, the SHW/DHW WWHPs **106**-B of each room can be directly fluidically connected to the AWHP unit **108** as well as to the HVAC WWHP **106**-A. These AWHP units **108** are configured to enable the exchange of heat, via thermally conductive fluid, between the environment and any of the HVAC WWHPs **106**-A and/or the SHW/DHW WWHPs **106**-B, which correspondingly enables the exchange of rejected or recovered heat between the environment, and the HVAC units **102**, and also enables the supply of hot or cold water to the SHW fixtures **104**.

[0068] The system **400**, **500** includes a thermal storage unit **112** involving a phase-changing material (PCM) and/or a buffer tank, which is fluidically configured between the SHW/DHW WWHP **106**-B/common WWHP **106** and the SHW fixtures **104** and/or between HVAC WWHP **106**-A/common WWHP **106** and the HVAC unit **102**, in each room to store rejected heat or cold water and transfer the stored heat or stored cold water back in the system and to the SHW fixtures **104** during the heating season or cooling season. The heat storage unit **112** also includes a potable makeup water source **114** fluidically connected to the PCM **112** to provide additional water to the heat storage unit **112** when required. The potable makeup water source **114** can also provide additional water in the conduits **122** of the system **400**, **500** to provide a sufficient amount of water in the SHW fixtures **104**. Further, the system **400**, **500** further includes the buffer tank configured with the HVAC unit **102** to ensure a constant and regular flow of cold or hot water to the HVAC unit **102**. Further, the system **400**, **500** includes an ERV or HRV **110** configured with each of the HVAC units **102** in each room of the building. The ERV or HRV **110** provides pre-conditioned ventilated air to the corresponding HVAC unit **102** to keep the room positively pressurized at a predefined pressure.

[0069] In some non-limiting embodiments, the HVAC unit **102** is connected to the HVAC load **118** inside each room to provide conditioned air within the room and extract warm/hot air from the room. Further, the ERV or HRV **110** is connected to an exhaust fan **116** provided in the toilet or bathroom associated with each room. Furthermore, the storage tank of the SHW/DHW unit **104** is connected to showers and faucets to provide hot/warm water in each room of the building.

[0070] It would be obvious for a person skilled in the art that while the components of the system **400**, **500** shown in FIGS. **4** and **5** have only been illustrated for the Nth floor of the building and are being configured in a single room just for the sake of simplicity and explaining the invention, however, the same components (shown for the Nth floor) of the system **400**, **500** may also provide on each floor and each room of the building with either no or minimal changes, and all such embodiments are well within the scope of this invention. Further, while various embodiments of this invention have been elaborated and illustrated for rooms as the AOI in a building, however, this invention can also be implemented at other locations in the building, and all such embodiments are also well within the scope of this invention.

[0071] The system of FIG. **1**A to **5** are designed in a packaged form factor or modular design, where the components/units (**102**, **106**, **110**, **112**) of the system are configured within a housing **700** forming a packaged system (also designated as **700**, herein) that is compact and easily installable at a desired location in the building or AOI. The locations can be but are not limited to rooms, entry halls, above doors, below a floor, above the floor, ceiling, corridors, staircases, basement, and storage spaces associated with the building. For instance, the packaged system **700** can be installed in a horizontal orientation on each floor above the door **702** in the entry hall in the AOI as shown in FIG. **7**A. Further, the packaged system **700** can be installed in a vertical orientation at exterior walls **704** at the AOI as shown in FIG. **7**B. In addition, the packaged system **700** can also be designed to be horizontally or vertically fitted in a closet, above doors **702**, walls **704**, entry hall, ceiling, corridors, staircases, basement, and storage spaces associated with the AOI or building, but not limited to the like.

[0072] Referring to FIG. **6**, method **600** of integrating existing or newly installed HVAC and SHW loads (units) of a building in a modular, efficient, and cost-effective way is illustrated, which provides comfort conditioning, sanitary hot water, and ventilation in the building and enables the exchange of recovered heat between the HVAC and SHW loads configured in rooms (AOI) of the building. Method **600** involves at least one WWHP and one or more AWHP units. Method **600** includes step **602** of fluidically connecting the one or more HVAC units and the one or more SHW units associated with each room of the building with each other, and with the one or more AWHP units via at least one WWHP unit. Method **600** further includes step **604** of enabling a controlled flow of fluid between the AWHP units, the at least one WWHP, the HVAC units, and the SHW units, which allows the exchange of heat between one or more of the environments, the AWHP units, the WWHP, the HVAC units, and the SHW units, thereby facilitating in maintaining predefined temperatures in the rooms/AOI, and of the water supplied by the SHW units in the bathroom associated with the rooms/AOI.

