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patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the
earlier application (Rule 4.17(iii))

(54) Title: HEAT PUMP SYSTEMS WITH BOOST HEAT PUMP

(57) Abstract: The disclosed technology includes a heat pump water heater sys-
tem comprising a primary heat pump and a boost heat pump. The primary heat pump
can heat water to a first temperature for a first hot water use, and the boost
heat pump can heat water to a second temperature for a second hot water use.
The heat pump water heater system can be configured to provide heated water for
the first hot water use and heated water at the second temperature for the second
hot water use.

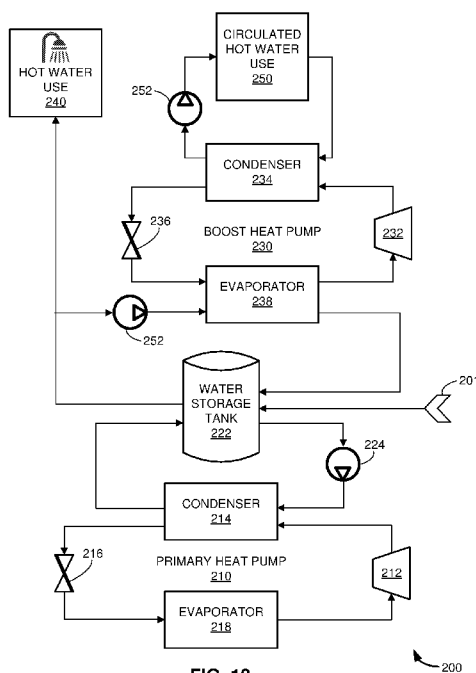


FIG. 13

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HEAT PUMP SYSTEMS WITH BOOST HEAT PUMP

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to U.S. Provisional Application Serial No. 63/310,317, filed February 15, 2022, the entire contents of which is incorporated herein by reference.

FIELD OF THE DISCLOSURE

[0002] The disclosed technology relates generally to heat pump systems, and more particularly, to a heat pump system including a boost heat pump.

BACKGROUND

[0003] Heat pump systems are becoming increasingly common as many industries move away from pollution-emitting combustion furnaces or heating systems and toward more efficient and environmentally-friendly systems. Rather than create heat energy directly through combustion (e.g., gas-fired heating systems) or other energy sources (e.g., electric heating elements), heat pumps are designed to transfer heat from one area to another area. In heating applications, heat pumps can transfer heat from a heat source (e.g., ambient air, geothermal heat sources, etc.) to a climate-controlled space (e.g., a building, a residential home, or other heated space) using a vapor-compression cycle. Thus, heat pumps can be used to efficiently heat a building or other space to a comfortable temperature for occupants of the space. In some existing applications, a heat pump system is combined with a hydronic heating system to provide heat to the space.

[0004] For example, referring to FIG. 1, an example of an existing heat pump hydronic system is illustrated. The heat pump hydronic system can include a heat pump 10 and a hydronic loop 20. The heat pump 10 includes a compressor 12, a condenser 14, an expansion valve 16, and an evaporator 18. As refrigerant is circulated by the compressor 12 sequentially through the condenser 14, expansion valve 16, and evaporator 18, the refrigerant is transitioned between vapor and liquid phases causing heat to be absorbed by the refrigerant at the evaporator 18 and released by the refrigerant at the condenser 14. The condenser 14 is typically a heat exchanger configured to transfer the heat from the refrigerant to water that is circulated through a water storage tank 22 by a pump 19. In other

prior art systems, the condenser 14 can be in contact with the water storage tank 22, such that the pump 19 is omitted. Regardless, the heated water in the water storage tank 22 is then circulated by another pump 24 to a hydronic heater 26, which can provide air heating for the building or other space.

5 [0005] Unfortunately, heat pumps have been limited in their application due to many heat pump systems being unable to effectively heat a building in low ambient temperatures. Thus, heat pumps have typically not been effectively implemented in regions having cooler climates. This is because the heat pump must work harder to heat the building as the ambient temperature decreases since the efficiency and capacity of the heat pump decreases with
10 decreasing ambient temperature. While certain refrigerants may be able to provide adequate heat lift for certain uses when ambient temperatures are low, such refrigerants (e.g., R-290, which is a propane-based refrigerant) are often subject to charge limitations due to certain regulations and/or such refrigerants (e.g., R-744, which is carbon dioxide) often operates at very high pressures and/or results in poor system efficiency, particularly at low ambient
15 conditions.

[0006] What is needed, therefore, is a heat pump system that can sufficiently heat water in low ambient temperature conditions while also increasing the overall efficiency of the heat pump system under various ambient conditions.

SUMMARY

20 [0007] These and other problems can be addressed by the technologies described herein. Examples of the present disclosure relate generally to heat pump systems, and more particularly, to a heat pump system including a boost heat pump.

[0008] The disclosed technology includes a heat pump water heater system comprising a primary heat pump configured to heat a first supply of water to a first temperature and a
25 boost heat pump configured to heat water to a second temperature greater than the first temperature. The primary heat pump can include a first heat exchanger (e.g., an evaporator) configured to facilitate heat exchange between ambient air proximate the first heat exchanger and a first refrigerant and a second heat exchanger (e.g., a condenser) configured to facilitate heat exchange between the first refrigerant and the first supply of water. The
30 boost heat pump can include a third heat exchanger (e.g., a condenser) configured to facilitate heat exchange between a second refrigerant and a second supply of water and a fourth heat exchanger (e.g., an evaporator) configured to facilitate heat exchange between

the second supply of water and the second refrigerant. The heat pump water heater system can be configured to provide heated water from the first supply of water for a first hot water use and heated water from the second supply of water at the second temperature for the second hot water use.

5 **[0009]** The heat pump water heater system can include a water storage tank configured to receive the first supply of water from the primary heat pump and store the first supply of water at the first temperature. The heated water from the first supply of water provided by the heat pump water heater system for the first hot water use can be at the first temperature and can be drawn from the water storage tank.

10 **[0010]** The second heat exchanger (e.g., a condenser) of the primary heat pump can be separate and distinct from the water storage tank. The heat pump water heater system can include a pump configured to flow water between the second heat exchanger and the water storage tank.

15 **[0011]** The second heat exchanger (e.g., a condenser) of the primary heat pump can be in direct contact with at least a portion of the water storage tank. Optionally, the second heat exchanger can be integrated into the water storage tank.

20 **[0012]** The heat pump water heater system can include the water storage tank configured to receive the first supply of water from the primary heat pump and store the first supply of water at the first temperature, and the heat pump water heater system can include an on-demand water heater downstream from the water storage tank. The on-demand water heater can be configured to receive, from the water storage tank, the heated water from the first supply of water at the first temperature and heat the heated water from the first supply of water to a third temperature that is greater than the first temperature. The heated water from the first supply of water provided by the on-demand water heater for the first hot water use
25 can be at the third temperature and can be drawn from the on-demand water heater.

[0013] The third temperature can be less than the second temperature.

[0014] The first hot water use can be a domestic hot water use.

[0015] The second hot water use can be a circulated hot water use. The circulated hot water use can be a hydronic heating system, a ductless heating system, or a heated floor
30 system. The circulated hot water use can be a hydronic air handler.

[0016] The boost heat pump can be a first boost heat pump, and the heat pump water heater system can include a second boost heat pump configured to heat the second supply of water to a third temperature for a third hot water use. The second boost heat pump can

include a fifth heat exchanger configured to facilitate heat exchange between a third refrigerant and the second supply of water and a sixth heat exchanger configured to facilitate heat exchange between the second supply of water and the third refrigerant.

5 [0017] The heat pump water heater system can include a primary heated water supply line configured to provide the heated water from the first supply of water for the first hot water use. Each, or either, of the first boost heat pump and the second boost heat pump can be configured to draw the second supply of water from the primary heated water supply line.

10 [0018] The first boost heat pump can include a first pump configured to draw a first portion of the second supply of water from the primary heated water supply line and flow the first portion of the second supply of water through the first boost heat pump and the second hot water use. The second boost heat pump can include a second pump configured to draw a second portion of the second supply of water from the primary heated water supply line and flow the second portion of the second supply of water through the second boost heat pump and the third hot water use.

15 [0019] The first pump can be configured to flow the first portion of the second supply of water sequentially through the third heat exchanger of the first boost heat pump, the second hot water use, and the fourth heat exchanger of the first boost heat pump. The second pump can be configured to flow the second portion of the second supply of water sequentially through the fifth heat exchanger of the second boost heat pump, the third hot water use, and the sixth heat exchanger of the second boost heat pump.

20 [0020] Water leaving the fourth heat exchanger of the first boost heat pump can be configured to flow to a water storage tank of the heat pump water heater system. Water leaving the sixth heat exchanger of the second boost heat pump can be configured to flow to the water storage tank.

25 [0021] At least one of the first, second, third, or fourth heat exchanger can be a counter-flow heat exchanger configured to flow refrigerant and water therethrough in opposite directions.

30 [0022] The second refrigerant of the boost heat pump can be an A3 refrigerant. The second refrigerant of the boost heat pump can be R-290 refrigerant. The second refrigerant can be R-1234yf refrigerant. The charge of refrigerant in the boost heat pump can be less than or equal to 150g. The charge of refrigerant in the boost heat pump can be less than or equal to 130g. The charge of refrigerant can be less than or equal to 125g. The charge of

refrigerant can be less than or equal to 110g. The charge of refrigerant can be less than or equal to 100g.

[0023] These and other aspects of the present disclosure are described in the Detailed Description below and the accompanying figures. Other aspects and features of the present disclosure will become apparent to those of ordinary skill in the art upon reviewing the following description of specific examples of the present disclosure in concert with the figures. While features of the present disclosure may be discussed relative to certain examples and figures, all examples of the present disclosure can include one or more of the features discussed herein. Further, while one or more examples may be discussed as having certain advantageous features, one or more of such features may also be used with the various other examples of the disclosure discussed herein. In similar fashion, while examples may be discussed below as devices, systems, or methods, it is to be understood that such examples can be implemented in various devices, systems, and methods of the present disclosure.

BRIEF DESCRIPTION OF THE FIGURES

[0024] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate various aspects of the presently disclosed subject matter and serve to explain the principles of the presently disclosed subject matter. The drawings are not intended to limit the scope of the presently disclosed subject matter in any manner.

[0025] FIG. 1 illustrates an existing heat pump hydronic heating system.

[0026] FIG. 2 illustrates a schematic diagram of an example heat pump water heating system, in accordance with the disclosed technology.

[0027] FIG. 3A illustrates a pressure-enthalpy chart corresponding to the existing heat pump hydronic heating system illustrated in FIG. 1 when using R134a refrigerant.

[0028] FIG. 3B illustrates a pressure-enthalpy chart corresponding to an example heat pump water heating system of FIG. 2 when using R134a refrigerant.

[0029] FIG. 4A illustrates a pressure-enthalpy chart corresponding to an example of the existing heat pump hydronic heating system illustrated in FIG. 1 when using R290 refrigerant.

[0030] FIG. 4B illustrates a pressure-enthalpy chart corresponding to an example heat pump water heating system of FIG. 2 when using R290 refrigerant.

[0031] FIG. 5 illustrates a schematic diagram of an example heat pump water heating system, in accordance with the disclosed technology.

[0032] FIG. 6 illustrates a schematic diagram of an example heat pump water heating system including an on-demand water heater and multiple zones, in accordance with the disclosed technology.

[0033] FIG. 7 illustrates a schematic diagram of an example heat pump water heating system including multiple zones, in accordance with the disclosed technology.

[0034] FIG. 8 illustrates a schematic diagram of an example heat pump water heating system, in accordance with the disclosed technology.

10 [0035] FIG. 9 illustrates a schematic diagram of an example heat pump water heating system including multiple zones, in accordance with the disclosed technology.

[0036] FIG. 10 illustrates a schematic diagram of an example heat pump water heating system including an on-demand water heater and a hydronic air handler, in accordance with the disclosed technology.

15 [0037] FIG. 11 illustrates a schematic diagram of an example heat pump water heating system including a hydronic air handler, in accordance with the disclosed technology.

[0038] FIG. 12 illustrates a schematic diagram of an example heat pump water heating system including a non-vapor compression heat pump, in accordance with the disclosed technology.

20 [0039] FIG. 13 illustrates a schematic diagram of an example heat pump water heating system including separated water loops for the primary heat pump and the boost heat pump, in accordance with the disclosed technology.

[0040] FIG. 14 illustrates a schematic diagram of an example heat pump water heating system, in accordance with the disclosed technology.

25 [0041] FIG. 15 illustrates a schematic diagram of an example heat pump water heating system including multiple zones, in accordance with the disclosed technology.

[0042] FIG. 16 illustrates a schematic diagram of a controller and various components of the heat pump water heating system, in accordance with the disclosed technology.

DETAILED DESCRIPTION

30 [0043] The disclosed technology can include heat pump heater systems that are configured to operate in both cool and warm climates. For example, the disclosed technology can include heat pump water heater systems that can sufficiently heat water in

warm climates, as well as in climates where the ambient temperature can remain below freezing temperatures for extended periods of time. As a non-limiting example, the heat pump water heater systems described herein can be configured to operate in ambient temperatures of -10°F or even lower. As another example, the disclosed technology can include heat pump system used for space conditioning and/or heating. Regardless of the particular application, the heat pump water heater system can include a primary heat pump and a secondary heat pump, also referenced herein as a boost heat pump.

[0044] The primary heat pump can extract heat from ambient air and can heat water to a desired intermediate temperature, which can be stored in a water tank at the intermediate temperature. In a system providing both space heating and domestic water heating, the water from the tank can be drawn for domestic water needs. For applications requiring a higher water temperature (e.g., hydronic heating), water can be drawn from the water storage tank and passed through the condenser of the boost heat pump to further heat the water to a higher water temperature. The evaporator of the boost heat pump can draw heat from the water returning from the higher water temperature application (e.g., hydronic heating). Since the temperature lift for the boost heat pump is lower, the coefficient of performance (COP) of the boost heat pump can be high. In addition, the overall COP of the water heater system can be equal or higher than that of a conventional single-stage system used for the same application (e.g., the system illustrated in FIG. 1). However, in a conventional single-stage system, there is no intermediate water storage temperature, requiring the stored water to be stored at a much higher temperature than the disclosed technology, resulting in comparatively high stand-by losses.

[0045] Although various aspects of the disclosed technology are explained in detail herein, it is to be understood that other aspects of the disclosed technology are contemplated. Accordingly, it is not intended that the disclosed technology is limited in its scope to the details of construction and arrangement of components expressly set forth in the following description or illustrated in the drawings. The disclosed technology can be implemented and practiced or carried out in various ways. In particular, the presently disclosed subject matter is described in the context of being systems and methods for use with a heat pump water heating system. The present disclosure, however, is not so limited, and can be applicable in other contexts. The present disclosure can, for example, include devices and systems for use with air conditioning systems, refrigeration systems, pool water heat systems, and other similar systems. Furthermore, although described in the context of being a water heater, the

disclosed technology can be configured to heat fluids other than water. For example, the disclosed technology can be implemented in various commercial and industrial fluid heating systems used to heat fluids other than water. Accordingly, when the present disclosure is described in the context of a heat pump water heater system, it will be understood that other implementations can take the place of those referred to.

