US 20250257917A1

(19) United States
(12) Patent Application Publication
Hjortland et al.
(10) Pub. No.: US 2025/0257917 A1
(43) Pub. Date: Aug. 14, 2025

(54) **ENERGY EFFICIENT HEAT PUMP WITH EJECTOR SYSTEM**

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(21) Appl. No.: **19/053,252**

(22) Filed: **Feb. 13, 2025**

Related U.S. Application Data

(60) Provisional application No. 63/553,016, filed on Feb. 13, 2024.

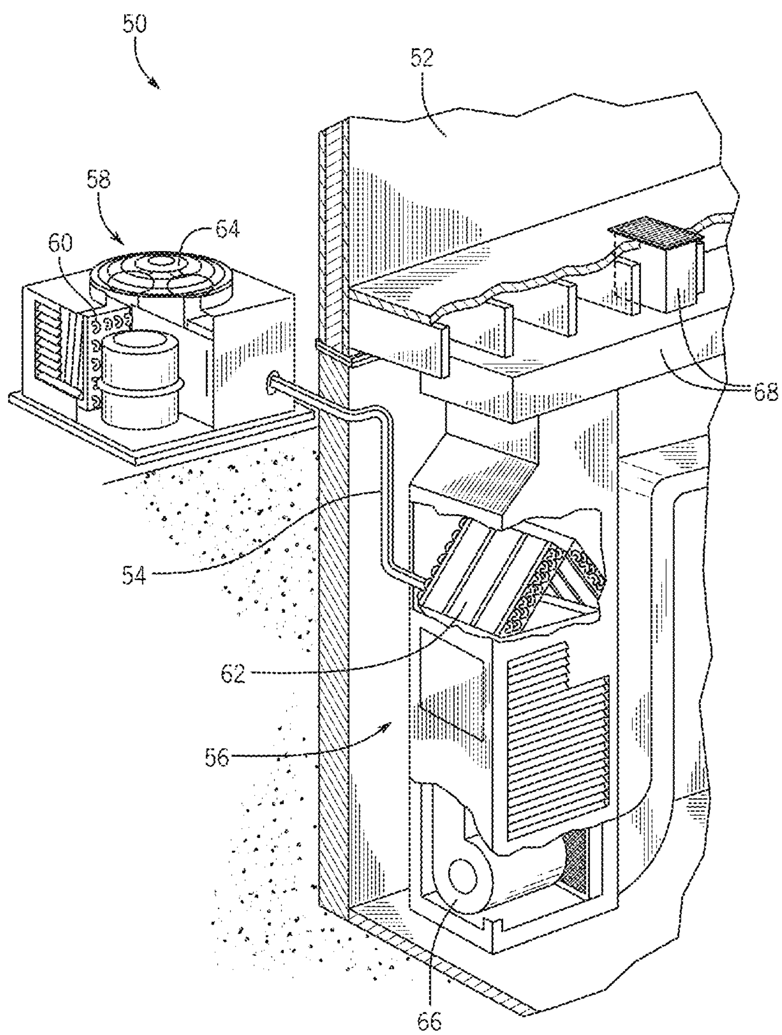
Publication Classification

(51) **Int. Cl.**
F25B 49/02 (2006.01)
F24F 11/84 (2018.01)
F25B 30/00 (2006.01)
F25B 41/31 (2021.01)

(52) **U.S. Cl.**
CPC ***F25B 49/02*** (2013.01); ***F24F 11/84*** (2018.01); ***F25B 30/00*** (2013.01); ***F25B 41/31*** (2021.01); *F25B 2313/027* (2013.01); *F25B 2700/19* (2013.01); *F25B 2700/21* (2013.01)

(57) **ABSTRACT**

An energy efficient heat pump for a heating, ventilation, and air conditioning (HVAC) system includes a working fluid circuit configured to circulate a working fluid. The working fluid circuit includes a compressor, a first heat exchanger, a second heat exchanger, and a reversing valve configured to adjust a flow direction of the working fluid through the working fluid circuit. The energy efficient heat pump also includes an ejector system having an ejector configured to receive a first flow of the working fluid from the working fluid circuit as a suction fluid, receive a second flow of the working fluid from the working fluid circuit as a motive fluid, and direct a combined flow of the first flow of the working fluid and the second flow of the working fluid toward the compressor.