[0073] In addition, method **600** includes the steps of storing the heat provided by the WWHP in a thermal storage unit comprising a phase-changing material, and transferring the stored heat to the SHW units and/or to the HVAC units for reheating the HVAC units. Further, method **600** includes the steps of storing cold water or heat generated by the WWHP units in a buffer tank that is used as the thermal storage unit and later transferring the stored cold water or stored heat to the HVAC units based on the heating season or cooling season requirements. Furthermore, method **600** includes the step of supplying pre-conditioned ventilated air, by an ERV or HRV, to the rooms when at least one occupant is present in the corresponding room.

[0074] During HVAC cooling operations, the AWHP units reject heat from the common loop into the environmental air, providing a tempered loop for the HVAC WWHPs or common WWHP to provide cooling capacity to the HVAC units and for the SHW/DHW WWHP to provide heating capacity to the SHW unit. Further, the return water from the HVAC WWHP or common WWHP can be diverted away from the common loop return stream into the SHW/DHW WWHP supply stream so that the rejected HVAC heat can be recovered in the system into the SHW unit. Besides, when no SHW load exists, the return water can be piped and directed back to the common loop.

[0075] Further, during HVAC heating operations, the AWHP units extract heat into the common loop from the environmental air, providing a tempered loop for the HVAC WWHPs or common WWHP to provide heating capacity to the HVAC unit and for the SHW/DHW WWHP or common WWHP to provide heating to the SHW unit. Further, the HVAC WWHP and the SHW/DHW WWHP can be sequenced to operate non-coincidentally when the AWHP units cannot provide sufficient capacity to serve both loads simultaneously.

[0076] The controller **128** prioritizes SHW units, as a decrease in hot water discharge temperature is immediately felt by the occupant or directly connected appliance effectiveness. While HVAC units can be cycled due to comparatively slow temperature drift in rooms. When the discharge temperature of the SHW unit decreases below a set threshold, the system sends capacity only to SHW generation, allowing the room air temperature to drift within limits. However, if the temperature exceeds these limits, the system can then activate the SHW unit's supplemental electrical heat and send capacity back to room conditioning.

[0077] The controller **128** used in this invention (system and method) can include one or more processors operatively coupled to a memory storing instructions executable by the processor. Further, the system can also include a set of actuators in communication with the processor of the controller **128**. These actuators are operatively connected to the valves **124**, HVAC units, SHW units, WWHPs, and AWHP units. The controller **128** is configured to receive the data captured by the flow meters **126**, and set of sensors **120** including the temperature sensors, humidity sensors, and occupancy sensors. The controller **128** can accordingly actuate at least one of the valves **124** to control the flow and direction of flow of the fluid between respective components of the system and also control the operation of the AWHP units, the WWHPs, the HVAC units, the SHW units, and the ERVs or HRVs in the system, to enable the exchange of recovered or rejected heat between HVAC units and the SHW units in the building, thereby efficiently utilizing and distributing the recovered or rejected heat in the building to facilitate maintaining predefined temperatures in the room, and of the water supplied by the SHW units. In addition, the controller **128** can operate the ERV or HRV to supply pre-conditioned ventilated air to the HVAC unit.

[0078] The AWHP unit used in the invention (system and method) includes an outdoor unit that takes in heat from the ambient air (environment) and transfers it to a coolant (for example water) A compressor then increases the temperature of the coolant that transfers the heat to HVAC units or SHW units via the WWHPs. The hot water is circulated to the WWHPs, and cold water from the WWHPs is transported back to the AWHP unit. The coolant is then transferred back to the outdoor unit. Similarly, by reversing the process above, the coolant in the outdoor unit of the AWHP unit takes the heat from the WWHPs and releases it into the outside environment, and returns cool water to the WWHPs.