[0046] It should also be noted that, as used in the specification and the appended claims, the singular forms “a,” “an,” and “the” include plural references unless the context clearly dictates otherwise. References to a composition containing “a” constituent is intended to include other constituents in addition to the one named.

[0047] Also, in describing the disclosed technology, terminology will be resorted to for the sake of clarity. It is intended that each term contemplates its broadest meaning as understood by those skilled in the art and includes all technical equivalents which operate in a similar manner to accomplish a similar purpose.

[0048] Ranges may be expressed herein as from “about” or “approximately” or “substantially” one particular value and/or to “about” or “approximately” or “substantially” another particular value. When such a range is expressed, the disclosed technology can include from the one particular value and/or to the other particular value. Further, ranges described as being between a first value and a second value are inclusive of the first and second values. Likewise, ranges described as being from a first value and to a second value are inclusive of the first and second values.

[0049] Herein, the use of terms such as “having,” “has,” “including,” or “includes” are open-ended and are intended to have the same meaning as terms such as “comprising” or “comprises” and not preclude the presence of other structure, material, or acts. Similarly, though the use of terms such as “can” or “may” are intended to be open-ended and to reflect that structure, material, or acts are not necessary, the failure to use such terms is not intended to reflect that structure, material, or acts are essential. To the extent that structure, material, or acts are presently considered to be essential, they are identified as such.

[0050] It is also to be understood that the mention of one or more method steps does not preclude the presence of additional method steps or intervening method steps between those steps expressly identified. Moreover, although the term “step” can be used herein to connote different aspects of methods employed, the term should not be interpreted as implying any particular order among or between various steps herein disclosed unless and except when the order of individual steps is explicitly required. Further, the disclosed technology does

not necessarily require all steps included in the methods and processes described herein. That is, the disclosed technology includes methods that omit one or more steps expressly discussed with respect to the methods described herein.

5 [0051] The components described hereinafter as making up various elements of the disclosed technology are intended to be illustrative and not restrictive. Many suitable components that would perform the same or similar functions as the components described herein are intended to be embraced within the scope of the disclosed technology. Such other components not described herein can include, but are not limited to, similar components that are developed after development of the presently disclosed subject matter.

10 [0052] Referring now to the drawings, in which like numerals represent like elements, the present disclosure is herein described. FIG. 2 illustrates a heat pump water heater system (HPWH) 200 that is configured to heat water, even in low ambient temperature conditions. The HPWH 200 can include a primary heat pump 210 that can include a compressor 212, an evaporator 214, an expansion valve (TXV) 216, and an evaporator 216. The compressor
15 212 can be configured to compress refrigerant in the primary heat pump 210 and circulate the refrigerant through the condenser 214, the TXV 216, and the evaporator 218. As will be appreciated by one of skill in the art, as the refrigerant is circulated by the compressor 212, the refrigerant can receive heat from ambient air at the evaporator 218 and transfer the heat to water at the condenser 214. The compressor 212 can be a single-speed compressor or a
20 variable-speed compressor. The primary heat pump 200 can be a split system or a monobloc system.

[0053] The water heated by the condenser 214 can be pumped into a water storage tank 222 by a pump 224. Alternatively, the condenser 214 can be configured to heat water that is already in the water storage tank. In such a configuration, the pump 224 can be omitted.
25 The heated water stored in the water storage tank 222 can be heated to a first target temperature, also referenced herein as an intermediate temperature. The intermediate temperature can correspond to a target temperature for a first type of hot water use 240 (e.g., domestic hot water). Thus, when water is needed at the intermediate temperature, heated water can be drawn directly from the water storage tank 222. Optionally, a supplemental
30 heat source (e.g., gas-fired heating, an electric heat element) can be configured to provide supplemental heat to the water in the water storage tank 222, as needed to meet system requirements.

[0054] For applications requiring a higher water temperature, water can be drawn from the water storage tank 222 and further heated by the boost heat pump 230. The boost heat pump 230 can include a compressor 232, an evaporator 234, an expansion valve (TXV) 236, and an evaporator 236. The compressor 232 can be configured to compress refrigerant in the boost heat pump 230 and circulate the refrigerant through the condenser 234, the TXV 236, and the evaporator 238. Water can be drawn from the water storage tank 222 (where the water is being stored at the intermediate temperature) and passed through the condenser of the boost heat pump 230 to further heat the water to a second target temperature that is higher than the first target temperature, also referenced herein as a high water temperature. After passing through the condenser 234, the water can be passed through a circulated hot water use 250, such as a hydronic heating system, a ductless heating system, or a heated floor system, as non-limiting examples. After the water has passed through the circulated hot water use 250, the water, which at this point has a temperature that is lower than the high water temperature, can be passed through the evaporator 236 of the boost heat pump 230, enabling the evaporator 236 to draw heat from the water returning from the circulated hot water use 250. The compressor 232 can be a single-speed compressor or a variable-speed compressor.

[0055] In some instances, it may be desirable or necessary to fluidly separate the water for the hot water use 240 from the water for any circulated hot water use 250. Thus, the water storage tank 222 can include a heat exchanger 223 through which water for the circulated hot water use 250 can flow and over which water for the domestic hot water use 240 can flow. The opposite configuration—in which water for the hot water use 240 flows inside the heat exchanger 223 and water for the hydronic air handler 1050 or any circulated hot water use 250 flows over the heat exchanger 1122—is also contemplated. Alternatively, all water lines (e.g., water lines leading to the hot water use 240 and water lines leading to or from any circulated hot water uses 250) can be in ultimate fluid communication via the water tank. That is to say, all supply lines can draw water from a single chamber of the water storage tank 222, and all return lines can deposit water into that single chamber of the water storage tank 222.

[0056] The HPWH 200 can be configured to receive water from a water source 201. For example, the water source 201 can be a city water supply, a well, a stream, a spring, or any other suitable water source for the particular application. The water from the water source 201 can be at a first, normally cooler, temperature prior to entering the water storage tank

220. As a non-limiting example, the water entering the HPWH 200 from the water source 201 can be between approximately 40°F and approximately 50°F. The intermediate temperature of the water stored in the water storage tank 220 and the target temperature for the hot water use 240 can be between approximately 110°F and approximately 170°F, as a non-limiting example, and/or can be approximately 140°F, as a more specific non-limiting example. The high water temperature and/or the target temperature for the circulated hot water use 250 can be between approximately 160°F and approximately 200°, as a non-limiting example, and/or can be approximately 180°F, as a more specific non-limiting example. As further non-limiting examples, the temperature of water entering the evaporator 238 of the boost heat pump 230 (i.e., downstream of the circulated hot water use 250) can be between approximately 145°F and approximately 175°F (e.g., approximately 160°F), the temperature of water entering the water storage tank 220 from the boost heat pump 230 can be between approximately 110°F and approximately 140°F (e.g., approximately 125°F), and the temperature of water entering the condenser 214 of the primary heat pump 210 from the water storage tank 222 can be between approximately 110°F and approximately 120°F.

[0057] As discussed above, the disclosed HPWH 200 can provide significant benefits as compared to existing heat pump hydronic systems, such as the system illustrated in FIG. 1. Referring to FIGs. 3A and 3B, pressure enthalpy charts are provided for the systems of FIG. 1 and FIG. 2, respectively, while operating using R134a refrigerant under the same conditions. Relatedly, the below tables illustrate the significant benefits provided by the disclosed technology. Table 1 illustrates calculated system metrics for the system of FIG. 1 while operating using R134a refrigerant, and Table 2 illustrates calculated system metrics for the system of FIG. 2 while operating using R134a refrigerant and under the same conditions as the system of FIG. 1. Moreover, the calculations in Table 2 does not contemplate heat loss arising from the system of FIG. 1 storing water at a higher temperature. Thus, the differences in COP are anticipated to be greater in practice.

Coefficient of Performance	2.109
Discharge Temperature	224°F
Pressure Ratio	16.42

Table 1.

Coefficient of Performance	2.004
Discharge Temperature	198°F (primary heat pump) 209°F (boost heat pump)
Pressure Ratio	3.51 (primary heat pump) 12.03 (boost heat pump)

Table 2.

[0058] Similarly, FIGs. 4A and 4B provide pressure enthalpy charts for the systems of FIG. 1 and FIG. 2, respectively, while operating using R290 refrigerant under the same conditions. Relatedly, the below tables illustrate the significant benefits provided by the disclosed technology. Table 3 illustrates calculated system metrics for the system of FIG. 1 while operating using R290 refrigerant, and Table 4 illustrates calculated system metrics for the system of FIG. 2 while operating using R290 refrigerant and under the same conditions as the system of FIG. 1.

Coefficient of Performance	2.081
Discharge Temperature	219°F
Pressure Ratio	10.75

Table 3.

Coefficient of Performance	1.977
Discharge Temperature	193°F (primary heat pump) 207°F (boost heat pump)
Pressure Ratio	2.57 (primary heat pump) 9.79 (boost heat pump)

Table 4.

[0059] It should be noted that the calculated COPs discussed above relate to particular operating conditions and particular temperatures of air and water. For other conditions, certain values—such as the COP, discharge temperature, and pressure ratio—can differ. Other system differences (e.g., refrigerant type) can result in different values.

[0060] Referring now to FIG. 5, the HPWH 200 can optionally omit the hot water tank 222. The heater water leaving the condenser 214 of the primary heat pump 210 can be drawn into the condenser of the boost heat pump 234 via the pump 252. Optionally, a small

tank 522 (e.g., 5-gallon, 2-gallon, 1-gallon) can be positioned between the condenser 214 of the primary heat pump 210 and the condenser 234 of the boost heat pump 230. The small tank 522 can be configured to store a small volume of water heated to an intermediate temperature, which can help to increase and/or maximize the cycle COP for the primary heat pump, reduce heat loss of the overall system, and/or reduce the overall cost of the system (e.g., by requiring a smaller water tank).

[0061] As shown in FIG. 6, the HPWH 200 can include the water storage tank 222 and can optionally include an on-demand water heater 521. While some of the primary heat pump 210 is omitted from FIG. 6 for clarity of illustration, the illustrated condenser 214 can interact with the remainder of the primary heat pump 210 as herein described and heated water leaving the condenser 214 of the primary heat pump 210 can be heated to the intermediate temperature and stored in the water storage tank 222. When water is demanded by a hot water use 240 (e.g., domestic hot water) or a circulated hot water use 250, water drawn from the hot water tank 222 can be further heated by the on-demand water heater 521 as needed for a hot water use 240 (e.g., domestic hot water). This can help reduce the temperature of the water stored in the hot water tank 222, which can reduce standby losses and/or performance metrics of the primary heat pump 210. Moreover, the size of the water storage tank 222 can be reduced without negatively impacting performance of the HPWH system 200. Alternatively or in addition, storing the water at a lower temperature can help facilitate the use of less expensive materials for the water storage tank and/or the use of a simpler and/or less expensive water storage tank design. To the extent necessary or useful for the hot water use 240, the on-demand water heater 521 can further increase the temperature of the water. As will be appreciated, the on-demand water heater 521 can be or include a tankless water heater. For applications requiring an even higher water temperature, water can be drawn from the water storage tank 222 and further heated by the boost heat pump 230.

[0062] As shown in FIGs. 6 and 7, the HPWH 200 can be configured to provide heated water to multiple zones. While the primary heat pump 210 and some of the water circuit (e.g., pump 224) are omitted from FIG. 7 for clarity of illustration, water can be circulated between the water storage tank 222 and the condenser 214 of the primary heat pump 210, as described herein can be heated to the intermediate temperature and stored in the water storage tank 222. The water stored in the water storage tank 222 can be stored at an intermediate temperature that is the target temperature desired for the hot water use 240

(e.g., domestic hot water use) (e.g., as shown in FIG. 7). Alternatively, the water stored in the water storage tank 222 can be stored at an intermediate temperature that is less than the target temperature desired for the hot water use 240 (e.g., domestic hot water use), and the on-demand water heater 521 can further heat water drawn from the water storage tank 222 to the target temperature desired for the hot water use 240 (e.g., as shown in FIG. 6). Regardless, each zone can have its own boost heat pump 234 (e.g., boost heat pump 234A, . . . boost heat pump 234n). The HPWH 200 can include any number of zones and/or boost heat pumps 234. The circulated hot water uses 250 can be the same for each zone or can be different for one or more zones. For example, a first circulated hot water use 250A can be hydronic heating for a first space, a second circulated hot water use 250B can be heat floors for a second space, and/or a third circulated hot water use 250C can be hydronic heating for a third space. The various boost heat pumps 230 for the various zones can be configured to heat the corresponding water to the same temperature. Alternatively, some or all of the various heat pumps 230 for the various zones can be configured to heat the corresponding water to different temperatures to meet the corresponding zone's specific temperature requirements. This can enable the water in the water storage tank 222 to be maintained at a lower temperature, which translates to a reduced heating load for the primary heat pump 210. This can reduce standby losses and/or reduce the temperature lift on the primary heat pump 210. Optionally, the HPWH 200 illustrated and described herein can omit the hot water use 240 (e.g., as shown in FIG. 15). As such, and referring to FIG. 7 as an example, the HPWH 200 can be configured to provide heat only for one or more circulated hot water uses 250, as a non-limiting example.

[0063] Referring now to FIG. 8, the boost heat pump 230 can be configured to provide supplemental heat to water used for the hot water use 240 (e.g., domestic hot water). That is, the intermediate temperature can be lower than the temperature required for the hot water use 240 such that water stored in the water storage tank 222 needs to be further heated to meet the target temperature for the hot water use 240. As illustrated, water drawn from the water storage tank 222 can be passed through the condenser 234 of the boost heat pump 234 (e.g., by the pump 252). Water not used by the hot water use 240 can be passed through the evaporator 238 of the boost heat pump 230 and then returned to the water storage tank 222. This can be particularly useful for supplemental water heating at the point of use. That is, the boost heat pump 230 can be located at or near the location of the hot water use 240. For example, the boost heat pump 230 can be an under-the-sink heat source. In such uses or

other uses where the refrigerant charge will be small, A3 refrigerants, such as R-290 can be used without exceeding regulations relating to A3 refrigerants (e.g., having a charge of less than 150g in an individual zones and/or refrigerant circuit).

[0064] As shown in FIG. 9, the HPWH 200 can be configured to provide heated water for a first hot water use 240A (e.g., domestic water use). At the same time, the HPWH 200 can include a boost heat pump 230A for a second hot water use 240B (e.g., commercial water use) that has a higher temperature requirement than the first hot water use 240A. Optionally, the HPWH 200 can include multiple zones for other water uses such as one or more circulated hot water uses 250. As will be understood, the various zones of the HPWH 200 can be used to provide heated water for one or more hot water uses 240 and/or one or more circulated hot water uses 250.