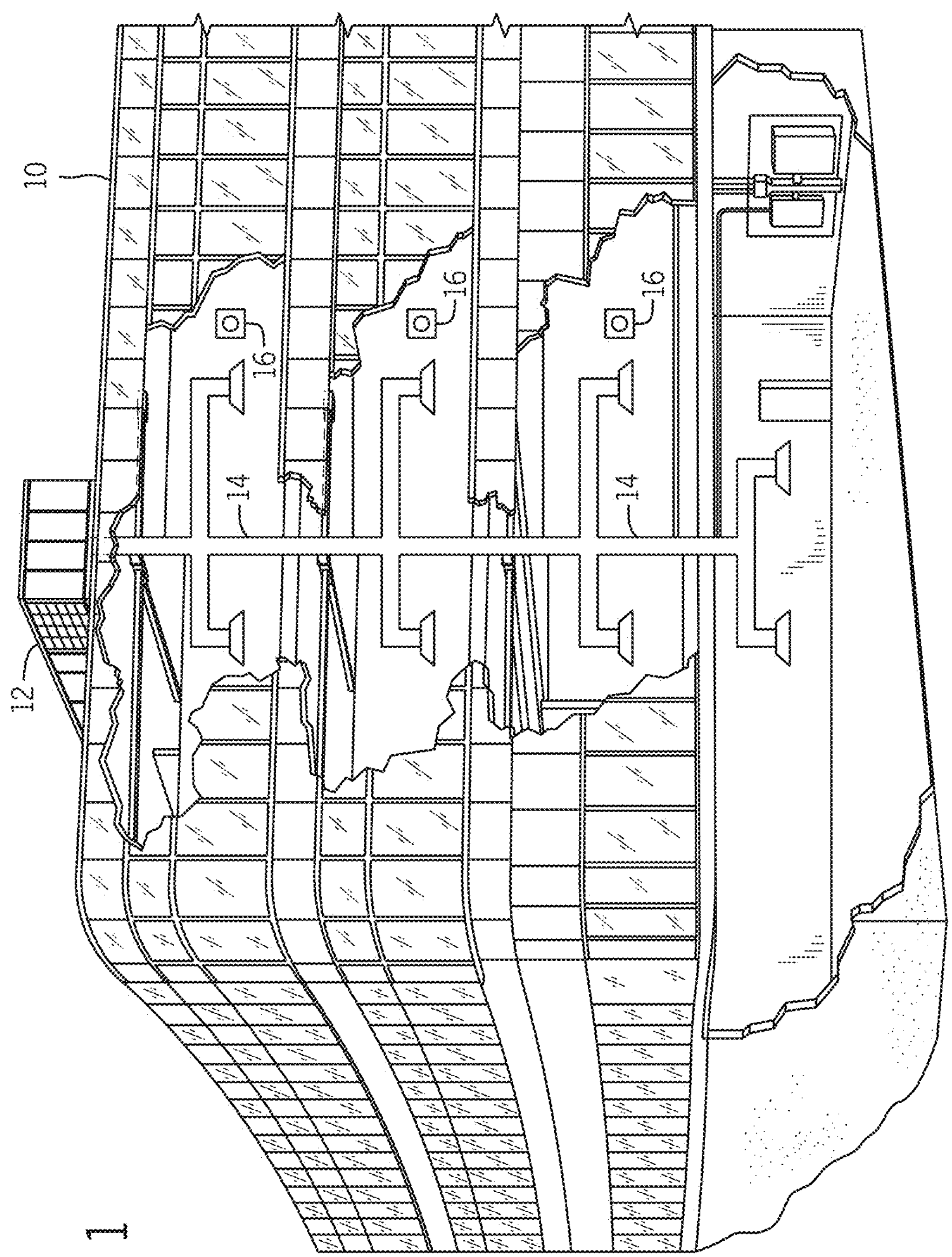


FIG. 1

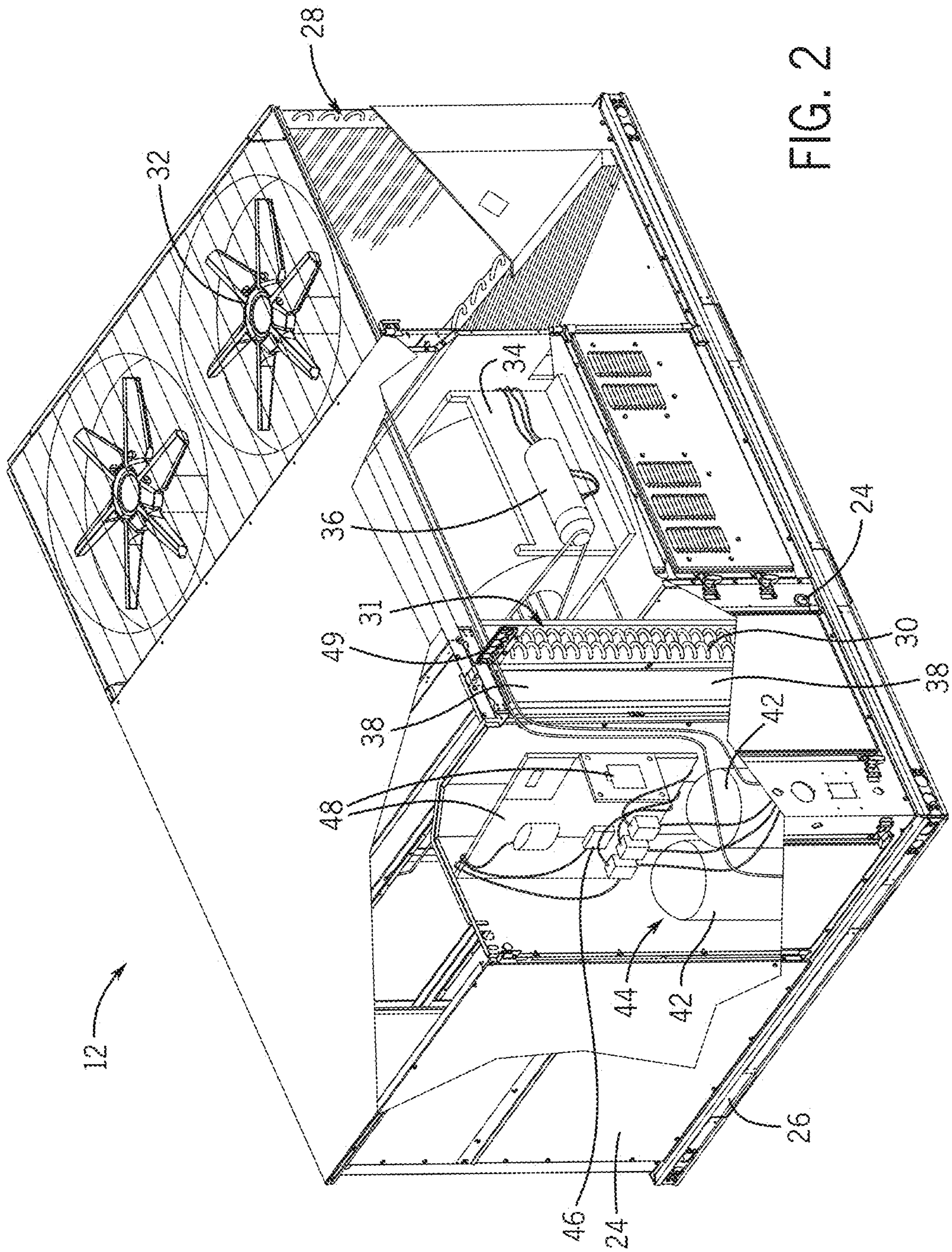


FIG. 2

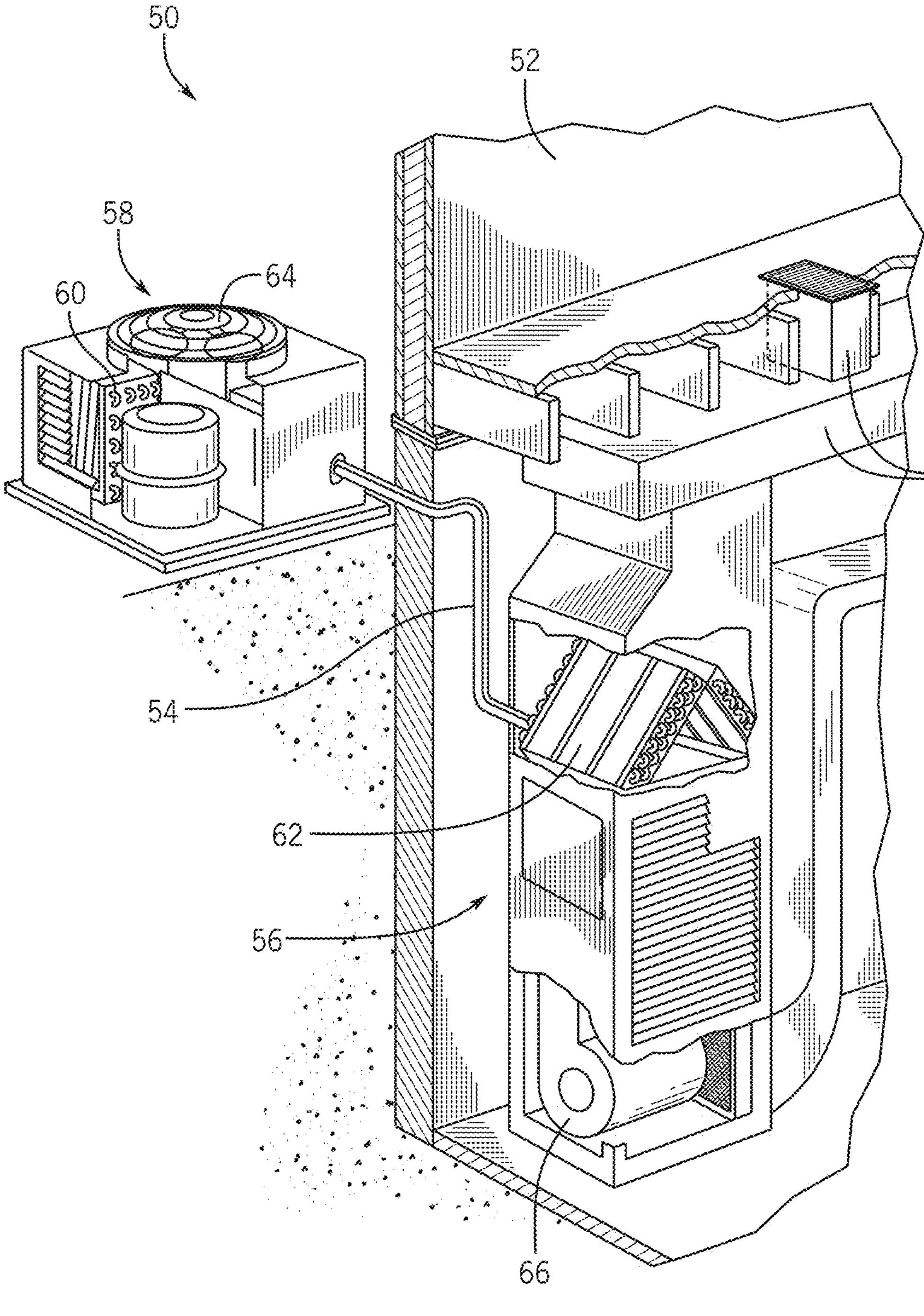
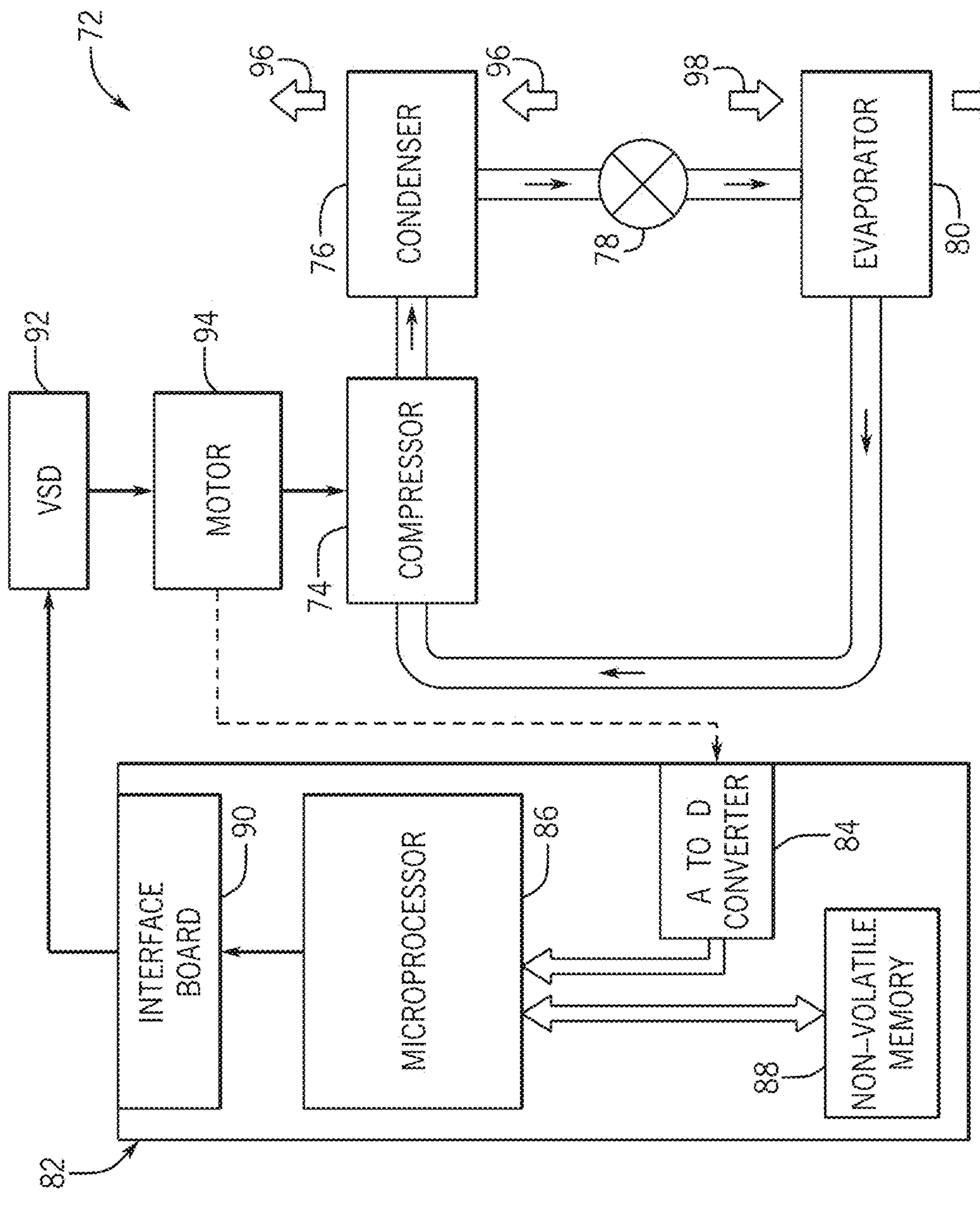


FIG. 3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MICROPROCESSOR
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A TO D CONVERTER
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NON-VOLATILE MEMORY
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FIG. 4

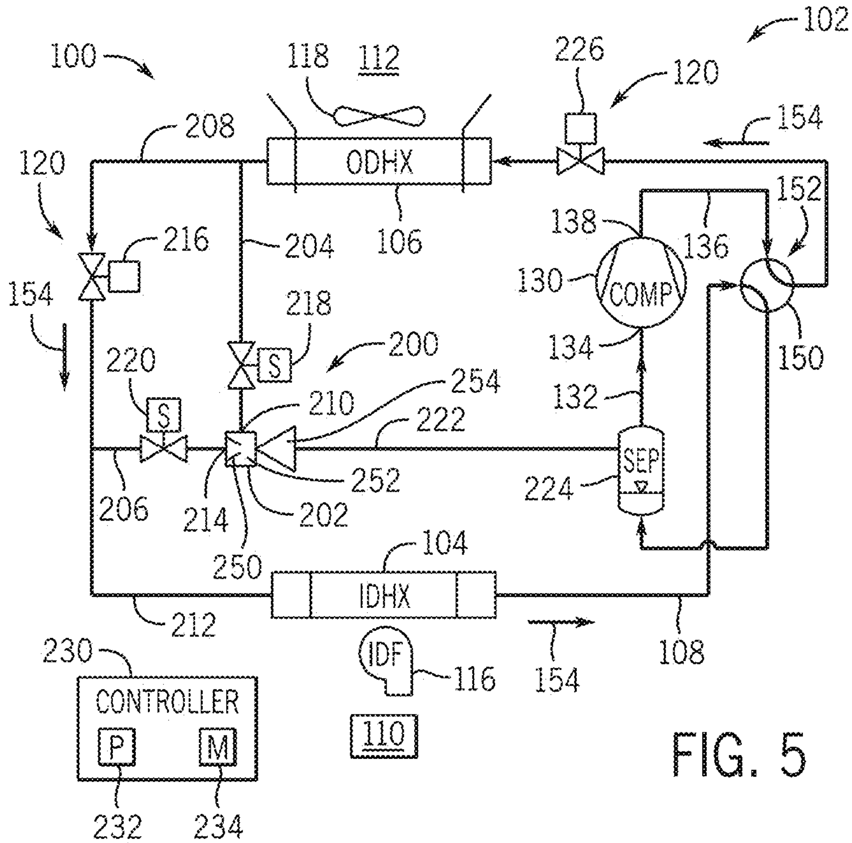
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FIG. 5

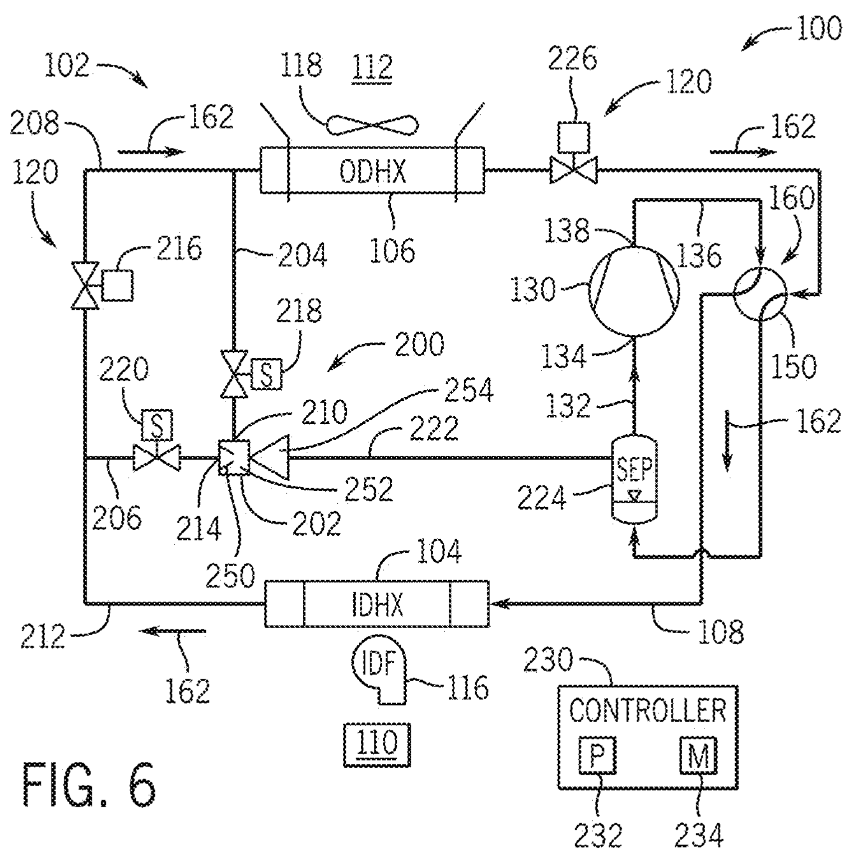
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FIG. 6