[0079] The WWHP used in this invention (system and method) is simply a water-to-water heat pump that functions as a heater as well as a cooler. WWHPs can be used for both cooling and heating purposes and can be very economical when used in combination with the HVAC unit and SHW unit. The WWHP work by reversing the flow of a coolant from the compressor through a condenser and evaporation coils. In the heater mode, the indoor coil of the WWHP becomes a condenser while the outdoor coil acts as an evaporator through which the coolant conveys the thermal energy to the indoor coil. The thermal energy is then transferred to the AWHP units or to the HVAC units and SHW units, which are then used for various heating purposes. In the cooling mode, the indoor coil acts as the evaporator while the outdoor coil acts as the condenser making it act as a cooler or air conditioner.

[0080] 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. 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.

[0081] In interpreting the specification, all terms should be interpreted in the broadest possible manner consistent with the context. In particular, the terms "comprise" 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, C . . . and N, the text should be interpreted as requiring only one element from the group, not A plus N, or B plus N, etc.

1. A modular HVAC-SHW system comprising:
a heating, ventilation and air conditioning (HVAC) unit configured in an area of interest (AOI);
a sanitary or domestic hot water (SHW/DHW) unit configured in the AOI; and
an air-to-water heat pump (AWHP) unit fluidically connected to the HVAC unit and the SHW/DHW unit through a water-to-water heat pump (WWHP),
wherein the AWHP unit is configured to enable the exchange of heat between environment and the WWHP, and
the WWHP is configured to enable the exchange of heat between any of the AWHP unit, the HVAC unit, and the SHW/DHW unit.

2. The system of claim **1**, wherein the system comprises a heat storage unit configured between the WWHP and the SHW unit,
wherein the heat storage unit comprises one or more of a phase-changing material, and a water tank that is adapted to store heat provided by the WWHP and transfer the stored heat to the SHW/DHW unit.

3. The system of claim **2**, wherein the system comprises:
a set of conduits connected between the AWHP unit and the WWHP, the WWHP and the HVAC unit, the

WWHP and the SHW/DHW unit, and an energy recovery ventilator (ERV) or a heat recovery ventilator (HRV) and the HVAC unit, to fluidically and thermally connect the AWHP unit with the WWHP, the WWHP with the HVAC unit, the WWHP with the SHW/DHW unit, and the ERV with the HVAC unit; and

a set of valves configured in the set of conduits to control the flow rate and direction of fluid between the AWHP unit and the WWHP, the WWHP and the HVAC unit, the WWHP and the SHW/DHW unit, and the ERV or HRV and the HVAC unit.

4. The system of claim **3**, wherein the system comprises:

a set of temperature sensors configured with the AWHP unit, the WWHP, the HVAC unit, the SHW/DHW unit, and the thermal storage unit, to monitor the temperature of the fluid across the system and monitor the temperature of the AOI; and

a set of flow meters to monitor the flow rate and the direction of the fluid through the set of conduits.

5. The system of claim **4**, wherein the system comprises a controller in communication with the set of temperature sensors and a set of relative humidity sensors, wherein the controller is configured to actuate at least one of the valves to enable the exchange of heat between one or more of the environments, the HVAC unit, and the SHW/DHW unit, to facilitate maintaining predefined temperatures in the room, and of the water supplied by the SHW/DHW unit.

6. The system of claim **5**, wherein the system comprises an energy recovery ventilator (ERV) or a heat recovery ventilator (HRV) configured with the HVAC unit, the ERV or the HRV is operable to provide pre-conditioned ventilated air to the HVAC unit to keep the AOI pressurized at a predefined pressure.

7. The system of claim **6**, wherein one or more components of the system comprising the HVAC unit, the SHW/DHW unit, the WWHP unit, the thermal storage unit, and the ERV or the HRV are packaged within a single housing, and wherein the housing is adapted to be installed at a predefined position at the AOI.

8. The system of claim **7**, wherein the predefined position comprises one or more of:

above a door in the AOI, wherein the packaged system is in a horizontal configuration; and

against a wall in the AOI, wherein the packaged system is in a vertical configuration.

9. The system of claim **6**, wherein the system comprises an occupancy sensor positioned in the AOI and configured to detect the presence of occupants in the AOI,

wherein the ERV or HRV is operatively coupled to the occupancy sensor and the controller, wherein upon detection of the presence of occupants in the AOI, the controller operates the ERV or HRV to supply pre-conditioned ventilated air to the HVAC unit.

10. The system of claim **1**, wherein the heat rejected by the HVAC unit into the WWHP unit is supplied to the SHW/DHW unit or is supplied to the HVAC unit to provide reheat for the HVAC unit.