[0065] Referring now to FIG. 10, the HPWH 200 can be configured to function as a high lift air-to-air heat pump, with or without simultaneous provision of water for a hot water use 240. That is, the boost heat pump can be configured to provide heated water to a hydronic air handler 1050, which can be configured to heat the air in a space. This configuration can provide air discharge temperatures that match or exceed gas furnaces. In addition, the boost heat pump 230 can have a small charge such that A3 refrigerants (e.g., R-290) can be used without exceeding regulations relating to A3 refrigerants. Optionally, the boost heat pump can be packaged within the housing of the hydronic air handler 1050. When the HPWH 200 includes the hydronic air handler 1050 and is configured to provide heated water for a hot water use 240, the HPWH 200 can provide continuous heating, even when the HPWH 200 is in defrost mode.

[0066] As illustrated in FIG. 10, the HPWH 200 can optionally include an on-demand water heater 521. Although the on-demand water heater 521 is shown as being located upstream from the line-split leading to the condenser 234 of the boost heat pump 230, the on-demand water heater 521 can instead be located at a position downstream from the line-split leading to the boost heat pump 230. As another alternative, a line-split can be located downstream from the condenser 214 of the primary heat pump 210 such that water can flow in parallel between a first line including the on-demand water heater 521 and leading to the hot water use 240 and a second line leading to the condenser 234 of the boost heat pump 230.

[0067] Alternatively, the HPWH 200 can omit the on-demand water heater 521 (e.g., if the HPWH 200 is used only for one or more circulated hot water uses 250). Thus, the

HPWH 200 can also omit the water source 201 and the hot water use 240. In cases such as this (e.g., where the HPWH 200 is not used to heat water for domestic consumption), the HPWH 200 can be configured to circulate a fluid other than water. For example, the circulated fluid can be glycol or any other non-water refrigerant, which can provide increased freeze protection as compared to water. That is to say, although the term “circulated hot water use 250” is used herein, such uses and applications are not limited to the use of water as the circulating fluid and can instead use any type of refrigerant.

[0068] Referring to FIG. 11, it may be desirable or necessary to fluidly separate the water for the hot water use 240 from the water for the hydronic air handler 1050 or any circulated hot water use 250, as described herein. Thus, the water storage tank 222 can include the heat exchanger 233 to separate water for the hydronic air handler 1050 from water for the domestic hot water use 240. As shown, water for the hydronic air handler 1050 is flowing within the heat exchanger 233, but the opposite configuration— in which water for the hot water user 240 flows inside the heat exchanger 233—is also contemplated.

[0069] As shown in FIG. 12, the boost heat pump can be a non-vapor compression heat pump 1230, such a thermo-electric heat pump or other not-in-kind heat pump technologies.

[0070] The HPWH 200 can optionally be reversible. Although not shown in the drawings, the HPWH 200 can include four-way valves to reverse the direction of refrigerant flow in the various heat pumps (e.g., primary heat pump 210, boost heat pump 230), or the HPWH 200 can include four-way valves to reverse the direction of water flow in HPWH 200. Thus, the HPWH 200 can be configured to operate as a chiller, providing cold water and/or cool air to a conditioned space.

[0071] The various compressors 212, 232 described herein can be any type of compressor. For example, the compressors 212, 232 can each be a positive displacement compressor, a reciprocating compressor, a rotary screw compressor, a rotary vane compressor, a rolling piston compressor, a scroll compressor, an inverter compressor, a diaphragm compressor, a dynamic compressor, an axial compressor, or any other form of compressor that can be integrated into the HPWH 200 for the particular application. The compressors 212, 232 can be a fixed speed or a variable speed compressor depending on the application. Furthermore, the compressors 212, 232 can both be the same type of compressor or each be a different type of compressor.

[0072] The heat exchangers described herein (e.g., condenser 214, the evaporator 218, condenser 234, the evaporator 238) can each be or include any type of heat exchanger coil

configured to facilitate heat transfer between fluids. The fluid, for example, can be refrigerant, air, water, glycol, propane, dielectric fluids, or any other type of fluid suitable for the particular application. As non-limiting examples, the evaporator 218 can be a heat exchanger configured to facilitate heat exchanger between air and refrigerant, while the condenser 214, the condenser 234, and the evaporator 238 can be configured to facilitate heat exchanger between the refrigerant and water. The various heat exchangers be or include, for example, a shell and tube heat exchanger, a double pipe heat exchanger, a plate heat exchanger, a tube-and-fin heat exchanger, a microchannel heat exchanger, or any other suitable heat exchanger for the application. In addition, one or more of the heat exchangers described herein can be counter-flow heat exchanger in that the refrigerant and the water are configured to flow through the corresponding heat exchanger in opposite directions.

[0073] Referring to FIG. 13, the boost heat pump 230 can be configured to interface with separated water loops. That is, a first water loop can pass through the evaporator 238, transferring heat between a refrigerant of the booth heat pump 230 and water flowing between the evaporator 238 and the water storage tank 222. A second water loop can pass through the condenser 234 and the circulated hot water use 250. As such, the water (or other refrigerant) used by the circulated hot water use 250 can be fluidly separated from water used for the hot water use 240 (e.g., domestic hot water).

[0074] As illustrated in FIG. 14, the HPWH 200 can be used in a minisplit system, in which the circulated hot water use 250 can be a ductless HVAC system. As such, the circulated hot water use 250 can be configured to provide space heating to a target space. Optionally, the HPWH 200 can be configured to switch between a heating mode (as illustrated) and a cooling mode. In cooling mode, the HPWH 200 can be configured to reverse the flow of refrigerant in the primary heat pump 210 and the boost heat pump 230, such as by a reversing valve (e.g., a four-way valve) in either heat pump 210, 230. Thus, the primary heat pump 210 can cool water or another refrigerant to a first temperature, and the boost heat pump 230 can further cool the water or other refrigerant to a second temperature that is lower than the first temperature. In the case of the ductless HVAC system, the HPWH 200 can thus be configured to provide cooling, rather than heating, to the target space.

[0075] Referring to FIG. 15, the HPWH 200 can be configured to provide heated water to multiple zones. While some of the primary heat pump 210 is omitted from FIG. 15 for clarity of illustration, the illustrated condenser 214 can interact with the remainder of the

primary heat pump 210 as herein described. Heated water (or another refrigerant) leaving the condenser 214 can be drawn into one or more boost heat pumps 230, which can further heat the water to one or more elevated water temperatures. For example, the circulated hot water uses 250 can correspond to different units of a multi-split system to provide heating to multiple rooms or other areas. This can enable the HPWH 200 to manage individual zones without active refrigerant management. The HPWH 200 can be or include a variable-speed and/or variable-capacity refrigeration system, which can help accommodate varying demands of each individual zone. Optionally, the HPWH 200 can include a small water tank and/or expansion tank (e.g., similar to small tank 522 discussed with respect to FIG. 5) inside an outdoor unit housing at least some of the primary heat pump 210.

[0076] FIG. 16 illustrates a schematic diagram of a controller 1600 and various components of the HPWH 200. As will be appreciated, the controller 1600 can be configured receive data from, and/or output instructions to, any sensors or controllable components of the HPWH 200. As illustrated in FIG. 16, the disclosed technology can include a controller 1600 that can be configured to receive data and determine actions based on the received data. For example, the controller 1600 can be configured to monitor the temperature of ambient air via an ambient air temperature sensor 1612 and output control signals to the various components described herein to heat the water. As another illustrative example, the controller 1600 can be configured to monitor the temperature of the water (e.g., water entering the HPWH 200) via a water temperature sensor 1620 and output control signals to the various components described herein to heat the water. As yet another illustrative example, the controller 1600 can be configured to monitor the temperature of the refrigerant in the HPWH via a refrigerant temperature sensor 1618 and output control signals to the various components described herein to heat the water. The controller 1600 can receive data from, or output data to, the user interface 1610, the ambient air temperature sensor 1612, one or more indoor temperature sensors 1614, one or more coil temperature sensors 1616, one or more refrigerant temperature sensors 1618, one or more water temperature sensors 1620, the compressor 214 of the primary heat pump 210, one or more compressors 234 of one or more corresponding boost heat pumps 238, one or more reversing valves 1622 and/or one or more pumps 252.

[0077] Based on the various data, the controller 1600 can be configured to control the HPWH 200 to optimize efficiency. For example, the controller 1600 can be configured to operate the various components of the HPWH 200 to increase, optimize, and/or maximize

the efficiency (e.g., COP) of the overall system for all heating needs or uses of the HPWH 200 while maintaining sufficient water temperatures for the various needs or uses of the HPWH 200.

5 [0078] The ambient air temperature sensor(s) 1612 can be configured to detect a temperature of the ambient air proximate the HPWH 200 (e.g., proximate the evaporator 218 of the primary heat pump 210). The water temperature sensor(s) 1620 can be configured to detect a temperature of the water supplied to the HPWH 200, a temperature of the water at one or more locations in the HPWH 200, and/or a temperature of the water supplied by the HPWH 200 at one or more locations. The refrigerant temperature sensor(s) 1618 can be
10 configured to detect a temperature of the refrigerant at one or more locations of the HPWH 200. Each of the temperature sensors can be any type of temperature sensor including a thermocouple, a resistance temperature detector, a thermistor, a semiconductor based integrated circuit, or any other suitable type of temperature sensor for the particular application.

15 [0079] The controller 1600 can have a memory 1602, a processor 1604, and a communication interface 1606. The controller 1600 can be a computing device configured to receive data, determine actions based on the received data, and output a control signal instructing one or more components of the HPWH 200 to perform one or more actions. One of skill in the art will appreciate that the controller 1600 can be installed in any location,
20 provided the controller 1600 is in communication with at least some of the components of the system. Furthermore, the controller 1600 can be configured to send and receive wireless or wired signals and the signals can be analog or digital signals. The wireless signals can include Bluetooth™, BLE, WiFi™, ZigBee™, infrared, microwave radio, or any other type of wireless communication as may be suitable for the particular application. The hard-wired
25 signal can include any directly wired connection between the controller and the other components described herein. Alternatively, the components can be powered directly from a power source and receive control instructions from the controller 1600 via a digital connection. The digital connection can include a connection such as an Ethernet or a serial connection and can utilize any suitable communication protocol for the application such as
30 Modbus, fieldbus, PROFIBUS, SafetyBus, Ethernet/IP, or any other suitable communication protocol for the application. Furthermore, the controller 1600 can utilize a combination of wireless, hard-wired, and analog or digital communication signals to communicate with and control the various components. One of skill in the art will appreciate

that the above configurations are given merely as non-limiting examples and the actual configuration can vary depending on the particular application.

[0080] The memory 1602 can store a program and/or instructions associated with the functions and methods described herein and can include one or more processors 1604
5 configured to execute the program and/or instructions. The memory 1602 can include one or more suitable types of memory (e.g., volatile or non-volatile memory, random access memory (RAM), read only memory (ROM), programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), magnetic disks, optical disks, floppy disks, hard disks,
10 removable cartridges, flash memory, a redundant array of independent disks (RAID), and the like) for storing files including the operating system, application programs (including, for example, a web browser application, a widget or gadget engine, and or other applications, as necessary), executable instructions and data. One, some, or all of the processing techniques or methods described herein can be implemented as a combination of
15 executable instructions and data within the memory.

[0081] The communication interface 1606 for sending and receiving communication signals between the various components. The communication interface 1606 can include hardware, firmware, and/or software that allows the processor(s) 1604 to communicate with
20 the other components via wired or wireless networks or connections, whether local or wide area, private or public, as known in the art. The communication interface 1606 can also provide access to a cellular network, the Internet, a local area network, or another wide-area network as suitable for the particular application.

[0082] Additionally, the controller 1600 can have or be in communication with a user interface 1610 for displaying system information and receiving inputs from a user. The user
25 interface 1610 can be installed locally or be a remotely controlled device such as a mobile device. The user, for example, can view system data on the user interface 1610 and input data or commands to the controller 1600 via the user interface 1610. For example, the user can view temperature threshold settings on the user interface 1610 and provide inputs to the controller 1600 via the user interface 1610 to change a temperature threshold setting. The
30 temperature threshold settings can be, for example, an ambient air temperature threshold, a water temperature threshold, and/or a refrigerant temperature threshold.

[0083] The controller 1600 can receive data indicative of the first target temperature (intermediate temperature), second target temperature, and/or third target temperature (e.g.,

via the user interface 1610), and based at least in part on that data, the controller 1600 can output instructions for operation of various components of the HPWH 200. For example, the controller 1600 can output instructions for the primary heat pump 210 (e.g., for the compressor 212 to operate) to heat water to the first target temperature (intermediate temperature), and water heated to the first target temperature can be stored in the water storage tank 222. The first target temperature can correspond to the target water temperature for one or more hot water uses 240 (e.g., domestic hot water), and thus, water at the first target temperature can be easily drawn from the water storage tank 222.

[0084] Alternatively, the first water temperature can correspond to a temperature that is less than the target temperature for the one or more hot water uses 240, and the controller 1600 can output instructions for the on-demand water heater 521 to further heat water from the first target temperature to the third target temperature, with the third target temperature corresponding to the target temperature for the one or more hot water uses 240. Optionally, a local controller of the on-demand water heater 521 can directly control operation the on-demand water heater 521, and in such cases, the controller 1600 can transmit certain data to the local controller of the on-demand water heater 521, such as the value of the third target temperature.

[0085] The controller 1600 can be configured to output instructions for operating one or more boost heat pumps 230 (boost heat pump 230A, . . . boost heat pump 230n). More specifically, the controller 1600 can be configured to output instructions for one or more corresponding pumps 252 (pump 252A, . . . pump 252n) for drawing water from the water storage tank 222 and/or the on-demand water heater 521 and flowing the water through the corresponding boost heat pump 230 and the corresponding circulated hot water use 250 (circulated hot water use 250A, . . . circulated hot water use 250n) and/or a hot water use 240 having a temperature requirement greater than that provided by the water storage tank 222 and/or the on-demand water heater 521 (see, e.g., FIGs. 8 and 9). The controller 1600 can be configured to receive use data from the circulated hot water use(s) 250, hot water use(s) 222, and/or sensors associated therewith (e.g., flow sensor(s) in communication with the controller 1600), and in response to the use data indicating that there is a need for heated water at a circulated hot water use 250 or hot water use 222, the controller 1600 can output instructions for the corresponding pump 250 and/or compressor 232 to operate. The controller 1600 can output instructions for the corresponding pump 250 and/or compressor

232 to cease operating upon receipt of use data indicating that there is no need for heat water at the circulated hot water use 250 or hot water use 222.

[0086] While the present disclosure has been described in connection with a plurality of exemplary aspects, as illustrated in the various figures and discussed above, it is understood
5 that other similar aspects can be used, or modifications and additions can be made to the described subject matter for performing the same function of the present disclosure without deviating therefrom. In this disclosure, methods and compositions were described according to aspects of the presently disclosed subject matter. But other equivalent methods or compositions to these described aspects are also contemplated by the teachings herein.
10 Therefore, the present disclosure should not be limited to any single aspect, but rather construed in breadth and scope in accordance with the appended claims.

[0087] Moreover, the various diagrams and figures presented herein are for illustrative purposes and are not to be considered exhaustive. That is, the systems described herein can include one or more additional components, such as various valves, expansions tanks, and
15 the like, as will be appreciated by one having ordinary skill in the art.