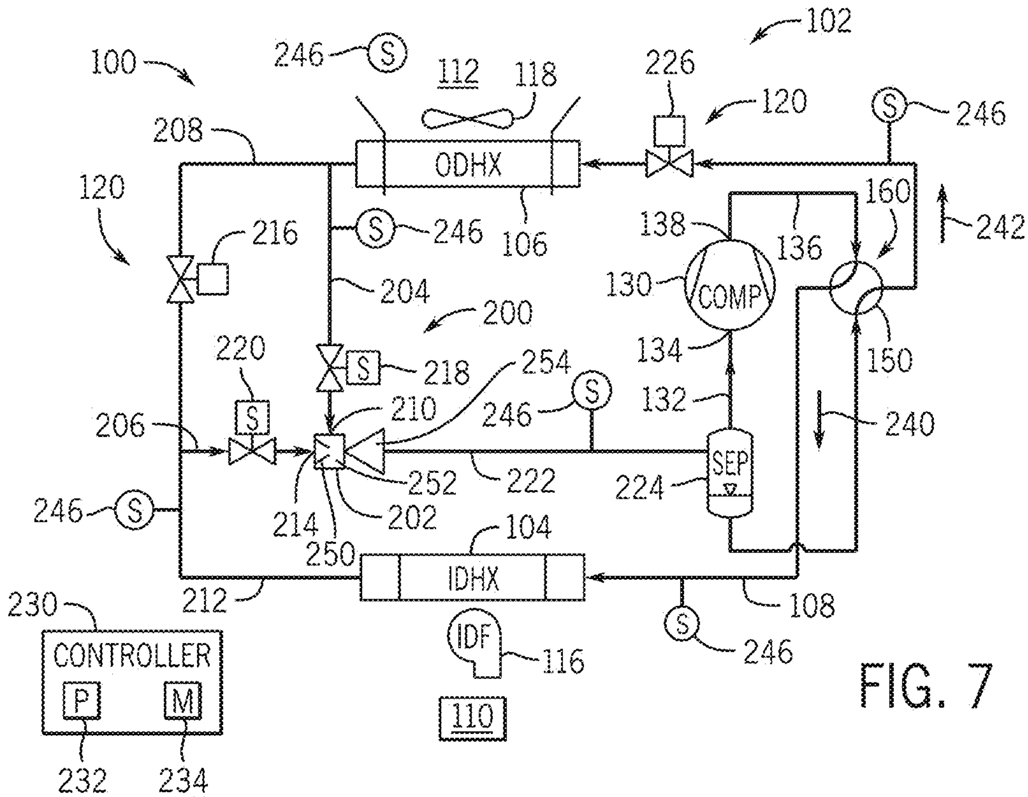
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FIG. 7

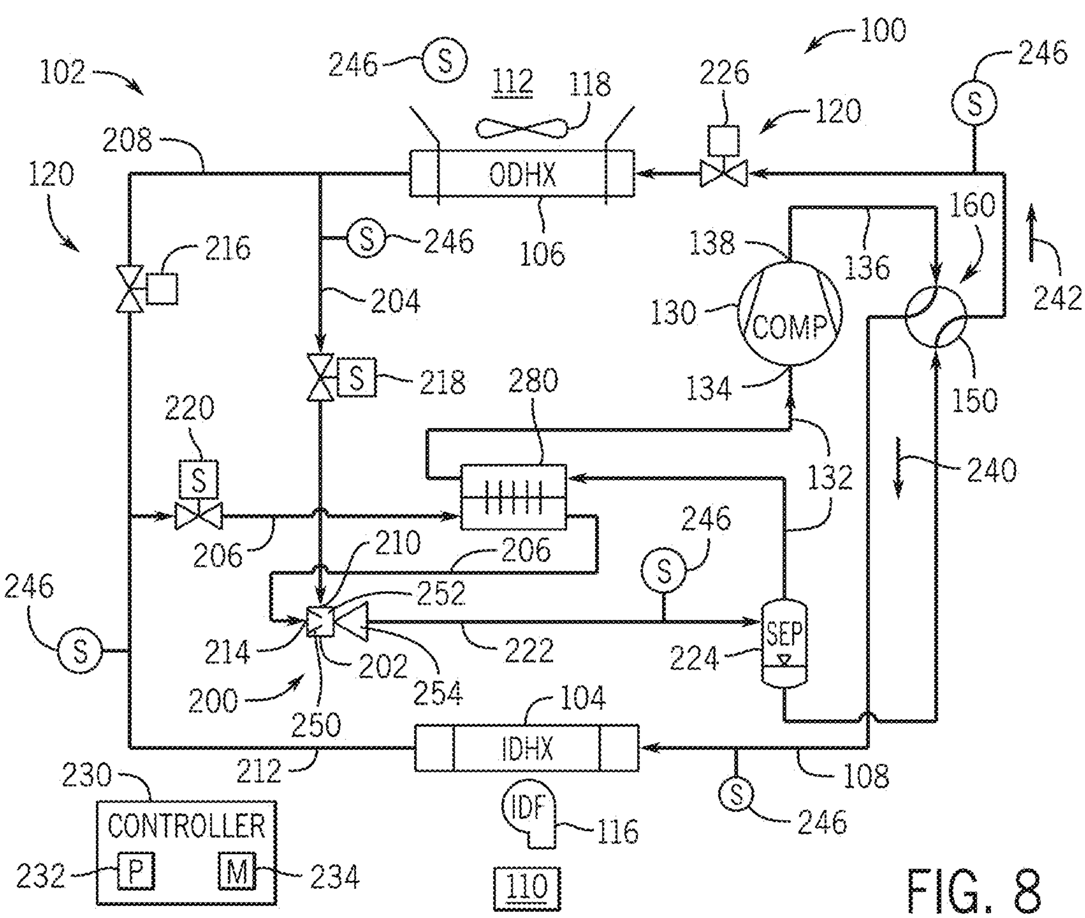
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FIG. 8