11. The system of claim **1**, wherein the system comprises a heat storage unit adapted to store heat or cold water provided by the WWHP unit and transfer the stored heat or cold water back to the HVAC unit based on cooling and heating requirement of the HVAC unit.

12. The system of claim **1**, wherein the system comprises a three-way control valve configured between the WWHP unit, an ambient loop (AL) return line, and AL supply line, wherein the AL supply line and the AL return line are fluidically connected between the AWHP unit and an ambient water flow of the AOI,

wherein, the three-way control valve is actuated to select source water from the AL supply line or the AL return line based on temperatures to produce optimum operational efficiency.

13. A modular HVAC-SHW/DHW system comprising:

one or more heating, ventilation, and air conditioning (HVAC) units configured in one or more areas of interest (AOI);

a first set of water-to-water heat pumps (WWHP) fluidically connected to each of the HVAC units, such that there being at least one of the first WWHP fluidically connected to one of the HVAC units;

one or more sanitary or domestic hot water (SHW/DHW) units configured in the one or more AOI;

a second set of WWHPs fluidically connected to each of the SHW/DHW units, such that there being at least one of the second WWHP fluidically connected to one of the SHW/DHW units,

wherein each of the second WWHPs is further fluidically connected to each of the first WWHPs, which allows the exchange of heat between the first set of WWHPs and the second set of WWHPs; and

one or more air-to-water heat (AWHP) units, each fluidically connected to the first set of WWHPs and the second set of WWHPs,

wherein the AWHP units are configured to enable the exchange of heat between environment and one or more of the first set of WWHPs and the second set of WWHPs, which correspondingly enables the exchange of heat between one or more of the environments, the one or more HVAC units, and the one or more SHW/DHW units.

14. The system of claim **13**, wherein the system comprises an energy recovery ventilator (ERV) or a heat recovery ventilator (HRV) configured with each of the HVAC units, the ERV or the HRV is operable to provide pre-conditioned ventilated air to each of the HVAC units to keep the one or more AOI pressurized at a predefined pressure.

15. The system of claim **14**, wherein the ERV or HRV supplies pre-conditioned ventilated air to the rooms in which occupants are present and restrict the supply of pre-conditioned ventilated air to the rooms in which occupants are not present.

16. The system of claim **12**, wherein the heat rejected by the HVAC units into the corresponding first WWHP units is supplied to the one or more SHW/DHW units or to the one or more HVAC units to provide reheat for the corresponding HVAC units.

17. The system of claim **15**, wherein the HVAC unit, the SHW/DHW unit, the WWHP unit, the thermal storage unit, and the ERV or HRV associated with each of the one or more AOI are packaged within a single housing, wherein the each of the housing is adapted to be installed at predefined positions in a horizontal and/or vertical configuration in the one or more AOI selected from rooms, above doors, below a floor, on the floor, walls, entry hall, ceiling, corridors, staircases, basement, and storage spaces associated with a building.

18. A method for efficient heat exchange between HVAC unit and SHW/DHW unit associated with one or more AOI of a building and environment, the method comprising the steps of:

fluidically connecting one or more HVAC units and one or more SHW units or one or more DHW units associated with one or more AOI in a building with each other, and with one or more AWHP units via at least one WWHP unit, wherein the AWHP units are configured to thermally connect the at least one WWHP to environment; and

enabling controlled flow of fluid between the AWHP units, the at least one WWHP, the HVAC units, and the SHW/DHW units, which allows the exchange of heat between one or more of the environments, the AWHP units, the WWHP, the HVAC units, and the SHW/DHW units, thereby facilitating in maintaining predefined temperatures in the one or more AOI, and of the water supplied by the SHW/DHW units in the one or more AOI.

19. The method of claim **18**, wherein the method comprises the steps of:

storing the heat provided by the at least one WWHP in a heat storage unit comprising a phase-changing material; and

transferring the stored heat to the SHW/DHW units and/or to the HVAC units for reheating the HVAC units.

20. The method of claim **18**, wherein the method comprises the steps of:

storing cold water or heat generated by the WWHP units in a buffer tank; and

transferring the stored cool water or stored heat to the HVAC units based on the cooling and heating requirement of the HVAC unit.

21. The method of claim **18**, wherein the method comprises the steps of supplying pre-conditioned ventilated air, by an ERV or HRV, to the one or more AOI when at least one occupant is present in the corresponding AOI.

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