CLAIMS

We claim:

1. A heat pump water heater system comprising:
 - a water storage tank configured to hold a first supply of water;
 - a primary heat pump configured to heat the first supply of water to a first temperature, the primary heat pump comprising:
 - a first heat exchanger configured to facilitate heat exchange between ambient air proximate the first heat exchanger and a first refrigerant; and
 - a second heat exchanger configured to facilitate heat exchange between the first refrigerant and the first supply of water;
 - a boost heat pump configured to heat a second supply of fluid to a second temperature greater than the first temperature, the second supply of fluid different from the first supply of water, the boost heat pump comprising:
 - a third heat exchanger configured to facilitate heat exchange between a second refrigerant and the first supply of water; and
 - a fourth heat exchanger configured to facilitate heat exchange between the second supply of fluid the second refrigerant,wherein the heat pump water heater system is configured to provide (i) the first supply of water for a first hot water use and (ii) the second supply of fluid for a second hot fluid use.
2. The heat pump water heater system of claim 1, wherein the first supply of water is separate and distinct from the second supply of fluid.
3. The heat pump water heater system of claim 1, wherein the first hot water use is domestic consumption hot water use.
4. The heat pump water heater system of claim 1, wherein the second hot fluid use comprises water or a non-water refrigerant.
5. The heat pump water heater system of claim 1, wherein the second hot fluid use is one or more of a hydronic heating system, a ductless heating system, or a heated floor heating system.

6. The heat pump water heater system of claim 1, wherein the first heat exchanger is an evaporator, the second heat exchanger is a condenser, the third heat exchanger is an evaporator, and the fourth heat exchanger is a condenser.
7. The heat pump water heater system of claim 1, further comprising a pump and piping, the piping in fluid communication with the pump and the water storage tank and configured to circulate at least a portion of the first supply of water and exchange heat with the second heat exchanger.
8. The heat pump water heater system of claim 1, further comprising a pump and piping, the piping in fluid communication with the pump and second hot fluid use and configured to circulate at least a portion of the second supply of fluid and exchange heat with the fourth heat exchanger.
9. The heat pump water heater system of claim 1, further comprising a pump and piping, the piping in fluid communication with the pump and the water storage tank and configured to circulate at least a portion of the first supply of water and exchange heat with the third heat exchanger.
10. The heat pump water heating system of claim 1, wherein the first hot water use is in fluid communication with the water storage tank.
11. The heat pump water heating system of claim 1, wherein the water storage tank is in fluid communication with a water source.
12. The heat pump water heating system of claim 1, wherein the boost heat pump is a non-vapor compression heat pump.
13. The heat pump water heater system of claim 1, wherein the second refrigerant is an A3 refrigerant.

14. A heat pump water heater system comprising:
a primary heat pump configured to heat a first supply of water to a first temperature, the primary heat pump comprising:
a first heat exchanger configured to facilitate heat exchange between ambient air proximate the first heat exchanger and a first refrigerant; and
a second heat exchanger configured to facilitate heat exchange between the first refrigerant and the first supply of water;
a boost heat pump configured to heat a second supply of fluid to a second temperature greater than the first temperature, where the second supply of fluid is different from the first supply of water, the boost heat pump comprising:
a third heat exchanger configured to facilitate heat exchange between a second refrigerant and the second supply of fluid; and
a fourth heat exchanger configured to facilitate heat exchange between the second supply of fluid and the second refrigerant,
a fifth heat exchanger configured to cause the second supply of fluid to flow through the first supply of water and the first supply of water to flow over the second supply of fluid to facilitate heat exchange between the first supply of water and the second supply of fluid,
wherein the heat pump water heater system is configured to provide (i) the first supply of water for a first hot water use and (ii) the second supply of fluid for a second hot fluid use.
15. The heat pump water heater system of claim 14, wherein the first supply of water is separate and distinct from the second supply of fluid and is not in fluid communication with the second supply of fluid.
16. The heat pump water heater system of claim 14, wherein the first hot water use is domestic consumption hot water use.
17. The heat pump water heater system of claim 14, wherein the second hot fluid use comprises water a non-water refrigerant.

18. The heat pump water heater system of claim 14, wherein the second hot fluid use is one or more of a hydronic heating system, a ductless heating system, or a heated floor heating system.
19. The heat pump water heater system of claim 14, wherein the first heat exchanger is an evaporator, the second heat exchanger is a condenser, the third heat exchanger is an evaporator, and the fourth heat exchanger is a condenser.
20. The heat pump water heater system of claim 14, further comprising a pump and piping, the piping in fluid communication with the pump and the water storage tank and configured to circulate at least a portion of the first supply of water and exchange heat with the second heat exchanger.
21. The heat pump water heater system of claim 14, further comprising a pump and piping, the piping in fluid communication with the pump and second hot fluid use and configured to circulate at least a portion of the second supply of fluid and exchange heat with the fourth heat exchanger and with the water storage tank.
22. The heat pump water heating system of claim 14, wherein the first hot water use is in fluid communication with the water storage tank.
23. The heat pump water heating system of claim 14, wherein the water storage tank is in fluid communication with a water source.
24. The heat pump water heating system of claim 14, wherein the boost heat pump is a non-vapor compression heat pump.
25. The heat pump water heater system of claim 14, wherein the second refrigerant is one of an A3 refrigerant.

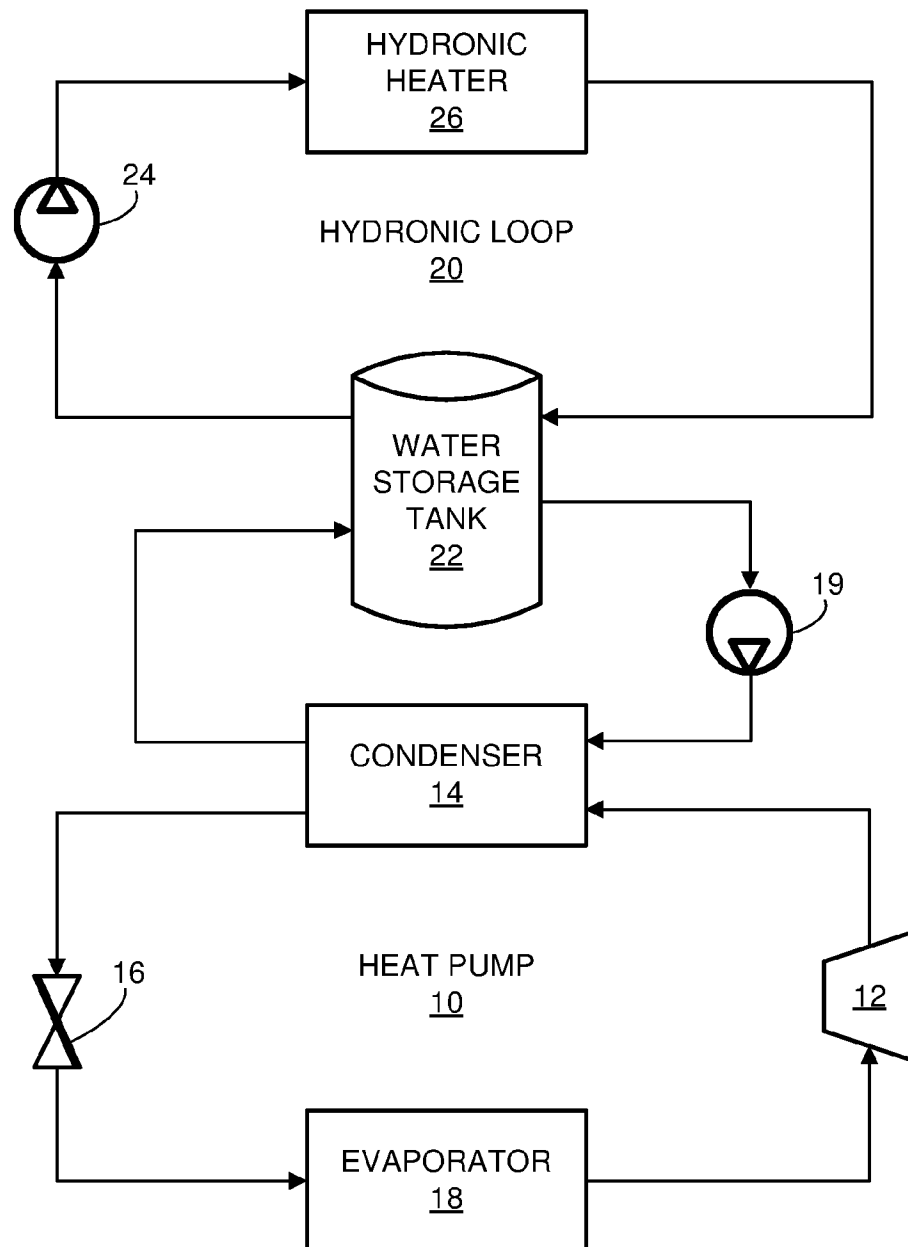
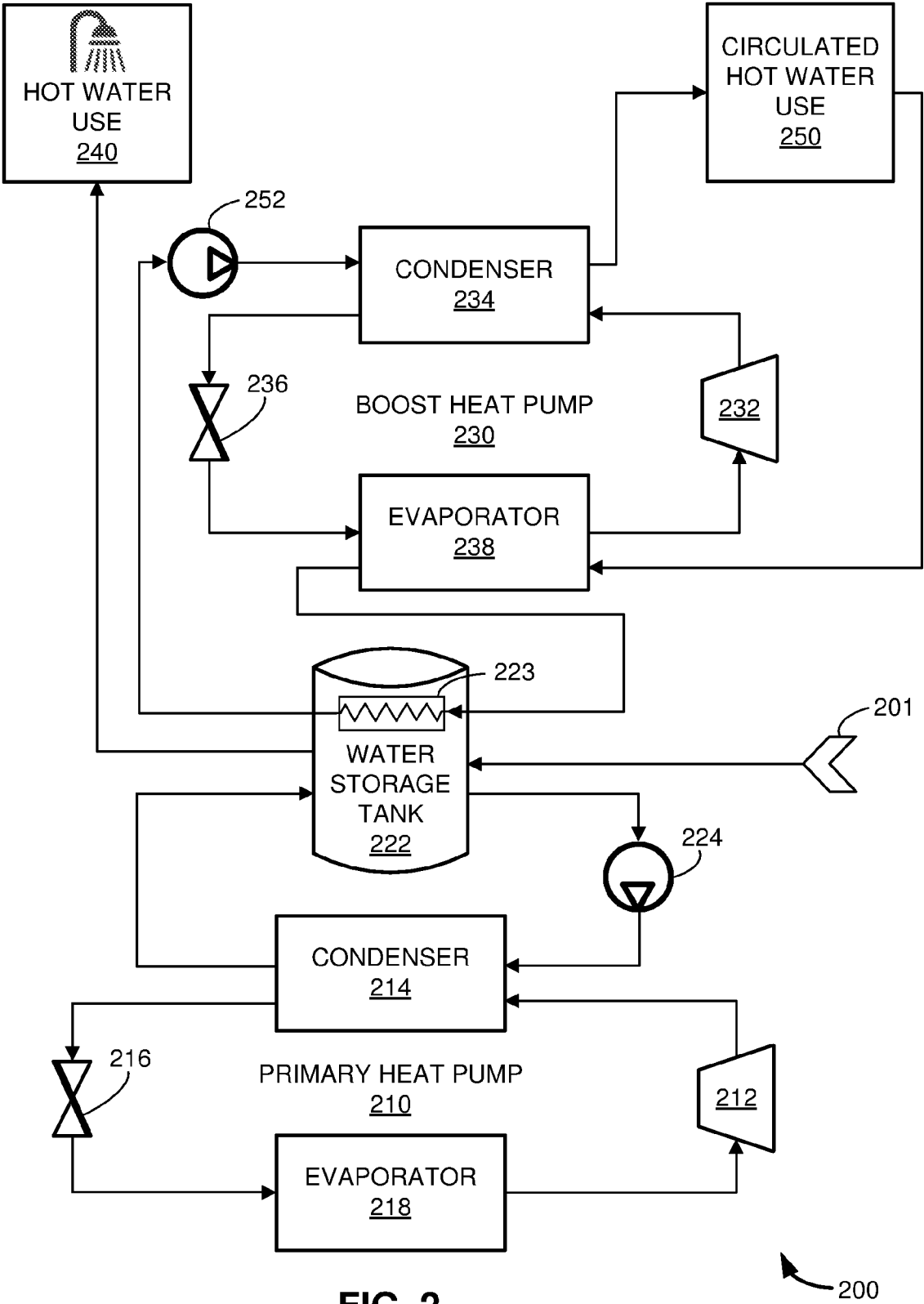
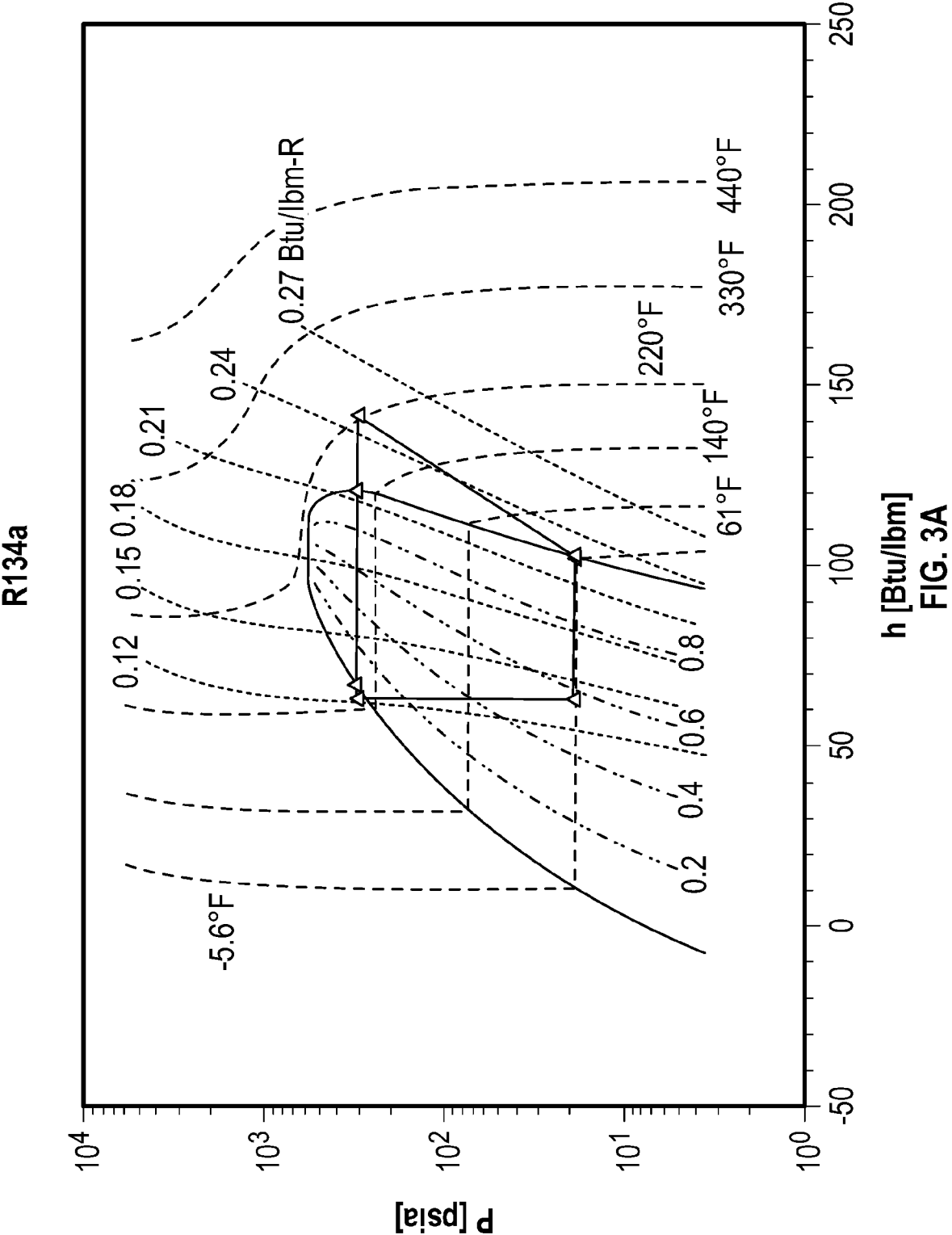
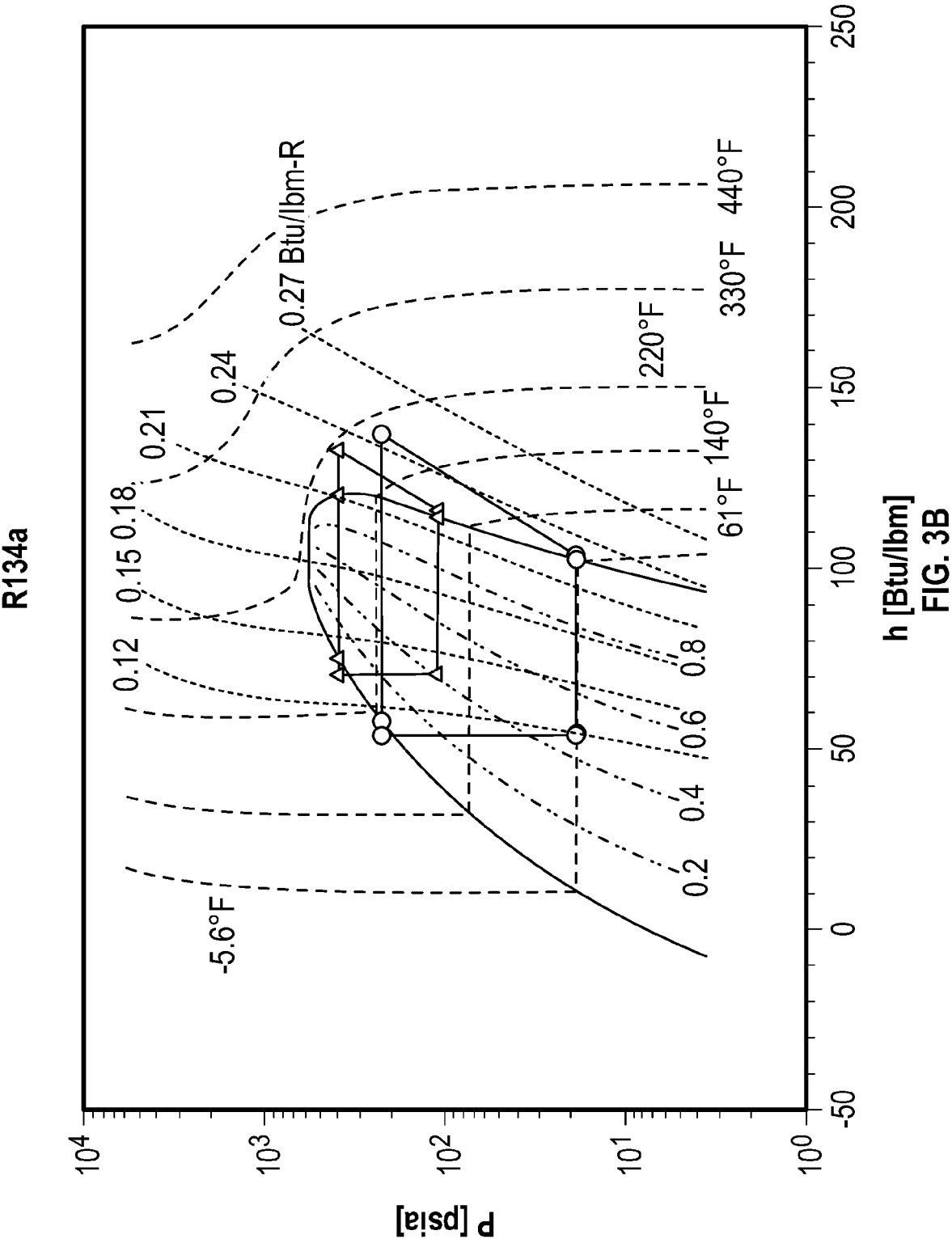
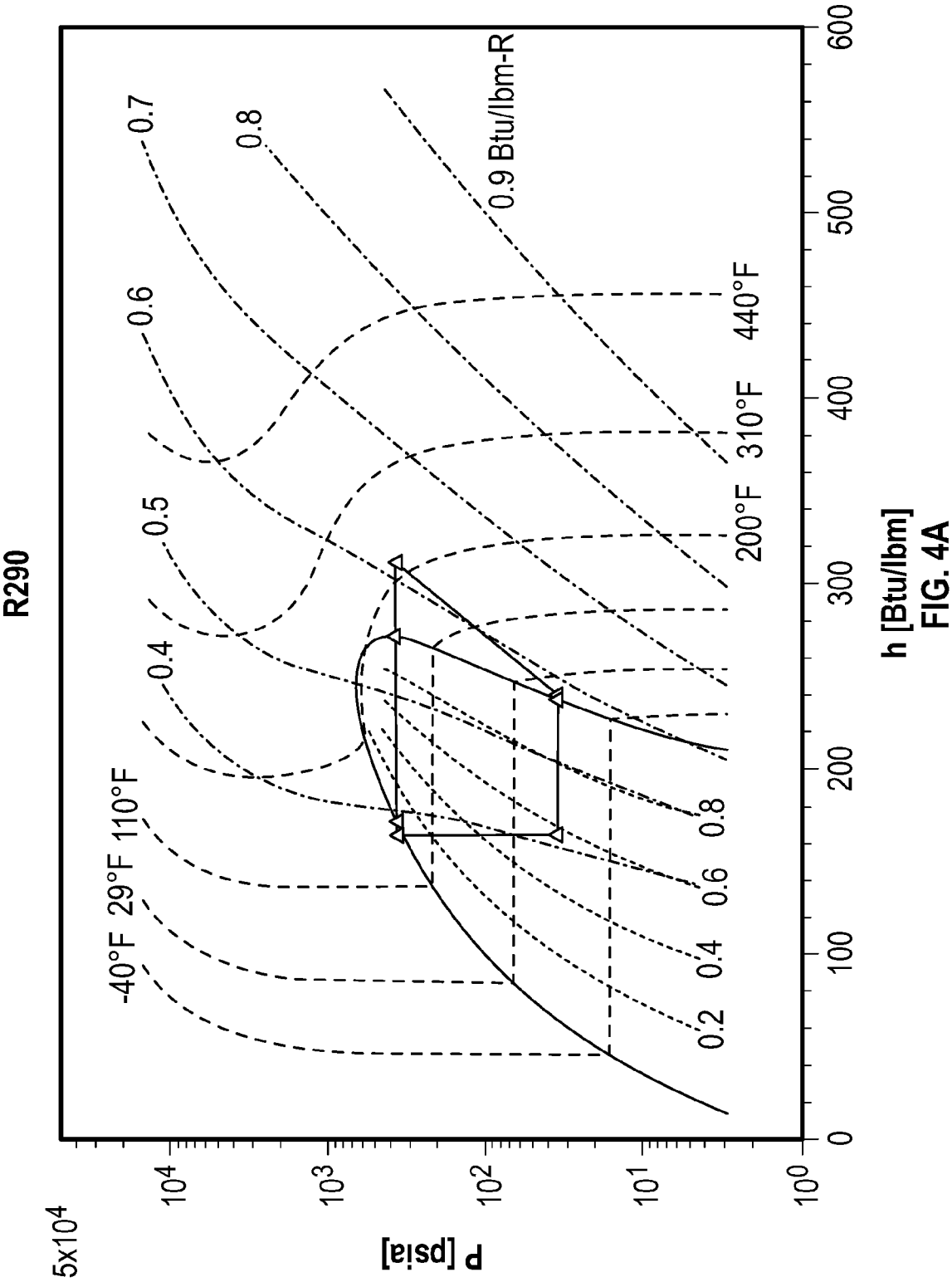