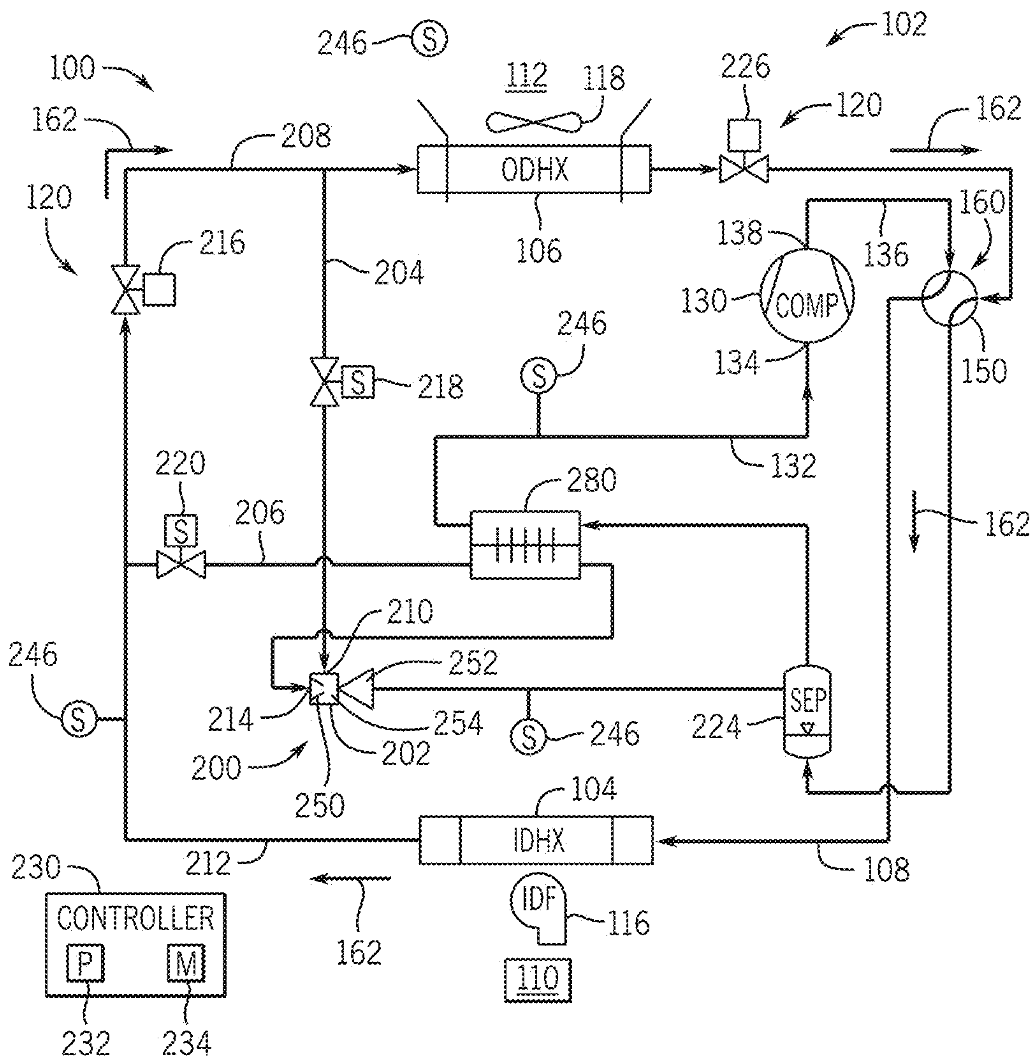

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FIG. 9

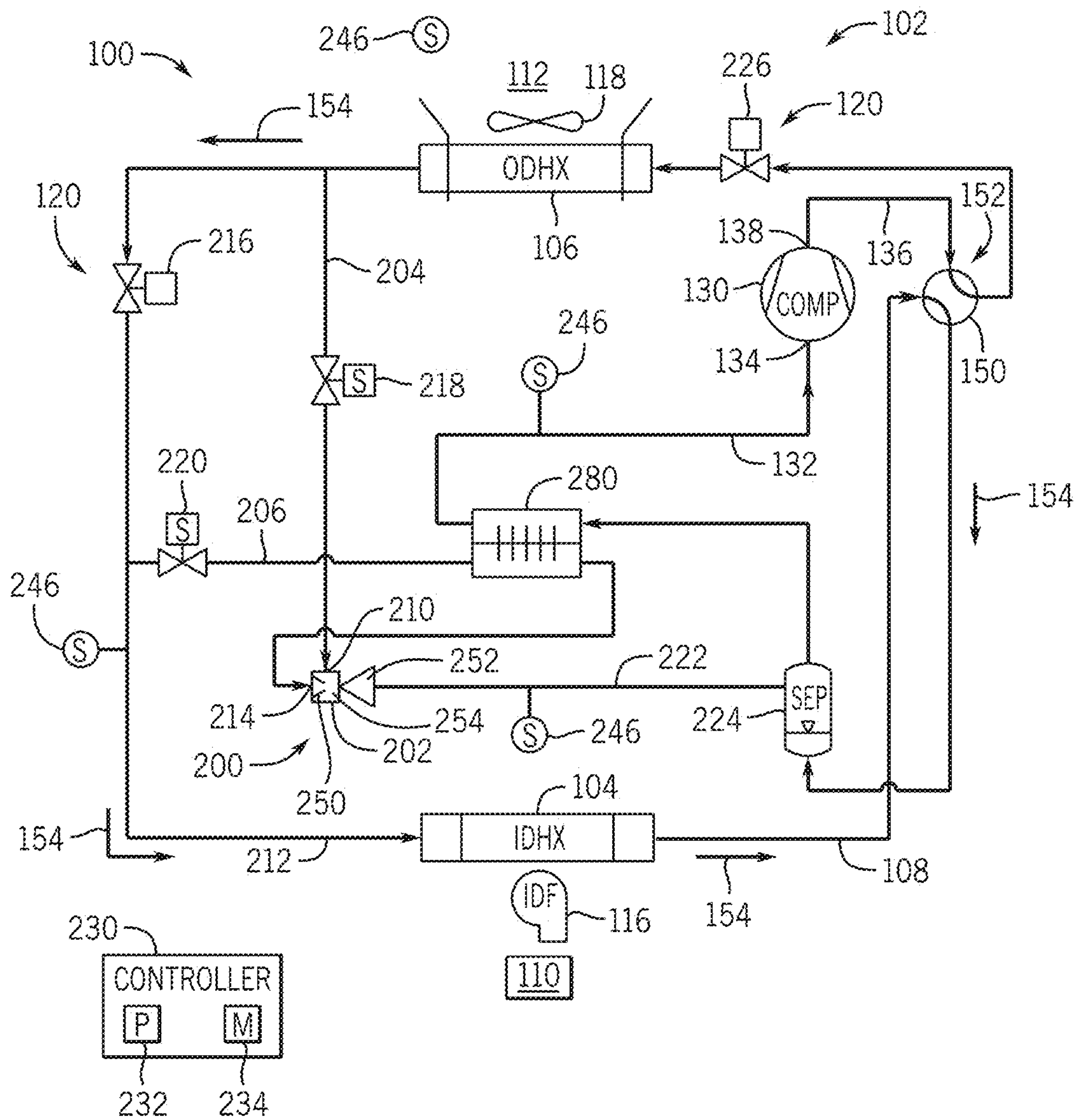

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FIG. 10

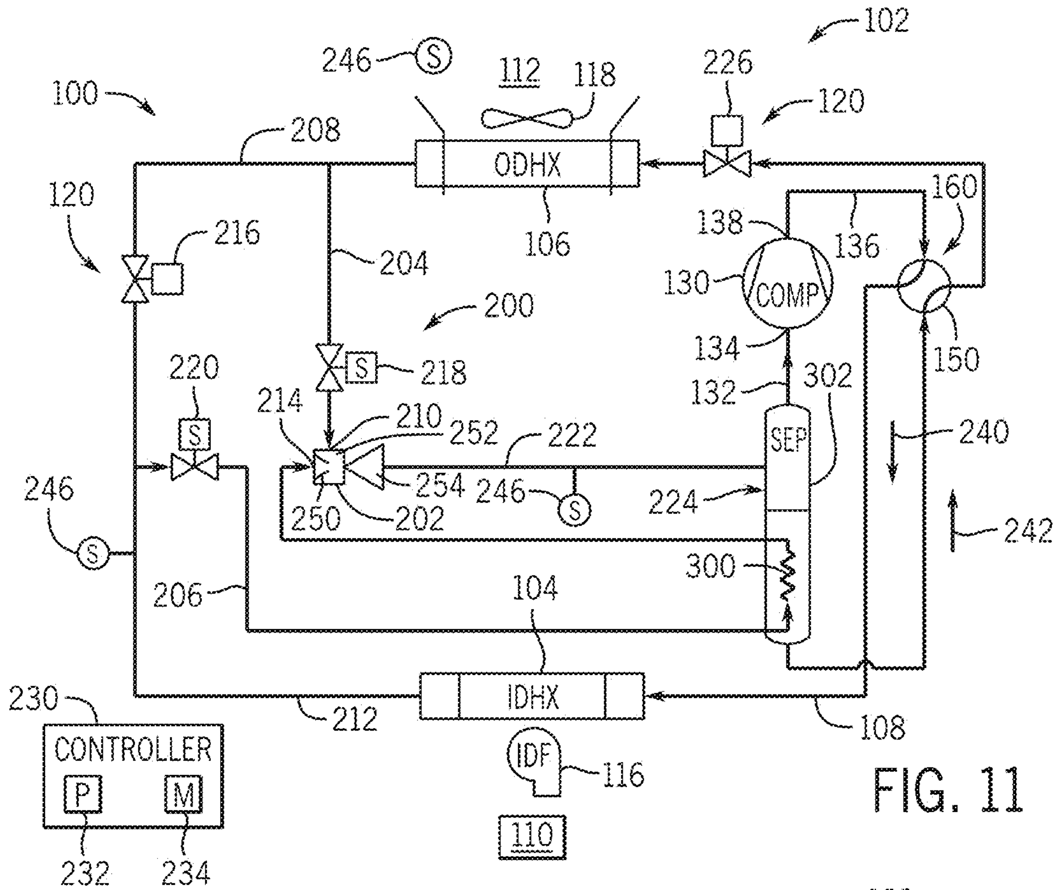
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FIG. 11

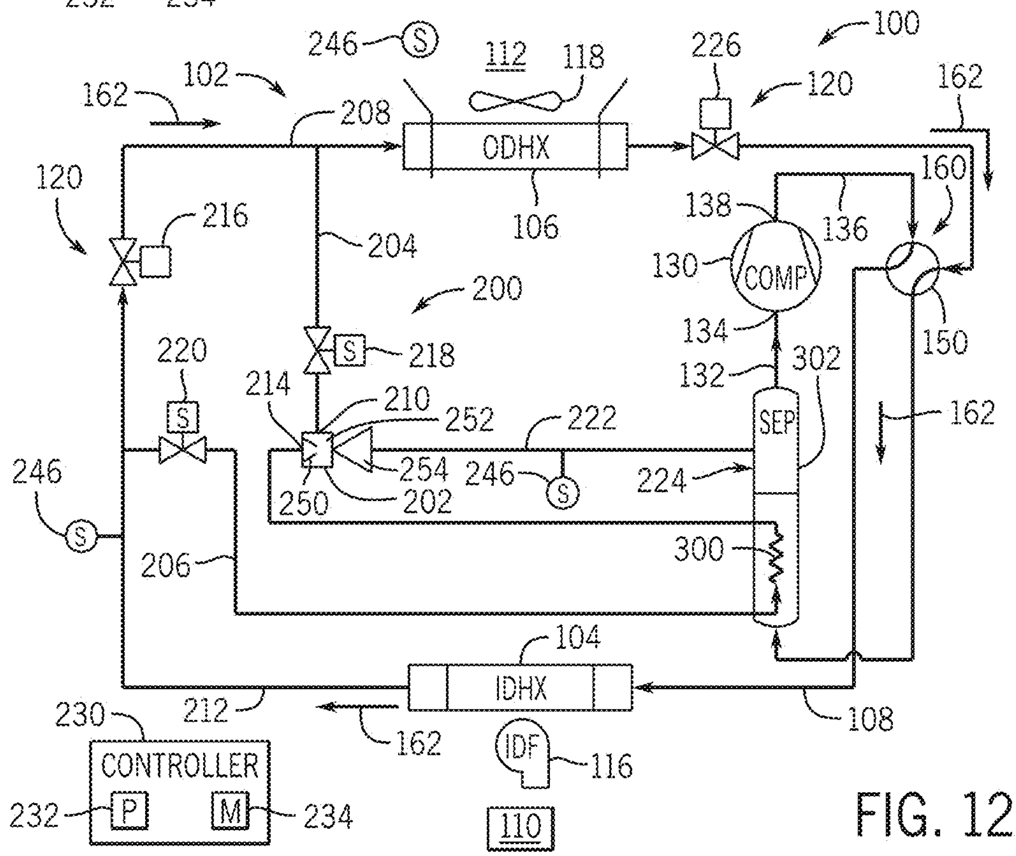
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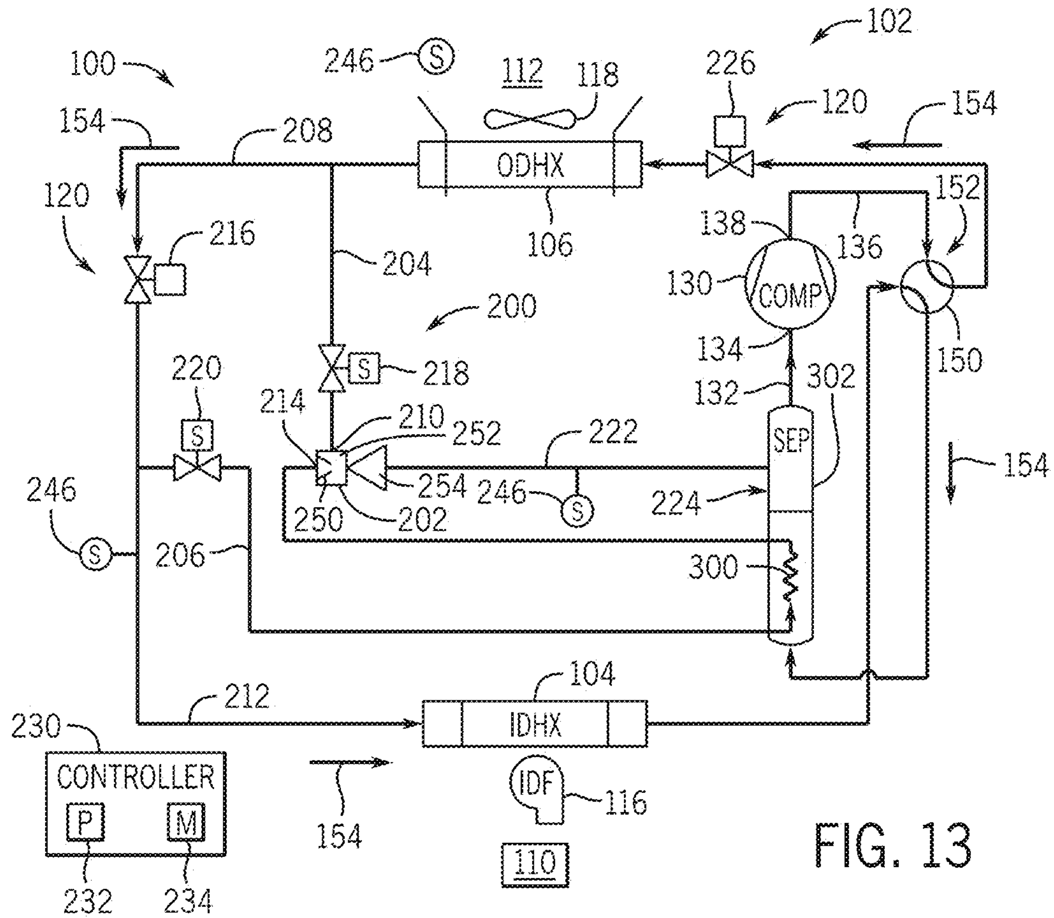
FIG. 12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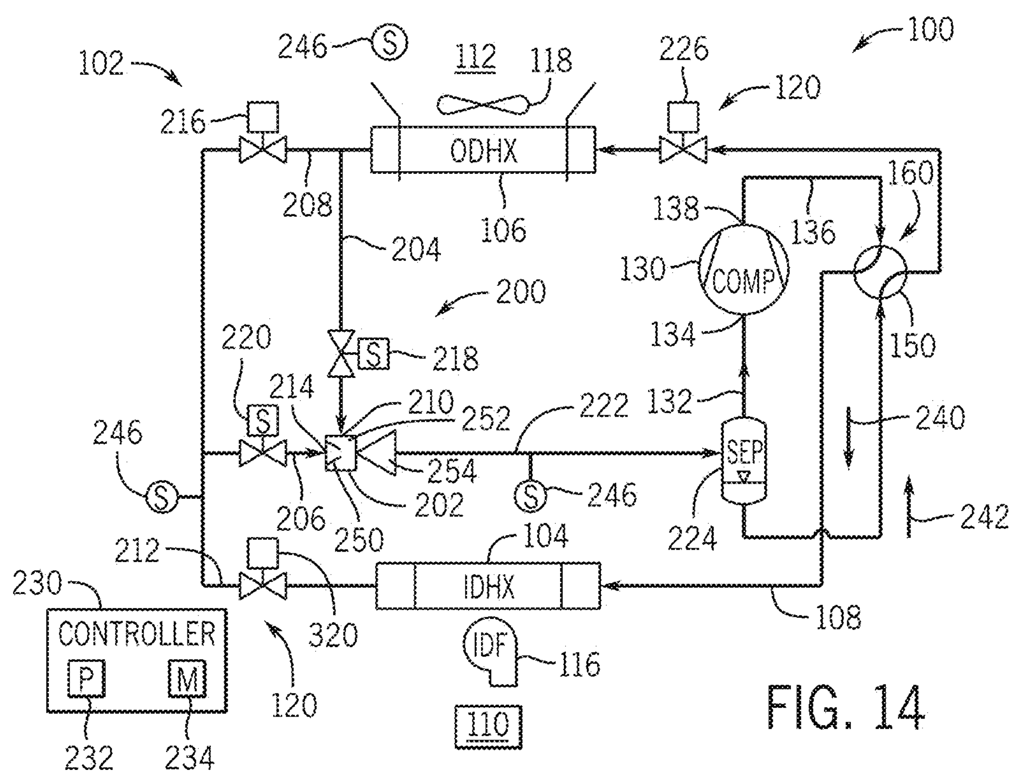
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FIG. 14