FIG. 1
PRIOR ART









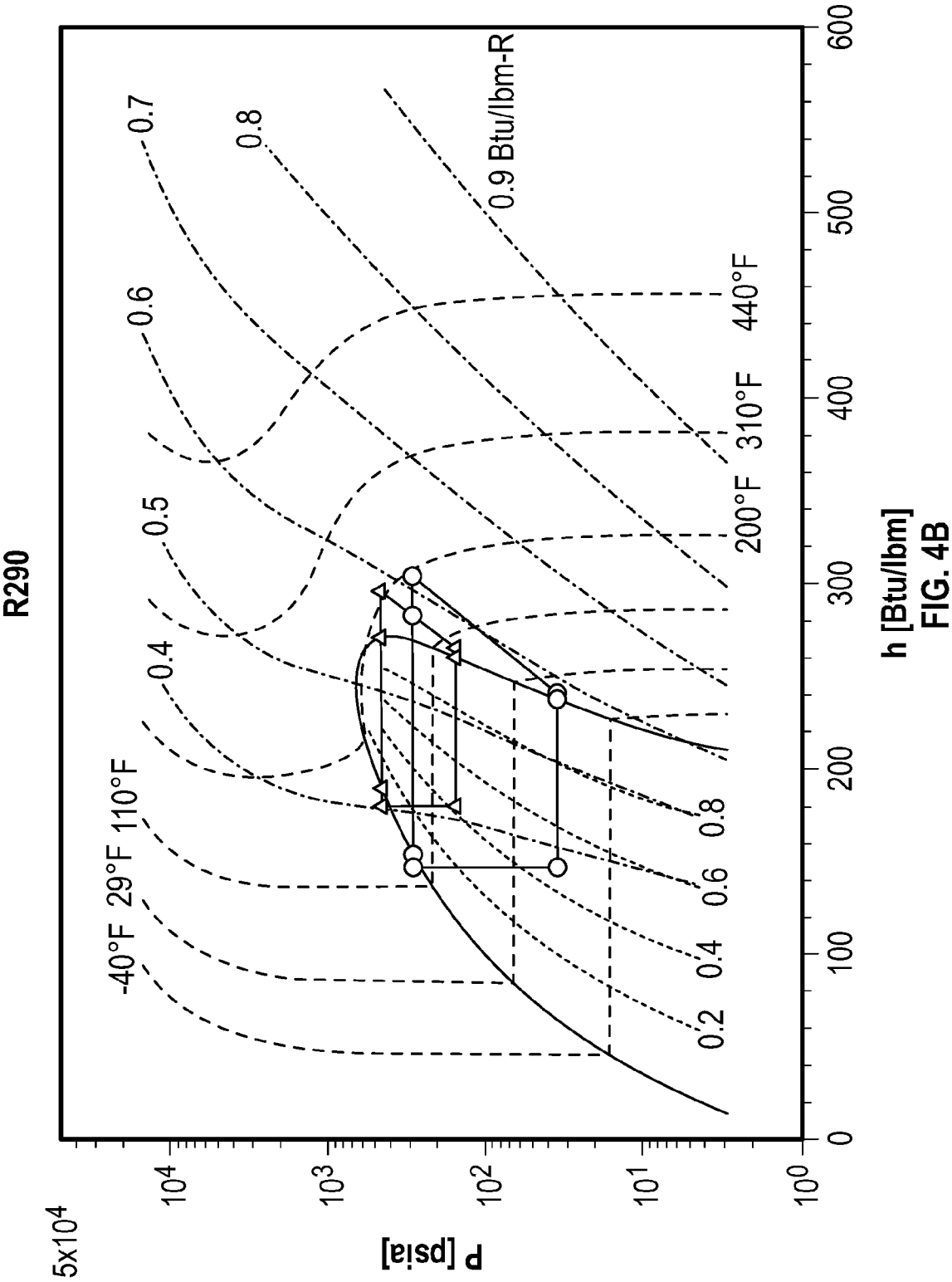


FIG. 4B

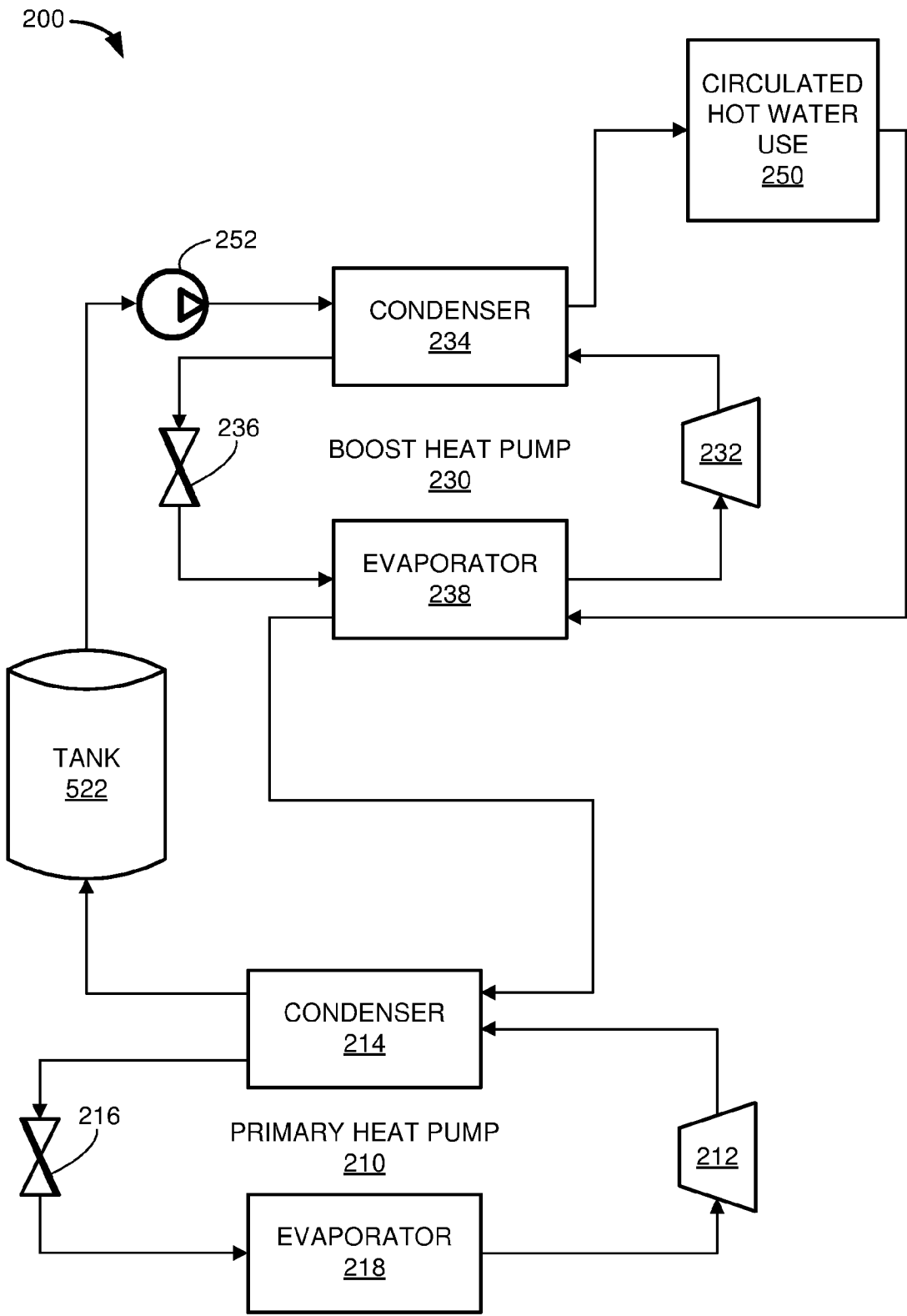


FIG. 5

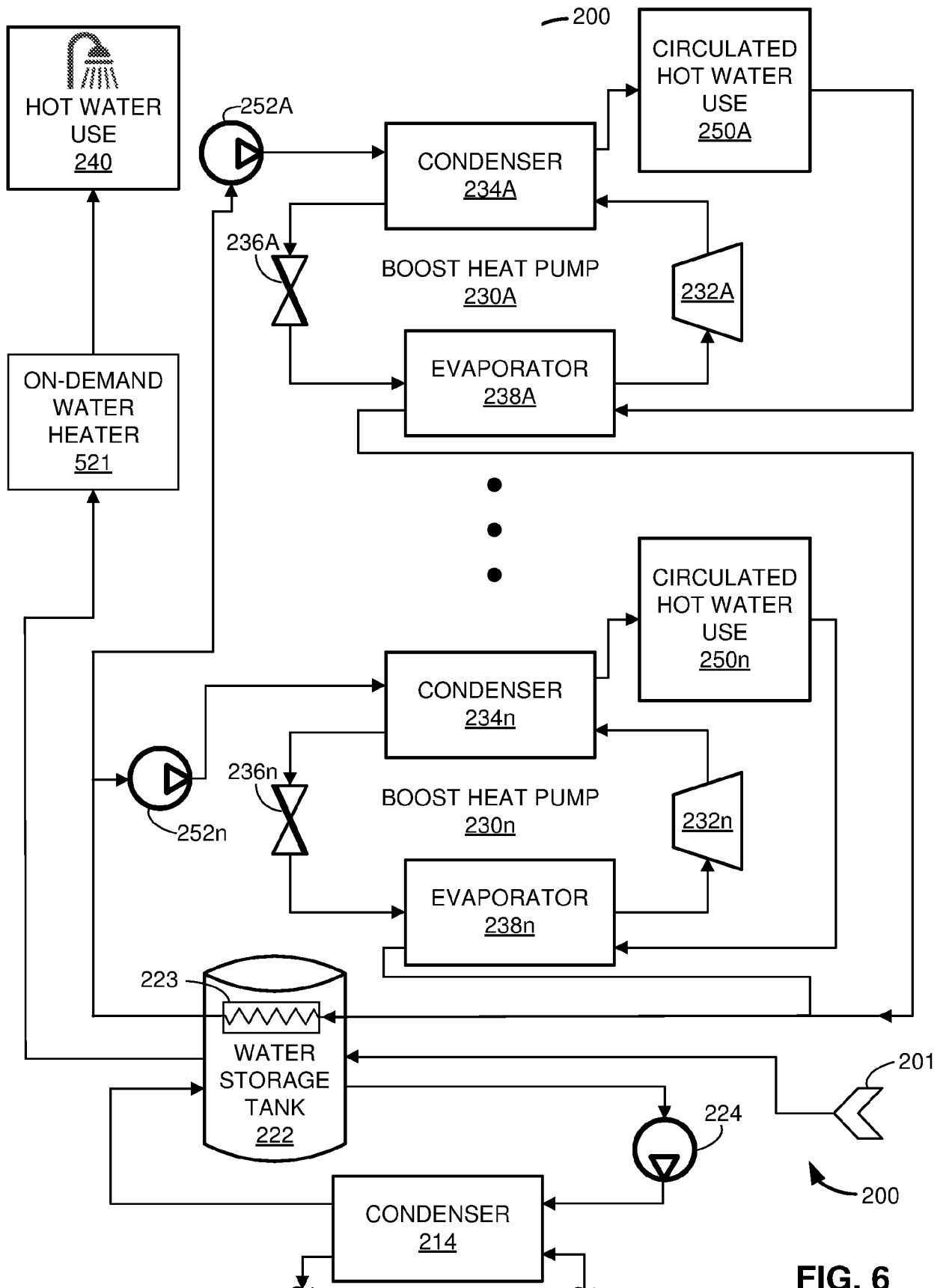


FIG. 6

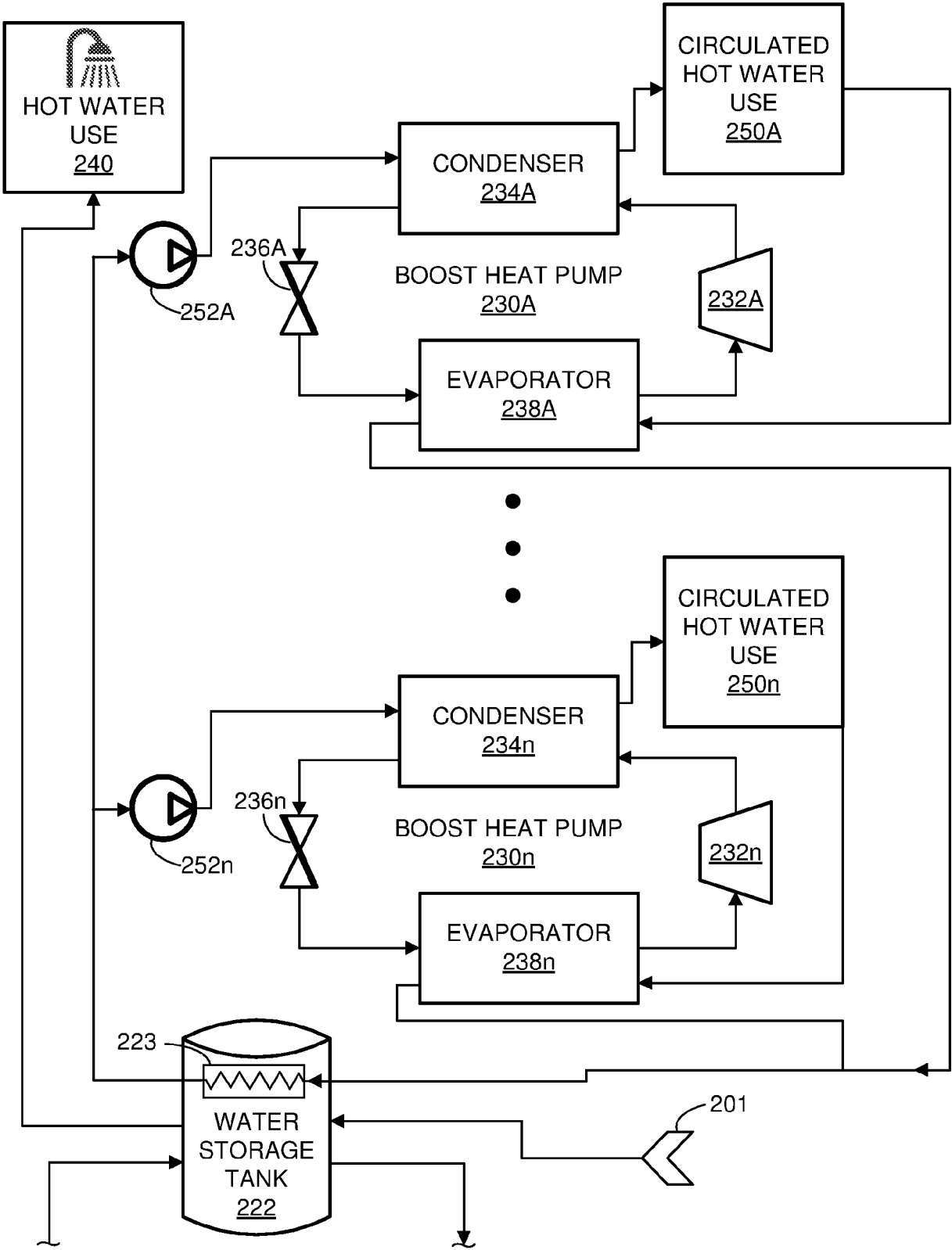


FIG. 7

200