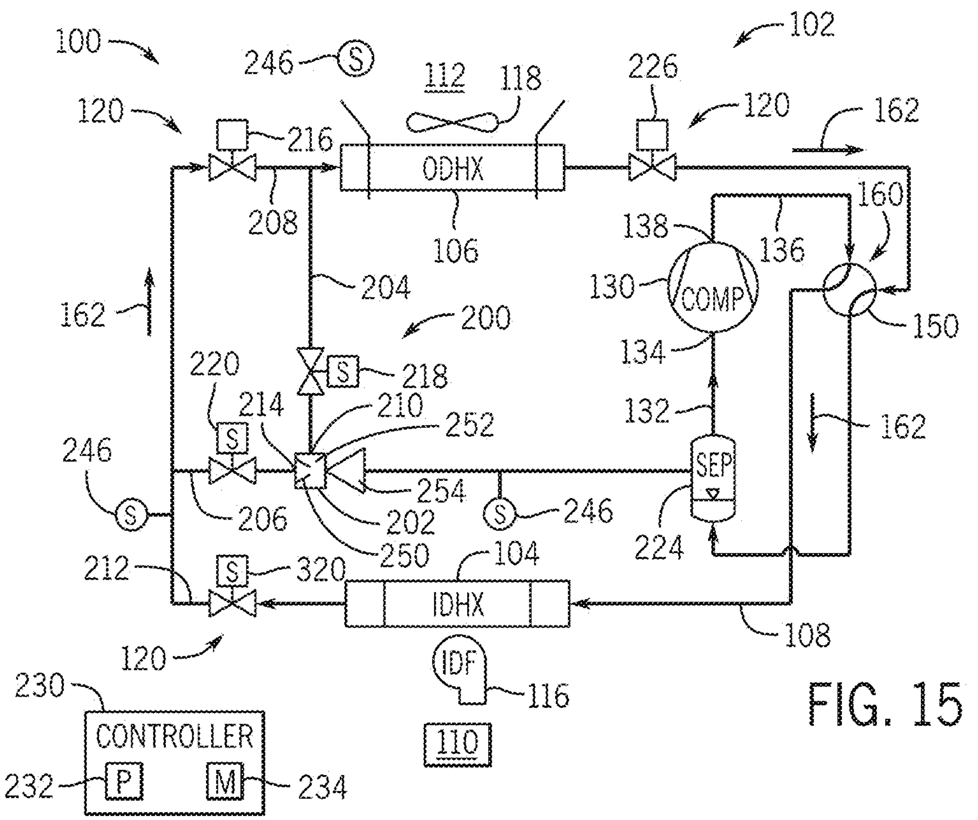
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FIG. 15

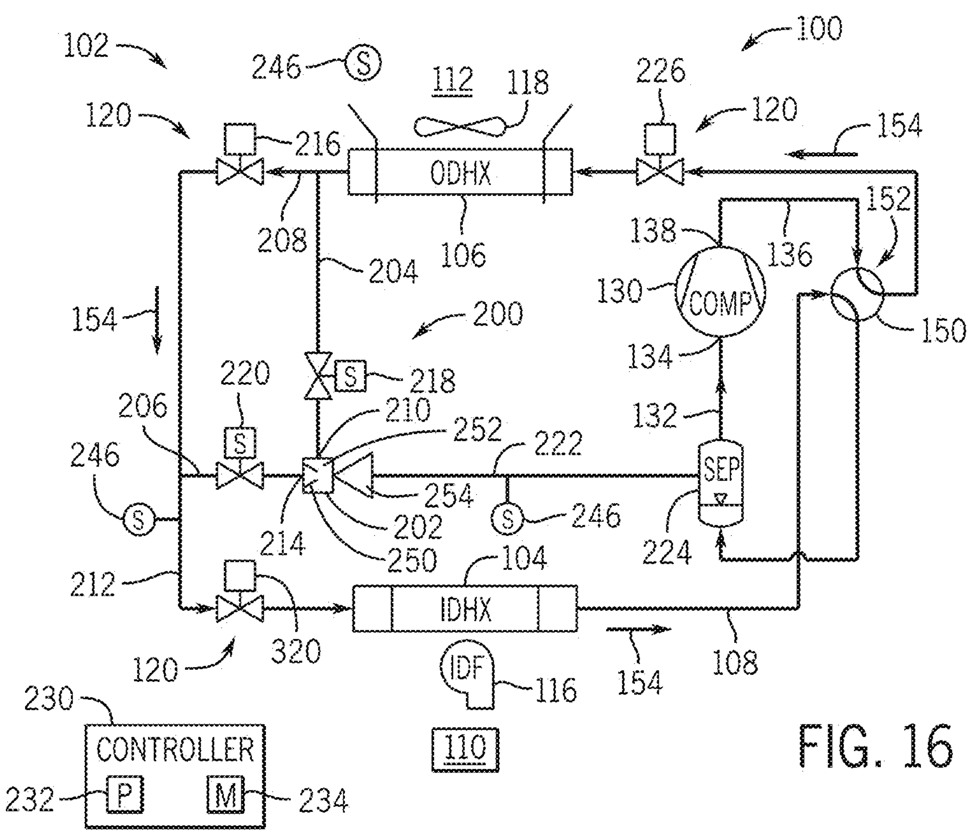
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FIG. 16

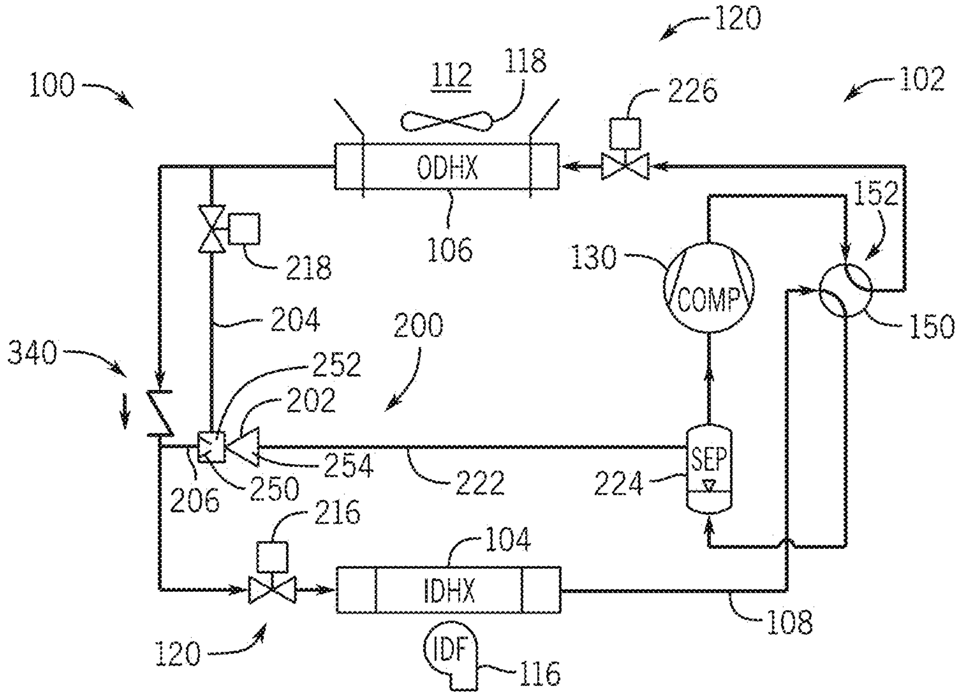
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FIG. 17

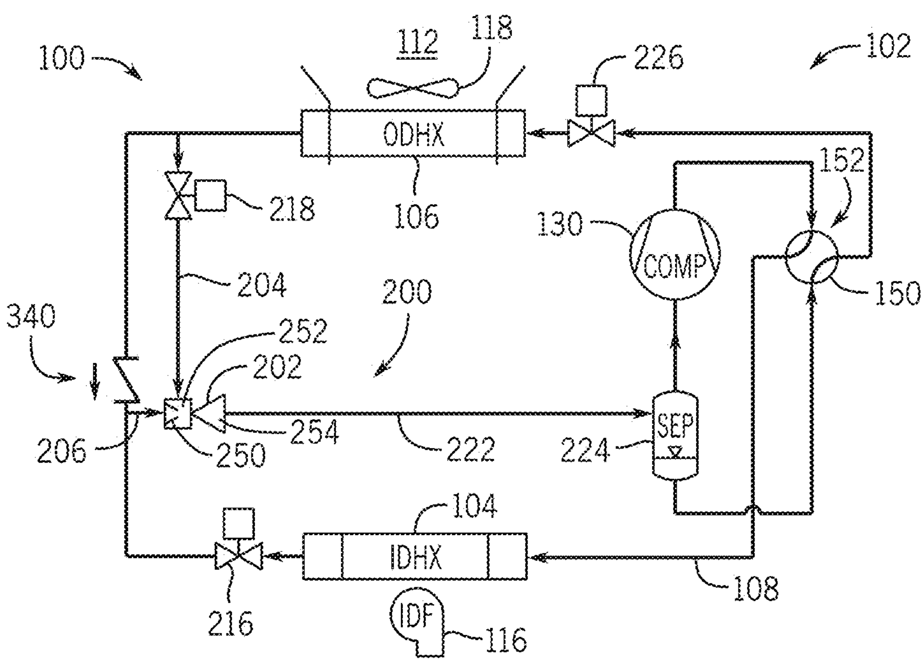
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FIG. 18

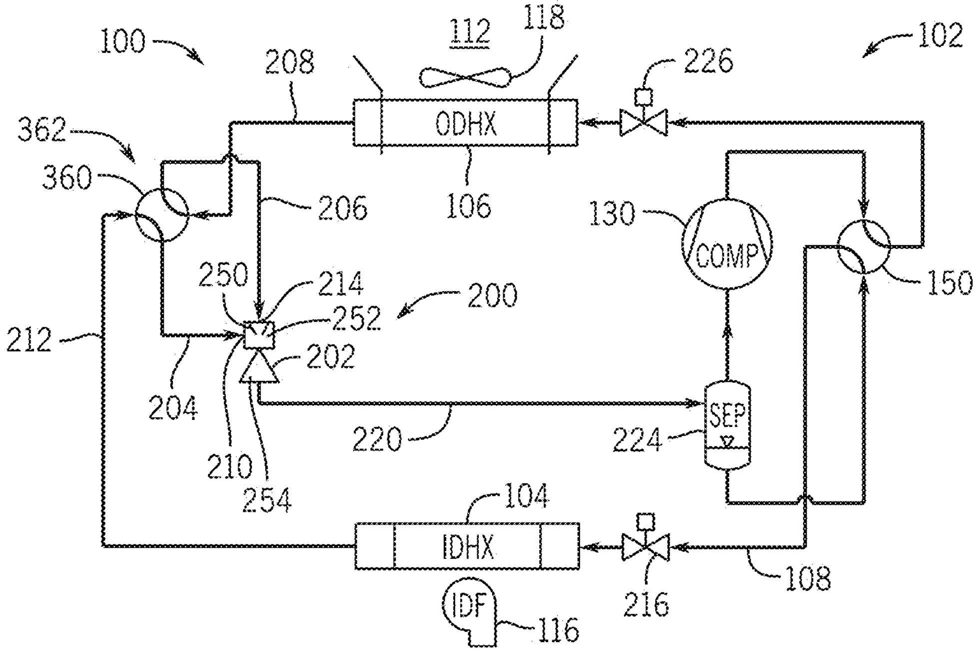
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FIG. 19

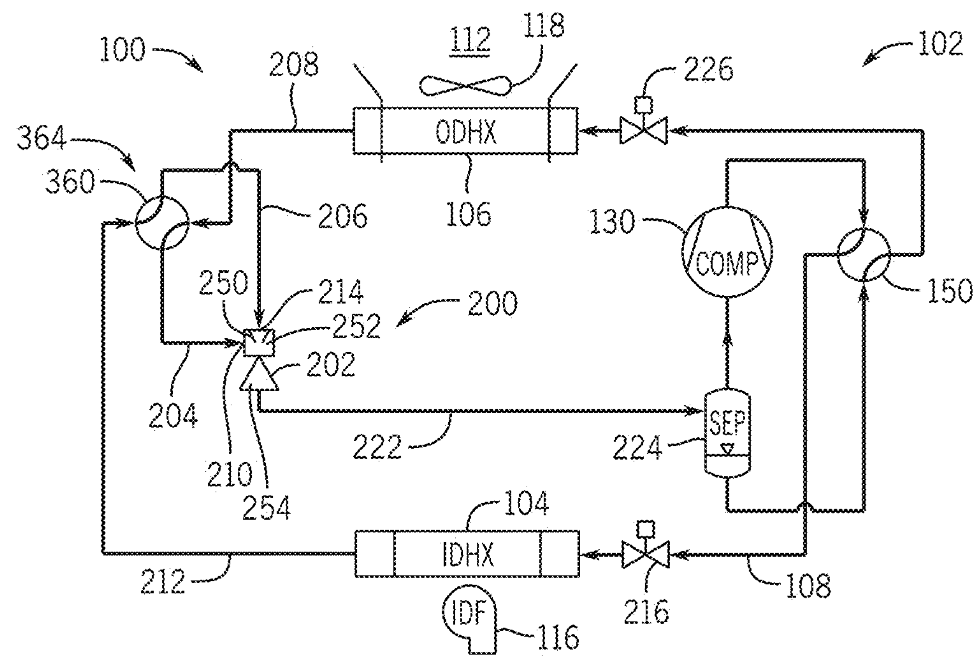
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FIG. 20

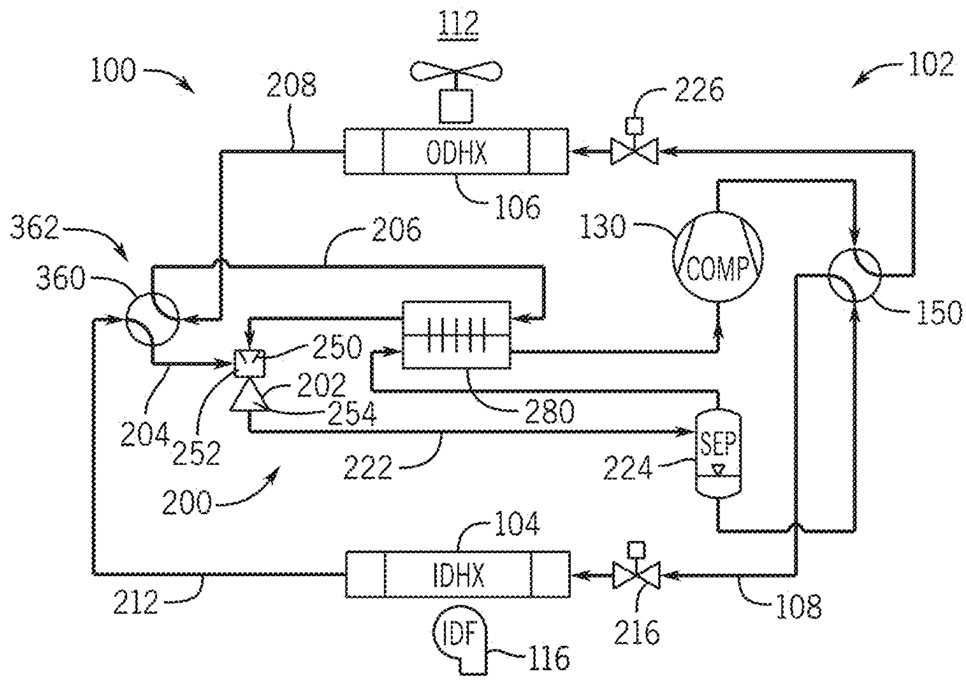
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FIG. 21

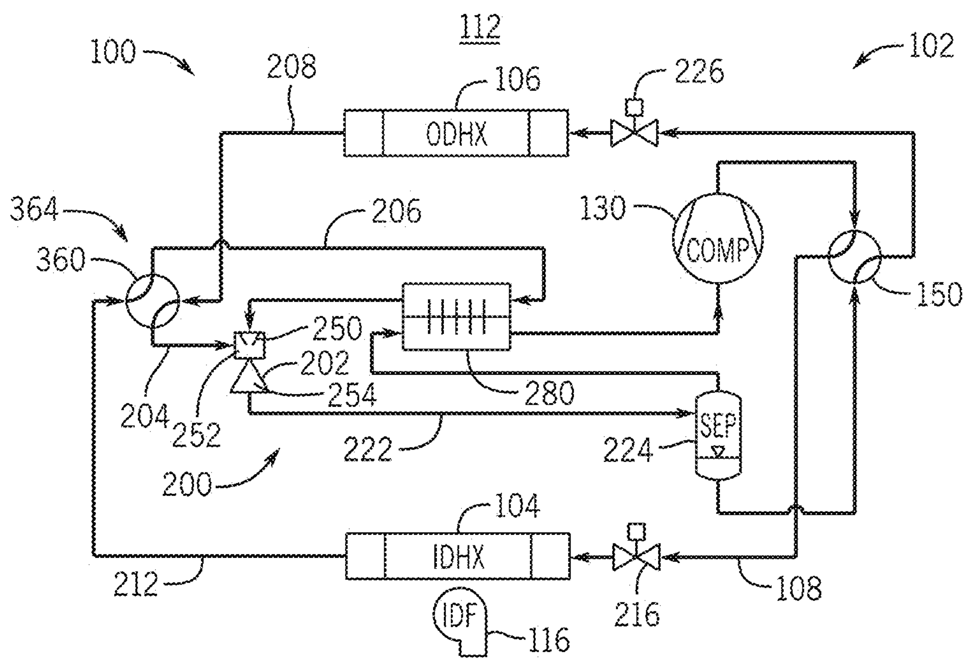
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FIG. 22

ENERGY EFFICIENT HEAT PUMP WITH EJECTOR SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from and the benefit of U.S. Provisional Patent Application No. 63/553,016, entitled "SYSTEMS AND METHODS FOR HEAT PUMP WITH EJECTOR SYSTEM," filed Feb. 13, 2024, which is hereby incorporated by reference in its entirety for all purposes.

BACKGROUND

[0002] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0003] Embodiments of the present disclosure are directed to heating, ventilation, and/or air conditioning (HVAC) systems configured to operate with reduced energy consumption and reduced greenhouse gas emissions. More particularly, embodiments of the present disclosure are directed to energy efficient heat pumps, including reverse cycle heat pumps and air-source heat pumps, configured to operate in a heating mode to heat a supply air flow in cold climate conditions with improved efficiency, reduced energy consumption, and reduced generation of greenhouse gas emissions.

[0004] A heating, ventilation, and/or air conditioning (HVAC) system may be used to thermally regulate an environment, such as a space within a building, home, or other structure. The HVAC system generally includes a vapor compression system having heat exchangers, such as a condenser and an evaporator, which transfer thermal energy between the HVAC system and the environment. Typically, a compressor is fluidly coupled to a refrigerant circuit of the vapor compression system and is configured to circulate a refrigerant between the condenser and the evaporator. In this way, the compressor facilitates heat exchange between the refrigerant, the condenser, the evaporator, and other fluids. In some cases, the HVAC system may be a heat pump configured to enable reversal of refrigerant flow through the refrigerant circuit. As such, the heat pump enables the condenser to operate as an evaporator (e.g., heat absorber) and the evaporator to operate as a condenser (e.g., heat rejector). Accordingly, the HVAC system may operate in multiple operating modes (e.g., cooling mode, heating mode) to provide both heating and cooling to the building with one refrigerant circuit. Unfortunately, conventional heat pump systems may operate with reduced efficiency in certain conditions.

SUMMARY

[0005] In one embodiment, an energy efficient heat pump for a heating, ventilation, and air conditioning (HVAC) system includes a working fluid circuit configured to circulate a working fluid. The working fluid circuit includes a compressor, a first heat exchanger, a second heat exchanger, and a reversing valve configured to adjust a flow direction of the working fluid through the working fluid circuit. The energy efficient heat pump also includes an ejector system having an ejector configured to receive a first flow of the working fluid from the working fluid circuit as a suction fluid, receive a second flow of the working fluid from the working fluid circuit as a motive fluid, and direct a combined flow of the first flow of the working fluid and the second flow of the working fluid toward the compressor.

[0006] In another embodiment, an energy efficient heat pump includes a working fluid circuit configured to circulate a working fluid therethrough. The working fluid circuit includes a first heat exchanger configured to exchange heat between the working fluid and a supply air flow, a second heat exchanger configured to exchange heat between the working fluid and an ambient air flow, and a reversing valve configured to adjust a flow direction of the working fluid along the working fluid circuit. The energy efficient heat pump also includes an ejector system having an ejector, a first conduit configured to direct the working fluid from the working fluid circuit to the ejector, a second conduit configured to direct the working fluid from the working fluid circuit to the ejector, and an outlet conduit configured to direct the working fluid from the ejector toward a compressor of the working fluid circuit. The energy efficient heat pump further includes a plurality of valves configured to control flow of the working fluid along the working fluid circuit and through the ejector system and a controller communicatively coupled to the plurality of valves and configured to adjust respective positions of the plurality of valves based on an operating mode of the energy efficient heat pump.

[0007] In a further embodiment, an energy efficient heat pump includes a first heat exchanger disposed along a working fluid circuit and configured to transfer heat from a working fluid to a supply air flow in a heating mode of the energy efficient heat pump and in an alternative heating mode of the energy efficient heat pump, a second heat exchanger disposed along the working fluid circuit and configured to transfer heat from an ambient air flow to the working fluid in the heating mode and in the alternative heating mode, and a gas-liquid separator disposed along the working fluid circuit. The energy efficient heat pump also includes an ejector system having an ejector with a nozzle inlet, a chamber inlet, and an outlet, a first conduit with a first valve, where the first conduit is configured to direct a first flow of the working fluid from the working fluid circuit to the chamber inlet of the ejector, a second conduit with a second valve, where the second conduit is configured to direct a second flow of the working fluid from the working fluid circuit to the nozzle inlet of the ejector, and an outlet conduit configured to direct a combined flow of the first flow of the working fluid and the second flow of the working fluid from the outlet of the ejector to the gas-liquid separator. The energy efficient heat pump further includes a controller configured to adjust the first valve and the second valve to respective closed positions in the heating mode of the energy efficient heat pump and to adjust the first valve and the second valve to respective open positions in the alternative heating mode of the energy efficient heat pump.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a perspective view of an embodiment of a building incorporating a heating, ventilation, and/or air conditioning (HVAC) system in a commercial setting, in accordance with an aspect of the present disclosure;

[0009] FIG. **2** is a perspective view of an embodiment of a packaged HVAC unit, in accordance with an aspect of the present disclosure;

[0010] FIG. **3** is a perspective view of an embodiment of a split, residential HVAC system, in accordance with an aspect of the present disclosure;

[0011] FIG. **4** is a schematic diagram of an embodiment of a vapor compression system used in an HVAC system, in accordance with an aspect of the present disclosure;

[0012] FIG. **5** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector, illustrating the heat pump system configured for operation in a cooling mode, in accordance with an aspect of the present disclosure;

[0013] FIG. **6** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector, illustrating the heat pump system configured for operation in a standard heating mode, in accordance with an aspect of the present disclosure;

[0014] FIG. **7** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector, illustrating the heat pump system configured for operation in an ejector heating mode, in accordance with an aspect of the present disclosure;

[0015] FIG. **8** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector and an intermediate heat exchanger, illustrating the heat pump system configured for operation in an ejector heating mode, in accordance with an aspect of the present disclosure;

[0016] FIG. **9** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector and an intermediate heat exchanger, illustrating the heat pump system configured for operation in a standard heating mode, in accordance with an aspect of the present disclosure;

[0017] FIG. **10** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector and an intermediate heat exchanger, illustrating the heat pump system configured for operation in a cooling mode, in accordance with an aspect of the present disclosure;

[0018] FIG. **11** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector and a separator having an internal heat exchanger, illustrating the heat pump system configured for operation in an ejector heating mode, in accordance with an aspect of the present disclosure;

[0019] FIG. **12** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector and a separator having an internal heat exchanger, illustrating the heat pump system configured for operation in a standard heating mode, in accordance with an aspect of the present disclosure;

[0020] FIG. **13** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector and a separator having an internal heat exchanger, illustrating the heat pump system configured for operation in a cooling mode, in accordance with an aspect of the present disclosure;

[0021] FIG. **14** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector, illustrating the heat pump system configured for operation in an ejector heating mode, in accordance with an aspect of the present disclosure;

[0022] FIG. **15** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector, illustrating the heat pump system configured for operation in a normal heating mode, in accordance with an aspect of the present disclosure;

[0023] FIG. **16** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector, illustrating the heat pump system configured for operation in a cooling mode, in accordance with an aspect of the present disclosure;

[0024] FIG. **17** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector, illustrating the heat pump system configured for operation in a cooling mode, in accordance with an aspect of the present disclosure;

[0025] FIG. **18** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector, illustrating the heat pump system configured for operation in a heating mode, in accordance with an aspect of the present disclosure;

[0026] FIG. **19** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector, illustrating the heat pump system configured for operation in a cooling mode, in accordance with an aspect of the present disclosure;

[0027] FIG. **20** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector, illustrating the heat pump system configured for operation in a heating mode, in accordance with an aspect of the present disclosure;

[0028] FIG. **21** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector, illustrating the heat pump system configured for operation in a cooling mode, in accordance with an aspect of the present disclosure; and

[0029] FIG. **22** is a schematic diagram of an embodiment of a portion of an HVAC system that includes a heat pump system with an ejector, illustrating the heat pump system configured for operation in a cooling mode, in accordance with an aspect of the present disclosure.