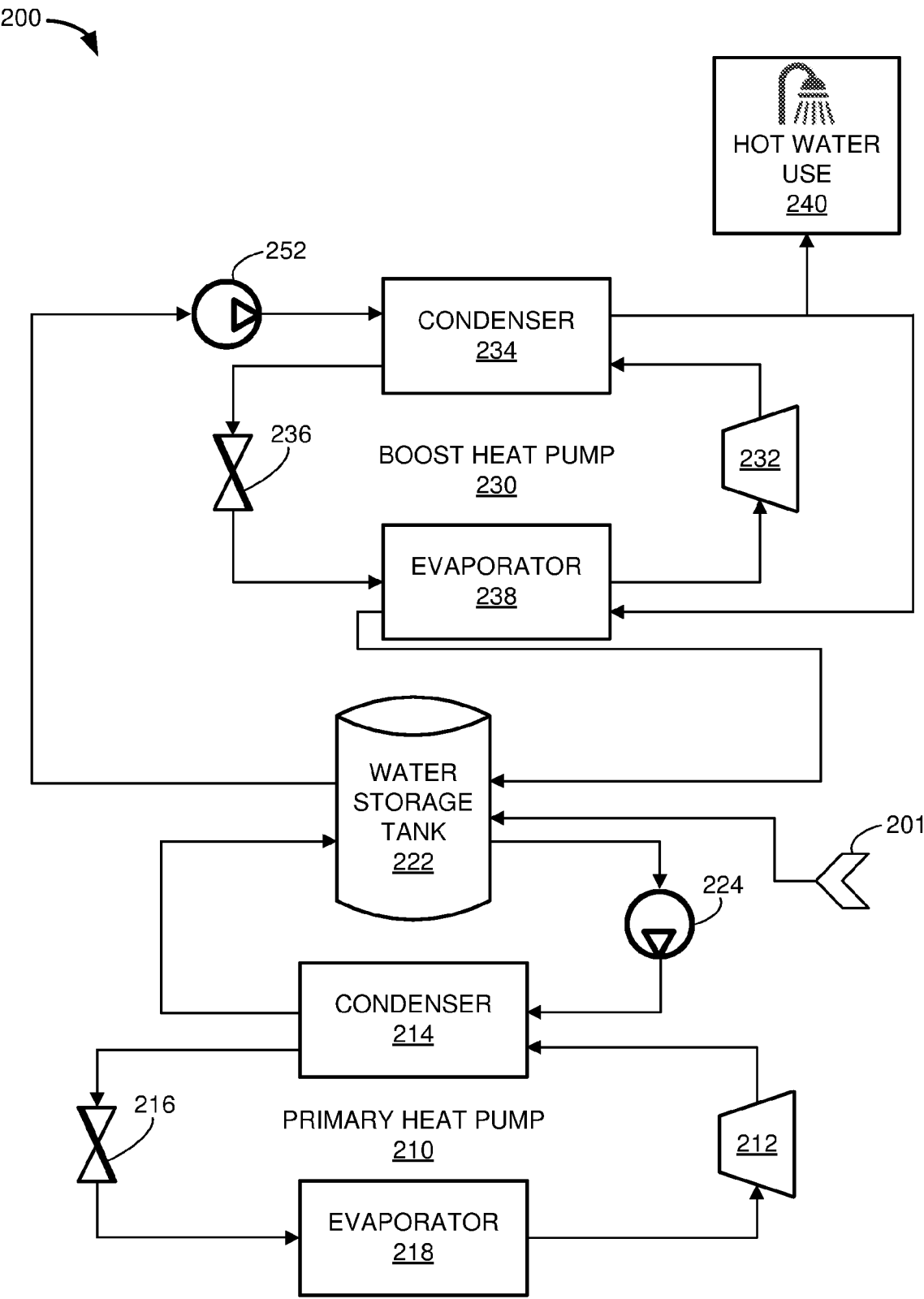


FIG. 8

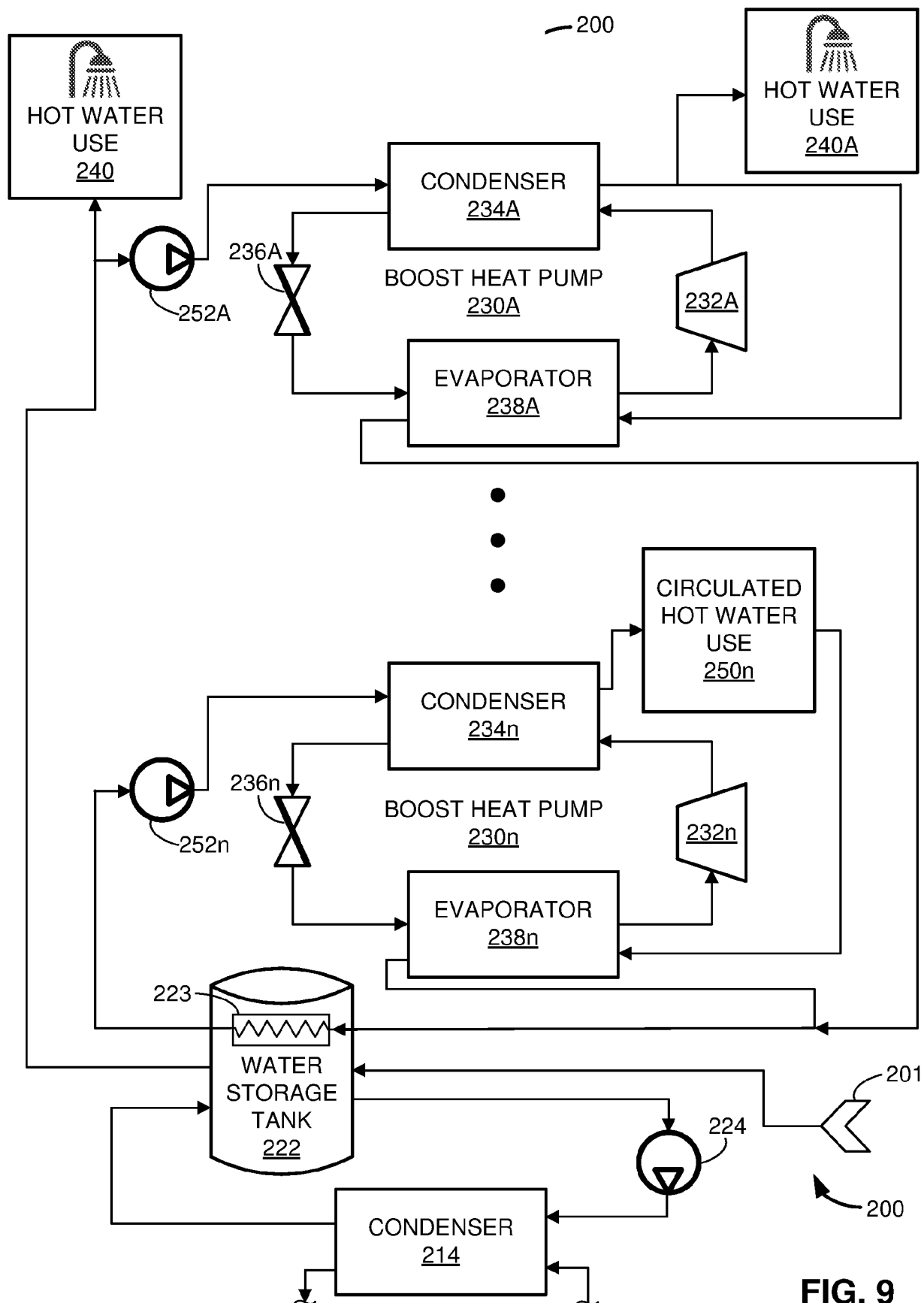


FIG. 9

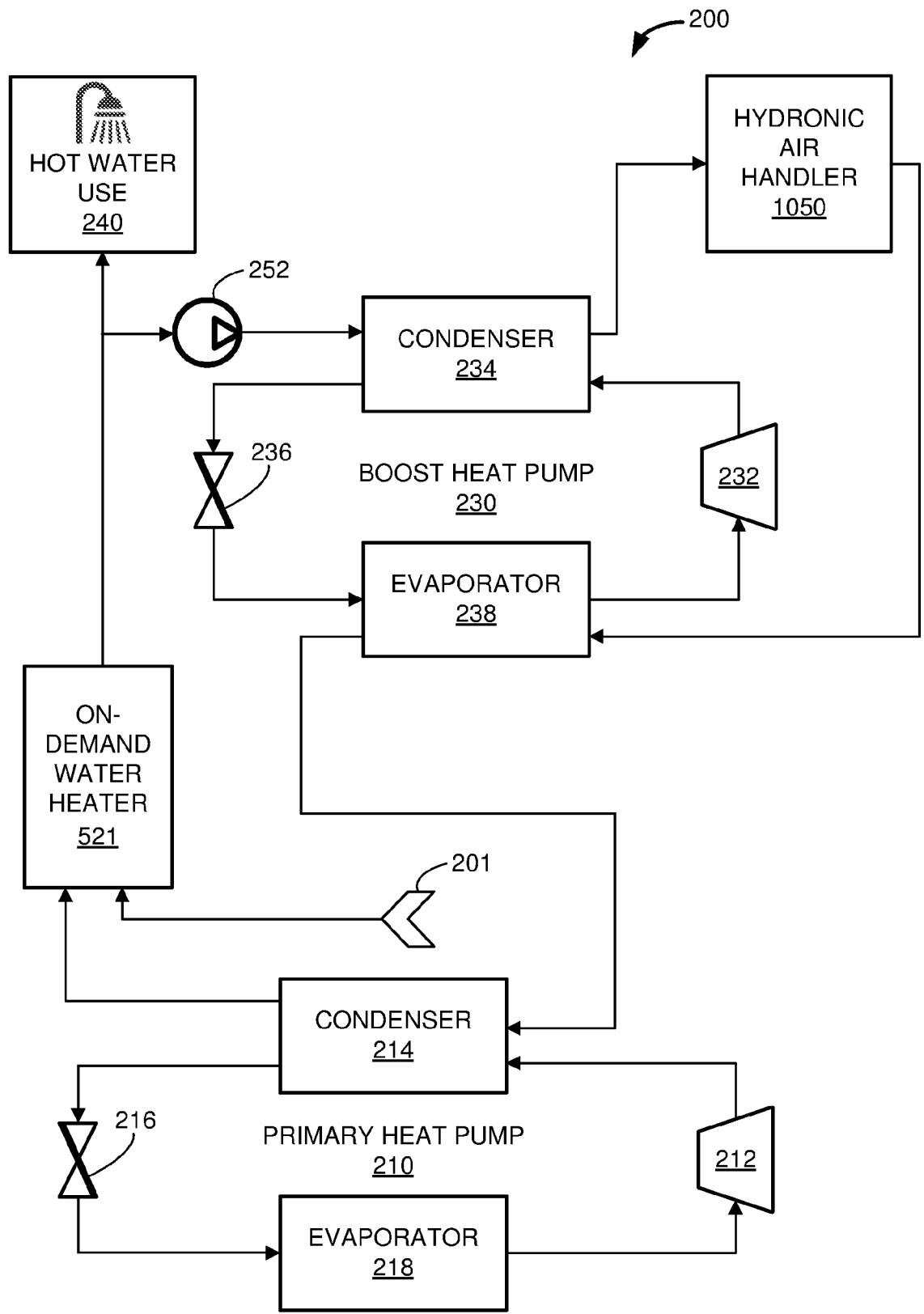


FIG. 10

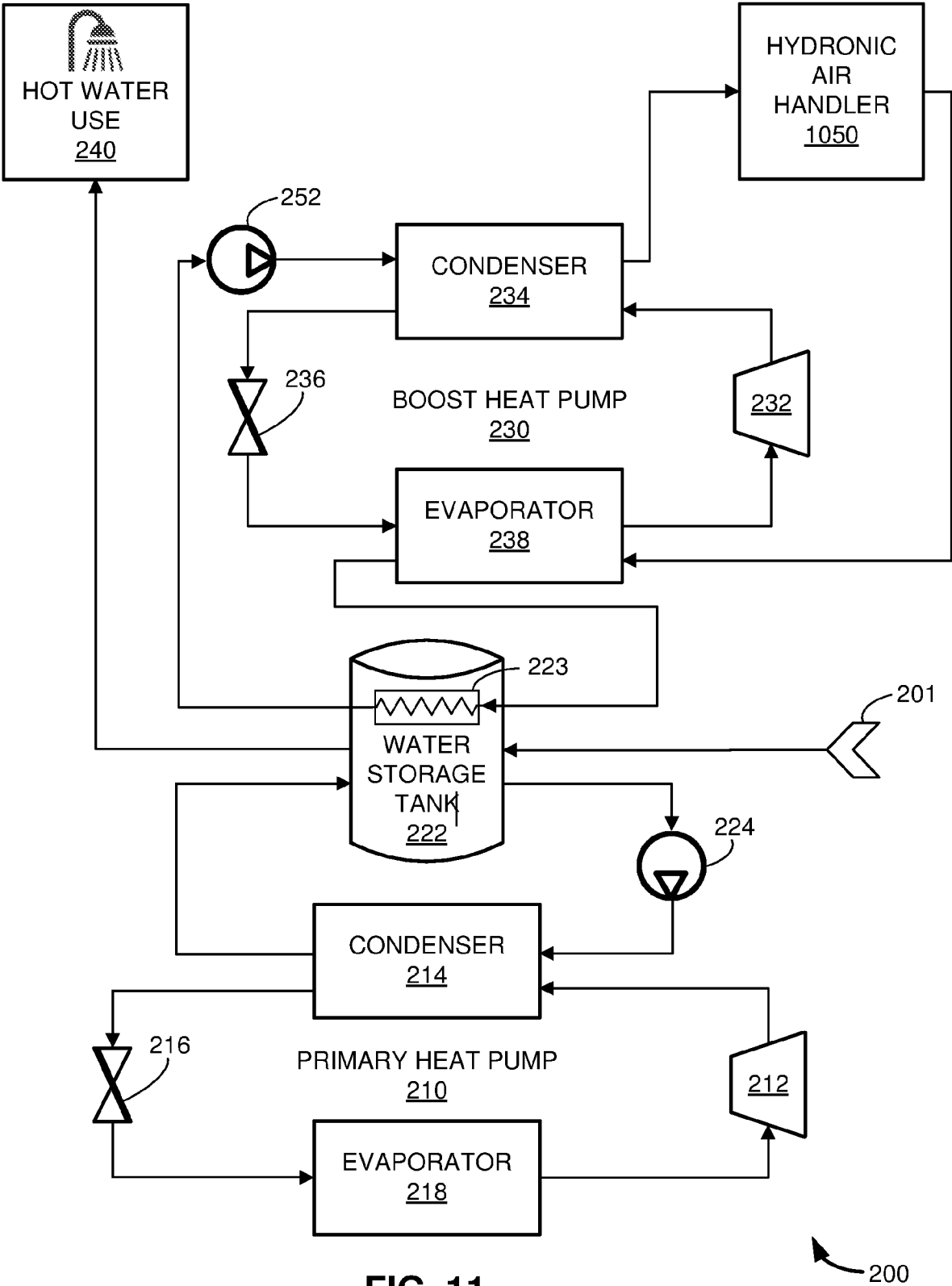
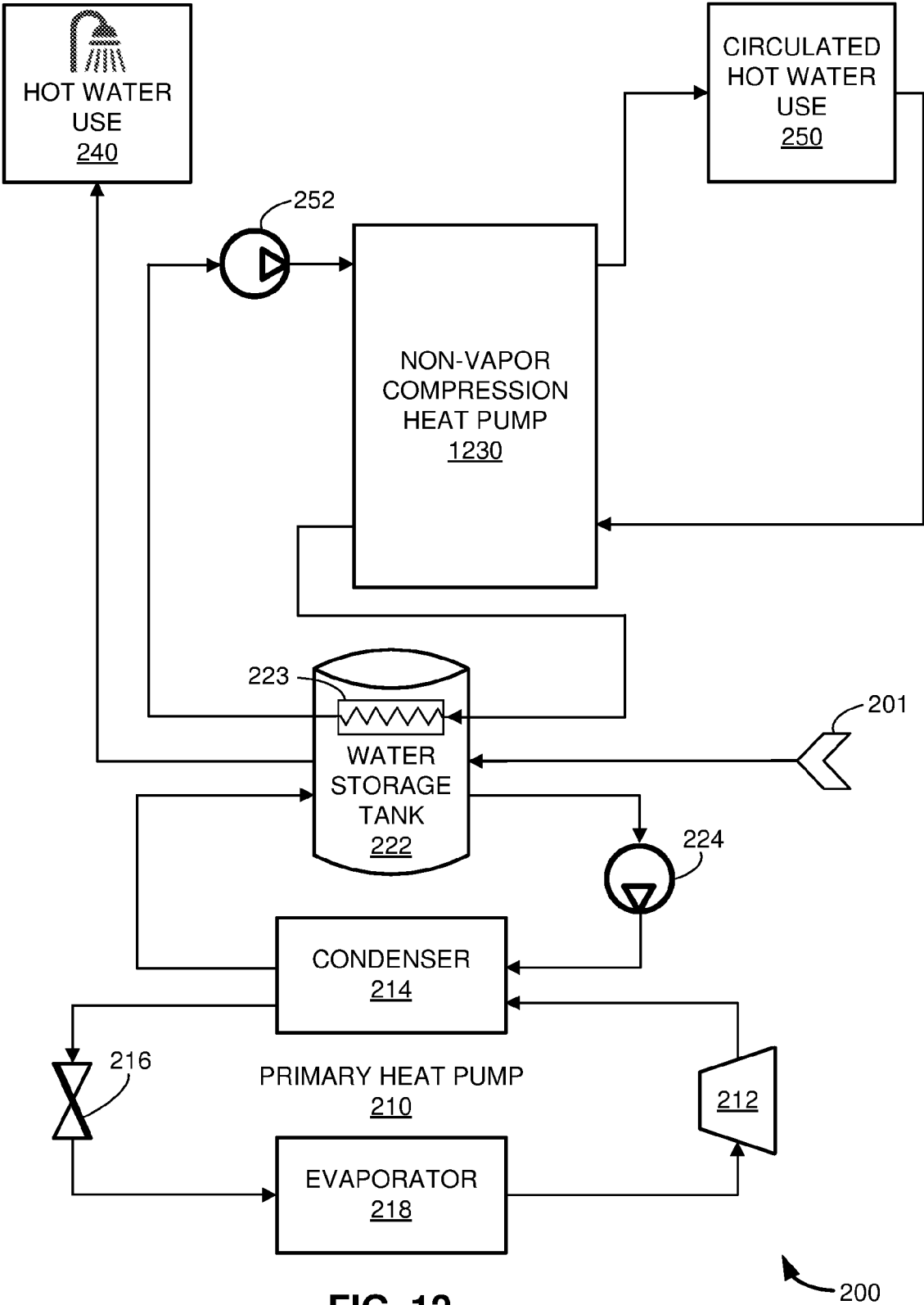


FIG. 11



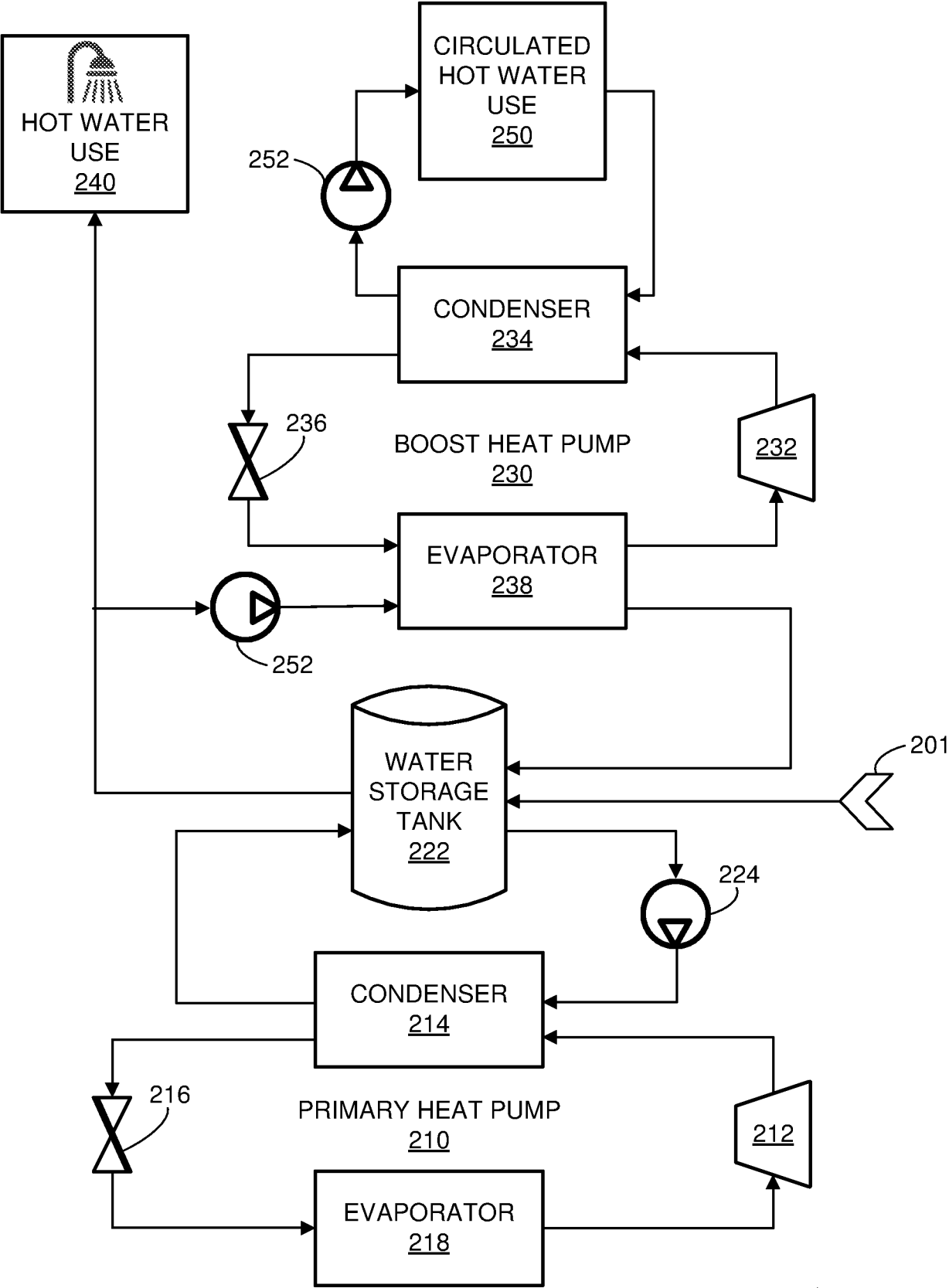


FIG. 13

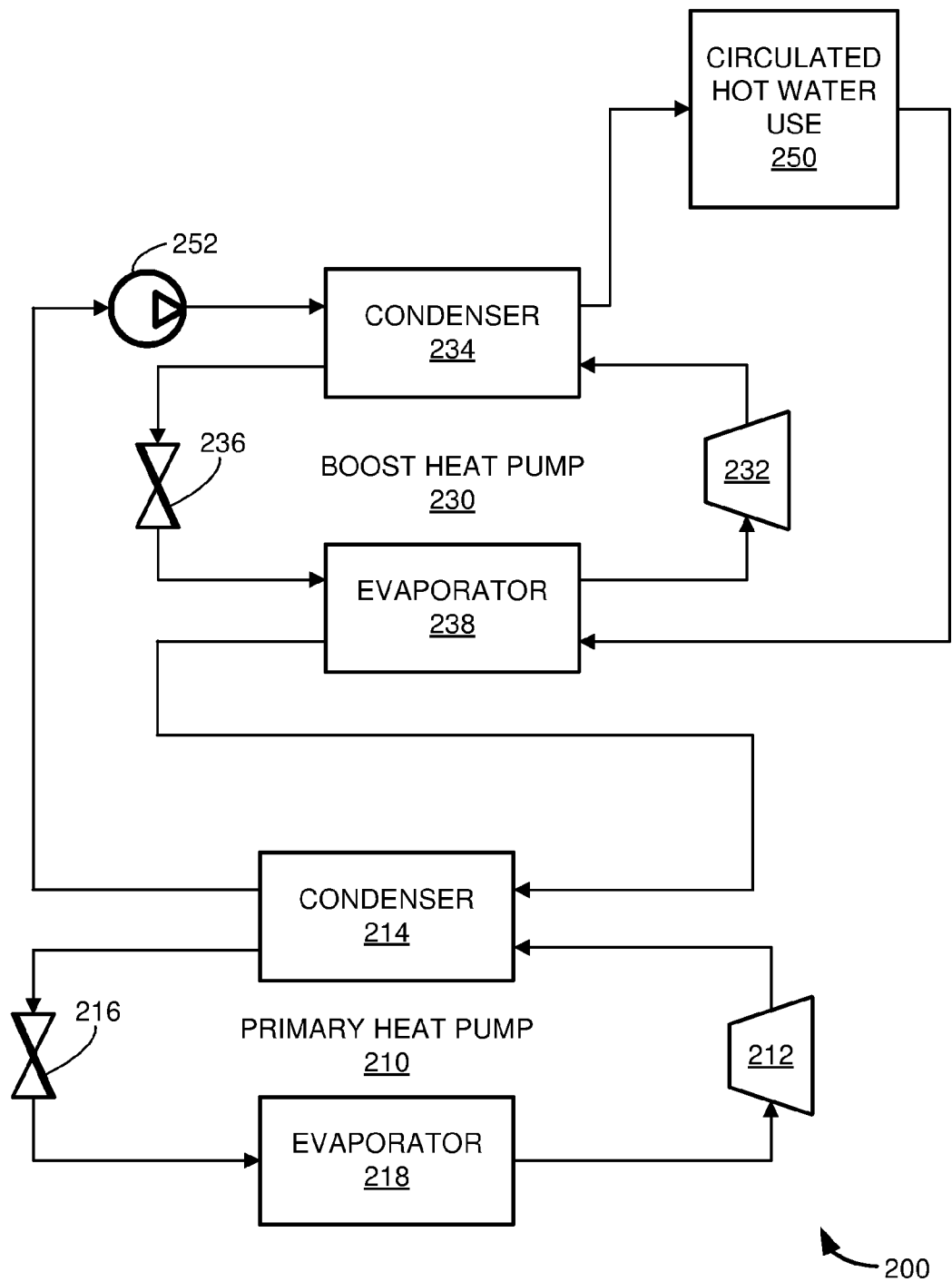


FIG. 14

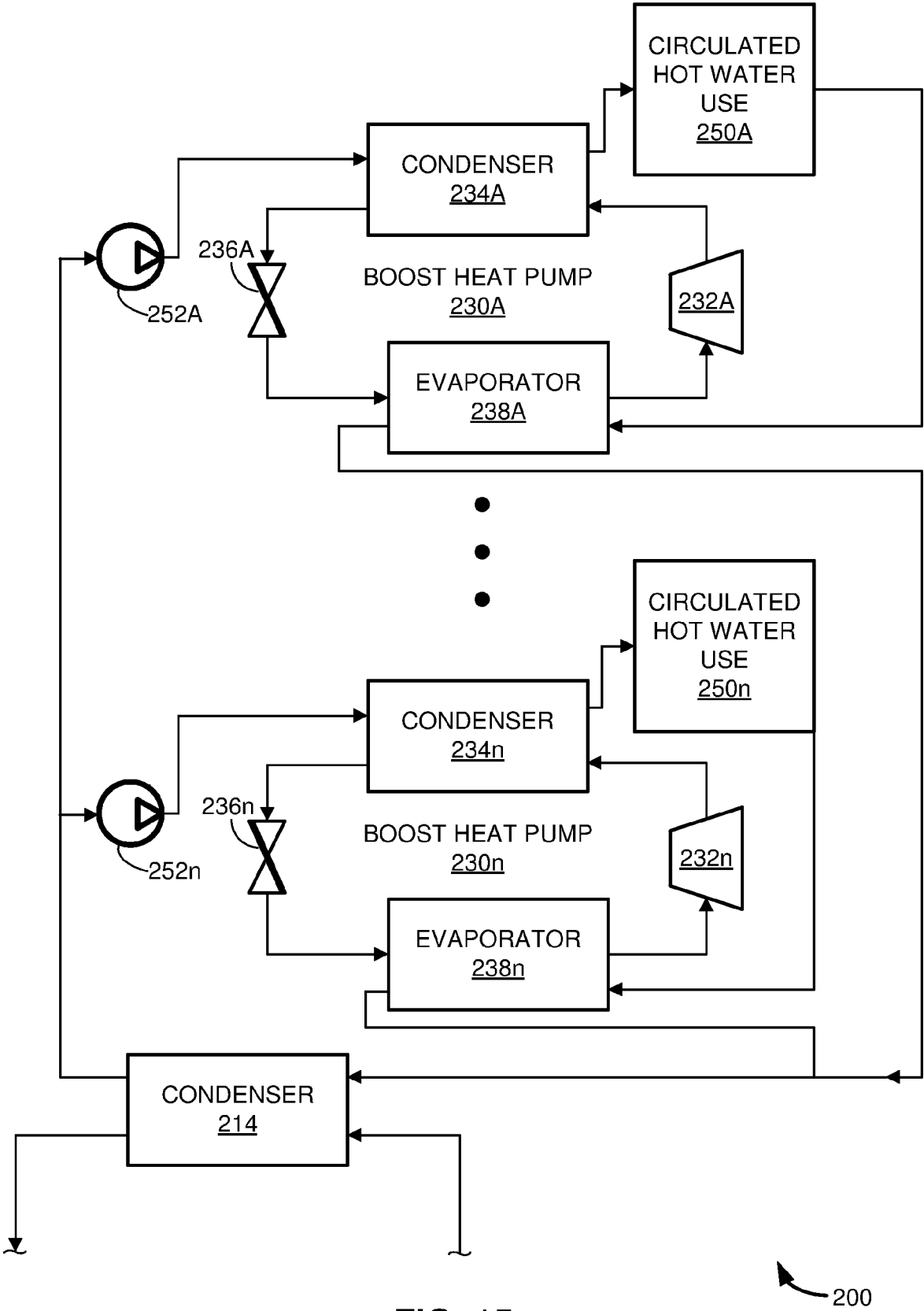
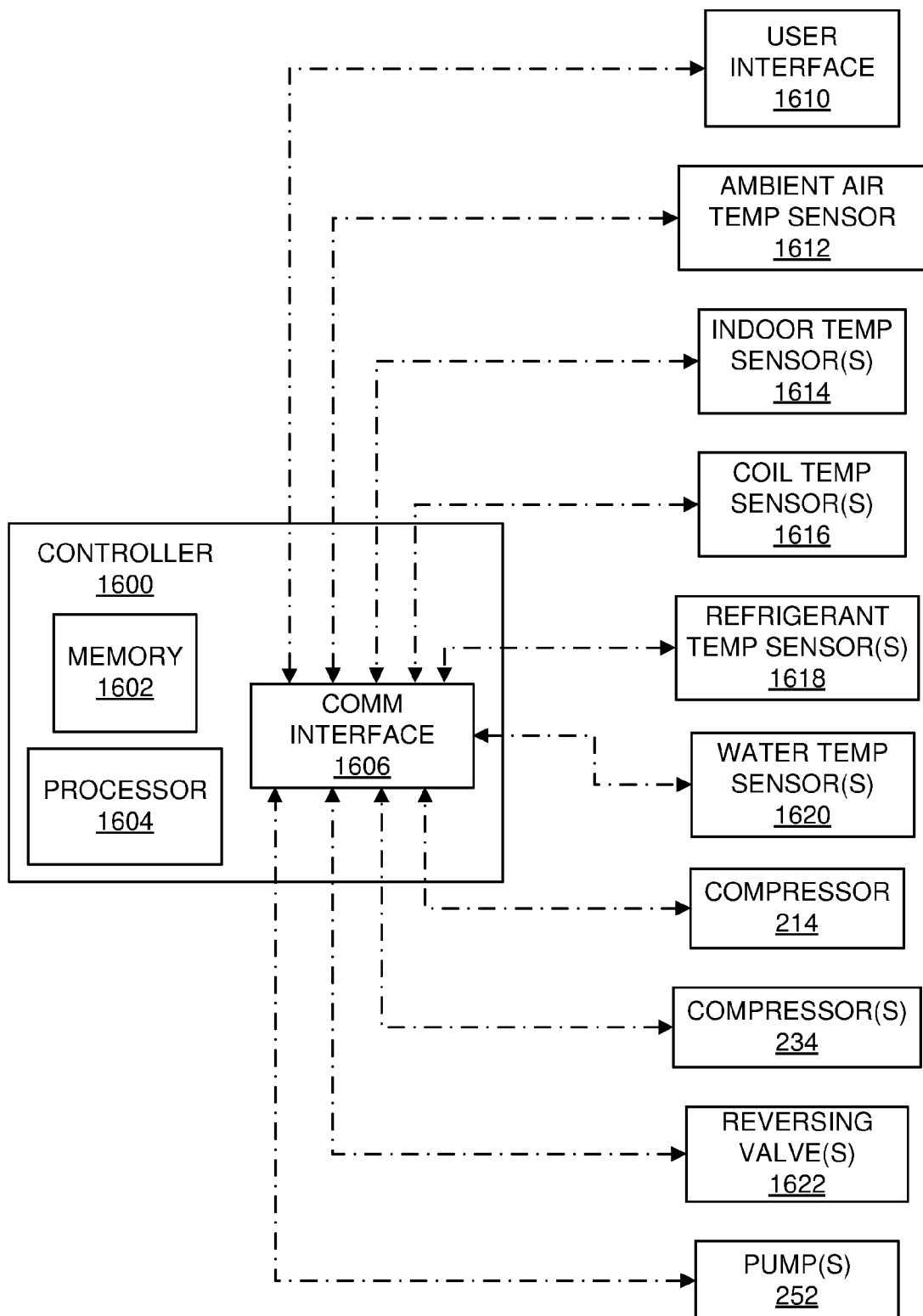


FIG. 15

**FIG. 16**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 23/12642

A. CLASSIFICATION OF SUBJECT MATTER

IPC - INV. F24H 4/04 (2023.01)

ADD. F24D 3/18, F24D 5/12, F24D 11/02 (2023.01)

CPC - INV. F24H 4/04

ADD. F24D 3/18, F24D 5/12, F24D 11/02, F24D 19/1054

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	~ CN 111288537 A (NANJING JIUDING PREC REFRIGERATION EQUIPMENT CO LTD) 16 June 2020 (16.06.2020), entire document, especially Fig 1; para [0020]-[0021], [0023]-[0024], [0026].	1-13
A		14-25
Y	~ KR 10-2014-0007676 A (NEWGREENTECH ENERGY CO., LTD.) 20 January 2014 (20.01.2014), entire document, especially Fig 1; para [0031]	1-13
A		14-25
Y	US 7,849,700 B2 (SEEFELDT) 14 December 2010 (14.12.2010), entire document, especially Fig 1, 3; col 5, ln 66-67; col 6, ln 50-59	5
Y	US 2006/0075758 A1 (RICE et al.) 13 April 2006 (13.04.2006), entire document, especially Fig 1; para [0009]-[0010], [0024]	12
Y	US 2022/0018580 A1 (LG ELECTRONICS INC.) 20 January 2022 (20.01.2022), entire document, especially Fig 1A; para [0015]-[0016], [0019]-[0020], [0025], [0071]	13
A	US 2021/0048203 A1 (MELINK SOLAR & GEO, INC.) 18 February 2021 (18.02.2021), entire document, especially Fig 1; para [0014], [0018]-[0019], [0021], [0030]-[0031]	14-25
A	US 9,994,238 B2 (ALSTOM TRANSPORT TECHNOLOGIES) 12 June 2018 (12.06.2018), entire document, especially Fig 1; col 4, ln 31-40; col 5, ln 57-64; col 6, ln 24-29; col 7, ln 51-59	14-25
A	US 2019/0360703 A1 (FRANCK) 28 November 2019 (28.11.2019), entire document	1-25

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

17 April 2023

Date of mailing of the international search report

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