DETAILED DESCRIPTION

[0030] One or more specific embodiments of the present disclosure will be described below. These described embodiments are examples of the presently disclosed techniques. Additionally, in an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0031] When introducing elements of various embodiments of the present disclosure, the articles "a," "an," and "the" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements. Additionally, it should be understood that references to "one embodiment" or "an embodiment" of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

[0032] As used herein, the terms "approximately," "generally," and "substantially," and so forth, are intended to convey that the property value being described may be within a relatively small range of the property value, as those of ordinary skill would understand. For example, when a property value is described as being "approximately" equal to (or, for example, "substantially similar" to) a given value, this is intended to mean that the property value may be within +/−5%, within +/−4%, within +/−3%, within +/−2%, within +/−1%, or even closer, of the given value. Similarly, when a given feature is described as being "substantially parallel" to another feature, "generally perpendicular" to another feature, and so forth, this is intended to mean that the given feature is within +/−5%, within +/−4%, within +/−3%, within +/−2%, within +/−1%, or even closer, to having the described nature, such as being parallel to another feature, being perpendicular to another feature, and so forth. Further, it should be understood that mathematical terms, such as "planar," "slope," "perpendicular," "parallel," and so forth are intended to encompass features of surfaces or elements as understood to one of ordinary skill in the relevant art, and should not be rigidly interpreted as might be understood in the mathematical arts. For example, a "planar" surface is intended to encompass a surface that is machined, molded, or otherwise formed to be substantially flat or smooth (within related tolerances) using techniques and tools available to one of ordinary skill in the art. Similarly, a surface having a "slope" is intended to encompass a surface that is machined, molded, or otherwise formed to be oriented at an angle (e.g., incline) with respect to a point of reference using techniques and tools available to one of ordinary skill in the art.

[0033] As briefly discussed above, a heating, ventilation, and/or air conditioning (HVAC) system may be used to thermally regulate a space within a building, home, or other suitable structure. For example, the HVAC system may include a vapor compression system that transfers thermal energy between a working fluid, such as a refrigerant, and a fluid to be conditioned, such as air. The vapor compression system includes heat exchangers, such as a condenser and an evaporator, which are fluidly coupled to one another via one or more conduits of a working fluid loop or circuit (e.g., refrigerant circuit). A compressor may be used to circulate the working fluid through the conduits and other components of the working fluid circuit (e.g., an expansion device) and, thus, enable the transfer of thermal energy between components of the working fluid circuit (e.g., between the condenser and the evaporator) and one or more thermal loads (e.g., an environmental air flow, a supply air flow). Additionally or alternatively, the HVAC system may include a heat pump (e.g., heat pump system) having a first heat exchanger (e.g., heating and/or cooling coil, indoor coil, the evaporator) positioned within the space to be conditioned, a second heat exchanger (e.g., heating and/or cooling coil, outdoor coil, the condenser) positioned in or otherwise fluidly coupled to an ambient environment (e.g., the atmosphere), and a pump (e.g., the compressor) configured to circulate the working fluid (e.g., refrigerant) between the first and second heat exchangers to enable heat transfer between the thermal load (e.g., an air flow to be conditioned) and the ambient environment, for example. The heat pump system is operable to provide both cooling and heating to the space to be conditioned (e.g., room, zone, or other region within a building) by adjusting a flow of the working fluid through the working fluid circuit. Thus, the heat pump may not include a dedicated heating system, such as a furnace or burner configured to combust a fuel, to enable operation of the HVAC system in the heating mode. As a result, the heat pump is configured to operate with reduced greenhouse gas emissions.

[0034] For example, during operation of the heat pump system in a cooling mode, the compressor may direct working fluid through the working fluid circuit and the first heat exchanger and the second heat exchanger in a first flow direction. While receiving working fluid in the first flow direction, the first heat exchanger, which may be positioned within the space to be conditioned, may operate as an evaporator and, thus, enable working fluid flowing through the first heat exchanger to absorb thermal energy from an air flow directed to the space. Further, the second heat exchanger, which may be positioned in the ambient environment surrounding the heat pump system, may operate as a condenser to reject the heat absorbed by the working fluid flowing from the first heat exchanger (e.g., to an ambient air flow directed across the second heat exchanger). In this way, the heat pump system may facilitate cooling of the space or other thermal load serviced by (e.g., in thermal communication with) the first heat exchanger.

[0035] Conversely, during operation in a heating mode, a reversing valve (e.g., switch-over valve) enables the compressor to direct working fluid through the working fluid circuit and the first and second heat exchangers in a second flow direction, opposite the first flow direction. While receiving working fluid in the second flow direction, the first heat exchanger may operate as a condenser instead of an evaporator, and the second heat exchanger may operate as an evaporator instead of a condenser. As such, the first heat exchanger may receive (e.g., from the second heat exchanger) a flow of heated working fluid to reject heat to thermal load serviced by the first heat exchanger (e.g., an air flow directed to the space) and, thus, facilitate heating of the thermal load. In this way, the heat pump system may facilitate either heating or cooling of the thermal load based on the current operational mode of the heat pump system (e.g., based on a flow direction of working fluid along the working fluid circuit).

[0036] As will be appreciated, it may be desirable to utilize certain working fluids with a heat pump or other HVAC system, such as working fluids having a low global warming potential (GWP). However, many working fluids having a low GWP operate at lower pressures, and conventional heat pumps are unable to operate properly at such lower pressures. Indeed, conventional heat pumps may be particularly susceptible to operational efficiencies in certain conditions or circumstances, such as cold climate conditions, that further render the use of certain low GWP working fluids unsuitable with conventional heat pumps. It is presently recognized that improved heat pump systems configured to utilize low GWP working fluids while operating more efficiently and reliably are desired.

[0037] Accordingly, embodiments of the present disclosure relate to a heat pump system (e.g., energy efficient heat pump) that is configured to operate with improved efficiency (e.g., in cold climate environments), utilize a low GWP working fluid, and enable a reduction in the generation of greenhouse gas emissions. For example, present embodiments include energy efficient heat pump systems that include an ejector (e.g., two-phase ejector) disposed along a working fluid circuit of the energy efficient heat pump system. As discussed in detail below, the ejector of the working fluid circuit may be configured to direct a flow of working fluid toward a compressor (e.g., compressor suction, compressor inlet) of the working fluid circuit at a pressure greater than that of a heat exchanger of the working fluid circuit operating as an evaporator. For example, in a heating mode of the heat pump, an outdoor heat exchanger may operate as the evaporator and may direct a flow of working fluid to the ejector, and the ejector may increase the pressure of the working fluid and direct the flow of working fluid toward the compressor. Thus, the compressor may receive the working fluid at a greater pressure compared to conventional heat pumps in which the evaporator directs the working fluid to the compressor at a pressure of the evaporator. In this way, operation of the compressor, particularly in cold climate conditions, may be improved by enabling operation of the compressor within an operational envelope (e.g., a design specification, a range of operating conditions) of the compressor. Further, incorporation of the ejector may enable higher mass flow of working fluid directed to the inlet of the compressor, which may reduce a displacement demand on the compressor. In this way, the techniques disclosed herein enable operation of heat pumps (e.g., to provide heating) with improved energy efficiency, reduced energy consumption, and reduced generation of greenhouse gas emissions. Present embodiments may also provide the benefits described herein with reduced costs and complexity, as well as improved reliability, for heat pump systems.

[0038] Turning now to the drawings, FIG. **1** illustrates an embodiment of a heating, ventilation, and/or air conditioning (HVAC) system for environmental management that employs one or more HVAC units in accordance with the present disclosure. As used herein, an HVAC system includes any number of components configured to enable regulation of parameters related to climate characteristics, such as temperature, humidity, air flow, pressure, air quality, and so forth. For example, an "HVAC system" as used herein is defined as conventionally understood and as further described herein. Components or parts of an "HVAC system" may include, but are not limited to, all, some of, or individual parts such as a heat exchanger, a heater, an air flow control device, such as a fan, a sensor configured to detect a climate characteristic or operating parameter, a filter, a control device configured to regulate operation of an HVAC system component, a component configured to enable regulation of climate characteristics, or a combination thereof. An "HVAC system" is a system configured to provide such functions as heating, cooling, ventilation, dehumidification, pressurization, refrigeration, filtration, or any combination thereof. The embodiments described herein may be utilized in a variety of applications to control climate characteristics, such as residential, commercial, industrial, transportation, or other applications where climate control is desired.

[0039] In the illustrated embodiment, a building **10** is air conditioned by a system that includes an HVAC unit **12** in accordance with present embodiments. The building **10** may be a commercial structure or a residential structure. As shown, the HVAC unit **12** is disposed on the roof of the building **10**; however, the HVAC unit **12** may be located in other equipment rooms or areas adjacent the building **10**. The HVAC unit **12** may be a single package unit containing other equipment, such as a blower and/or integrated air handler. In other embodiments, the HVAC unit **12** may be part of a split HVAC system, such as the system shown in FIG. **3**, which includes an outdoor HVAC unit **58** and an indoor HVAC unit **56**.

[0040] The HVAC unit **12** is an air-cooled device that implements a refrigeration cycle to provide conditioned air to the building **10**. Specifically, the HVAC unit **12** may include one or more heat exchangers across which an air flow is passed to condition the air flow before the air flow is supplied to the building. In the illustrated embodiment, the HVAC unit **12** is a rooftop unit (RTU) that conditions a supply air flow, such as environmental air and/or a return air flow from the building **10**. After the HVAC unit **12** conditions the air, the air is supplied to the building **10** via ductwork **14** extending throughout the building **10** from the HVAC unit **12**. For example, the ductwork **14** may extend to various individual floors or other sections of the building **10**. In certain embodiments, the HVAC unit **12** may be a heat pump that provides both heating and cooling to the building with one refrigeration circuit configured to operate in different modes.

[0041] A control device **16**, one type of which may be a thermostat, may be used to designate the temperature of the conditioned air. The control device **16** also may be used to control the flow of air through the ductwork **14**. For example, the control device **16** may be used to regulate operation of one or more components of the HVAC unit **12** or other components, such as dampers and fans, within the building **10** that may control flow of air through and/or from the ductwork **14**. In some embodiments, other devices may be included in the system, such as pressure and/or temperature transducers or switches that sense the temperatures and pressures of the supply air, return air, and so forth. Moreover, the control device **16** may include computer systems that are integrated with or separate from other building control or monitoring systems, and even systems that are remote from the building **10**.

[0042] FIG. **2** is a perspective view of an embodiment of the HVAC unit **12**. In the illustrated embodiment, the HVAC unit **12** is a single package unit that may include one or more independent working fluid circuits and components that are tested, charged, wired, piped, and ready for installation. The HVAC unit **12** may provide a variety of heating and/or cooling functions, such as cooling only, heating only, cooling with dehumidification, heating with a heat pump, and/or cooling with a heat pump. As described above, the HVAC unit **12** may directly cool and/or heat an air flow provided to the building **10** to condition a space in the building **10**.

[0043] As shown in the illustrated embodiment of FIG. **2**, a cabinet **24** encloses the HVAC unit **12** and provides structural support and protection to the internal components from environmental and other contaminants. In some embodiments, the cabinet **24** may be constructed of galvanized steel and insulated with aluminum foil faced insulation. Rails **26** may be joined to the bottom perimeter of the cabinet **24** and provide a foundation for the HVAC unit **12**. In certain embodiments, the rails **26** may provide access for a forklift and/or overhead rigging to facilitate installation and/or removal of the HVAC unit **12**. In some embodiments, the rails **26** may fit into "curbs" on the roof to enable the HVAC unit **12** to provide air to the ductwork **14** from the bottom of the HVAC unit **12** while blocking elements such as rain from leaking into the building **10**.

[0044] The HVAC unit **12** includes heat exchangers **28** and **30** in fluid communication with one or more working fluid circuits. Tubes within the heat exchangers **28** and **30** may circulate a working fluid (e.g., refrigerant), such as R-454B and/or R32, through the heat exchangers **28** and **30**. The tubes may be of various types, such as multichannel tubes, conventional copper or aluminum tubing, and so forth. Together, the heat exchangers **28** and **30** may implement a thermal cycle in which the working fluid undergoes phase changes and/or temperature changes as it flows through the heat exchangers **28** and **30** to produce heated and/or cooled air. For example, the heat exchanger **28** may function as a condenser where heat is released from the working fluid to ambient air, and the heat exchanger **30** may function as an evaporator where the working fluid absorbs heat to cool an air flow. In some embodiments, the HVAC unit **12** may operate in a heat pump mode where the roles of the heat exchangers **28** and **30** may be reversed. That is, the heat exchanger **28** may function as an evaporator and the heat exchanger **30** may function as a condenser. While the illustrated embodiment of FIG. **2** shows the HVAC unit **12** having two of the heat exchangers **28** and **30**, in other embodiments, the HVAC unit **12** may include one heat exchanger or more than two heat exchangers.

[0045] The heat exchanger **30** is located within a compartment **31** that separates the heat exchanger **30** from the heat exchanger **28**. Fans **32** draw air from the environment through the heat exchanger **28**. Air may be heated and/or cooled as the air flows through the heat exchanger **28** before being released back to the environment surrounding the HVAC unit **12**. A blower assembly **34**, powered by a motor **36**, draws air through the heat exchanger **30** to heat or cool the air. The heated or cooled air may be directed to the building **10** by the ductwork **14**, which may be connected to the HVAC unit **12**. Before flowing through the heat exchanger **30**, the conditioned air flows through one or more filters **38** that may remove particulates and contaminants from the air. In certain embodiments, the filters **38** may be disposed on the air intake side of the heat exchanger **30** to prevent contaminants from contacting the heat exchanger **30**.

[0046] The HVAC unit **12** also may include other equipment for implementing the thermal cycle. Compressors **42** increase the pressure and temperature of the working fluid before the working fluid enters the heat exchanger **28**. The compressors **42** may be any suitable type of compressors, such as scroll compressors, rotary compressors, screw compressors, or reciprocating compressors. In some embodiments, the compressors **42** may include a pair of hermetic direct drive compressors arranged in a dual stage configuration **44**. However, in other embodiments, any number of the compressors **42** may be provided to achieve various stages of heating and/or cooling. As may be appreciated, additional equipment and devices may be included in the HVAC unit **12**, such as a solid-core filter drier, a drain pan, a disconnect switch, an economizer, pressure switches, phase monitors, and humidity sensors, among other components.

[0047] The HVAC unit **12** may receive power through a terminal block **46**. For example, a high voltage power source may be connected to the terminal block **46** to power the equipment. The operation of the HVAC unit **12** may be governed or regulated by a control board **48**. The control board **48** may include control circuitry connected to a thermostat, sensors, and alarms. One or more of these components may be referred to herein separately or collectively as the control device **16**. The control circuitry may be configured to control operation of the equipment, provide alarms, and monitor safety switches. Wiring **49** may connect the control board **48** and the terminal block **46** to the equipment of the HVAC unit **12**.

[0048] FIG. **3** illustrates a residential heating and cooling system **50**, also in accordance with present techniques. The residential heating and cooling system **50** may provide heated and cooled air to a residential structure, as well as provide outside air for ventilation and provide improved indoor air quality (IAQ) through devices such as ultraviolet lights and air filters. In the illustrated embodiment, the residential heating and cooling system **50** is a split HVAC system. In general, a residence **52** conditioned by a split HVAC system may include working fluid conduits **54** (e.g., refrigerant conduits) that operatively couple the indoor unit **56** to the outdoor unit **58**. The indoor unit **56** may be positioned in a utility room, an attic, a basement, and so forth. The outdoor unit **58** is typically situated adjacent to a side of the residence **52** and is covered by a shroud to protect the system components and to prevent leaves and other debris or contaminants from entering the unit. The working fluid conduits **54** transfer working fluid between the indoor unit **56** and the outdoor unit **58**, typically transferring primarily liquid working fluid in one direction and primarily vaporized working fluid in an opposite direction.

[0049] When the system shown in FIG. **3** is operating as an air conditioner, a heat exchanger **60** in the outdoor unit **58** serves as a condenser for re-condensing vaporized working fluid flowing from the indoor unit **56** to the outdoor unit **58** via one of the working fluid conduits **54**. In these applications, a heat exchanger **62** of the indoor unit functions as an evaporator. Specifically, the heat exchanger **62** receives liquid working fluid, which may be expanded by an expansion device, and evaporates the working fluid before returning it to the outdoor unit **58**.

[0050] The outdoor unit **58** draws environmental air through the heat exchanger **60** using a fan **64** and expels the air above the outdoor unit **58**. When operating as an air conditioner, the air is heated by the heat exchanger **60** within the outdoor unit **58** and exits the unit at a temperature higher than it entered. The indoor unit **56** includes a blower or fan **66** that directs air through or across the heat exchanger **62**, where the air is cooled when the system is operating in air conditioning mode. Thereafter, the air is passed through ductwork **68** that directs the air to the residence **52**. The overall system operates to maintain a desired temperature as set by a system controller. When the temperature sensed inside the residence **52** is higher than the set point on the thermostat, or the set point plus a small amount, the residential heating and cooling system **50** may become operative to refrigerate additional air for circulation through the residence **52**. When the temperature reaches the set point, or the set point minus a small amount, the residential heating and cooling system **50** may stop the refrigeration cycle temporarily.

[0051] The residential heating and cooling system **50** may also operate as a heat pump. When operating as a heat pump, the roles of heat exchangers **60** and **62** are reversed. That is, the heat exchanger **60** of the outdoor unit **58** will serve as an evaporator to evaporate working fluid and thereby cool air entering the outdoor unit **58** as the air passes over the outdoor heat exchanger **60**. The heat exchanger **62** will receive a stream of air blown over it and will heat the air by condensing the working fluid.

[0052] FIG. **4** is an embodiment of a vapor compression system **72** that can be used in any of the systems described above. The vapor compression system **72** may circulate a working fluid through a circuit starting with a compressor **74**. The circuit may also include a condenser **76**, an expansion valve(s) or device(s) **78**, and an evaporator **80**. The vapor compression system **72** may further include a control panel **82** that has an analog to digital (A/D) converter **84**, a microprocessor **86**, a non-volatile memory **88**, and/or an interface board **90**. The control panel **82** and its components may function to regulate operation of the vapor compression system **72** based on feedback from an operator, from sensors of the vapor compression system **72** that detect operating conditions, and so forth.

[0053] In some embodiments, the vapor compression system **72** may use one or more of a variable speed drive (VSDs) **92**, a motor **94**, the compressor **74**, the condenser **76**, the expansion valve or device **78**, and/or the evaporator **80**. The motor **94** may drive the compressor **74** and may be powered by the variable speed drive (VSD) **92**. The VSD **92** receives alternating current (AC) power having a particular fixed line voltage and fixed line frequency from an AC power source, and provides power having a variable voltage and frequency to the motor **94**. In other embodiments, the motor **94** may be powered directly from an AC or direct current (DC) power source. The motor **94** may include any type of electric motor that can be powered by a VSD or directly from an AC or DC power source, such as a switched reluctance motor, an induction motor, an electronically commutated permanent magnet motor, or another suitable motor.

[0054] The compressor **74** compresses a working fluid vapor and delivers the vapor to the condenser **76** through a discharge passage. In some embodiments, the compressor **74** may be a centrifugal compressor, a scroll compressor, a screw compressor, a rotary compressor, or any other suitable type of compressor. The working fluid vapor delivered by the compressor **74** to the condenser **76** may transfer heat to a fluid passing across the condenser **76**, such as ambient or environmental air **96**. The working fluid vapor may condense to a working fluid liquid in the condenser **76** as a result of thermal heat transfer with the environmental air **96**. The liquid working fluid from the condenser **76** may flow through the expansion device **78** to the evaporator **80**.

[0055] The liquid working fluid delivered to the evaporator **80** may absorb heat from another air flow, such as a supply air flow **98** provided to the building **10** or the residence **52**. For example, the supply air flow **98** may include ambient or environmental air, return air from a building, or a combination of the two. The liquid working fluid in the evaporator **80** may undergo a phase change from the liquid working fluid to a working fluid vapor. In this manner, the evaporator **80** may reduce the temperature of the supply air flow **98** via thermal heat transfer with the working fluid. Thereafter, the vapor working fluid exits the evaporator **80** and returns to the compressor **74** by a suction line to complete the cycle.

[0056] In some embodiments, the vapor compression system **72** may further include a reheat coil. In the illustrated embodiment, the reheat coil is represented as part of the evaporator **80**. The reheat coil is positioned downstream of the evaporator heat exchanger relative to the supply air flow **98** and may reheat the supply air flow **98** when the supply air flow **98** is overcooled to remove humidity from the supply air flow **98** before the supply air flow **98** is directed to the building **10** or the residence **52**.

[0057] It should be appreciated that any of the features described herein may be incorporated with the HVAC unit **12**, the residential heating and cooling system **50**, or other HVAC systems. Additionally, while the features disclosed herein are described in the context of embodiments that directly heat and cool a supply air flow provided to a building or other load, embodiments of the present disclosure may be applicable to other HVAC systems as well. For example, the features described herein may be applied to mechanical cooling systems, free cooling systems, chiller systems, or other heat pump or refrigeration applications.

[0058] As briefly discussed above, embodiments of the present disclosure are directed to an HVAC system having an improved heat pump system. The heat pump system (e.g., reverse-cycle heat pump system, energy efficient heat pump) may include a working fluid circuit having an ejector configured to increase a pressure of a flow of working fluid and to direct the working fluid to a compressor of the working fluid circuit. More specifically, the ejector may receive a flow of working fluid from a heat exchanger (e.g., outdoor heat exchanger) of the working fluid circuit operating as an evaporator, increase the pressure of the flow of working fluid, and direct the flow of working fluid toward the compressor at the increased pressure. Thus, the compressor may receive the flow of working fluid at an elevated pressure relative to the pressure within the evaporator. As a result, the heat pump system may operate in a heating mode, with an outdoor heat exchanger of the working fluid circuit operating as the evaporator, and the compressor may nevertheless receive the flow of working fluid at a pressure greater than the pressure of the working fluid within the outdoor heat exchanger. During cold climate conditions, in which the pressure within the outdoor heat exchanger may be particularly low during operation of the heat pump system in a heating mode, the present techniques may enable the compressor to receive the flow of working fluid at a suitable pressure that enables the compressor to operate within a desired operational envelope. Further, the present techniques may enable operation of the heat pump system utilizing a low GWP working fluid that has lower operating pressures relative to other working fluids. Therefore, the present techniques provide energy efficient heat pumps configured to operate and satisfy heating demands, such as in cold climate conditions, with improved efficiency, reduced energy consumption, low GWP working fluids, and without operation of a furnace or other heating system configured to combust or consume a fuel, thereby enabling a reduction of greenhouse gas emissions.

[0059] To provide context for the following discussion, FIG. **5** is a schematic of an embodiment of a portion of an HVAC system **100** that includes a heat pump **102** (e.g., heat pump system, reverse-cycle heat pump, energy efficient heat pump) in accordance with present embodiments. The heat pump **102** may include one or more components of the vapor compression system **72** discussed above and/or may be included in any of the systems described above (e.g., HVAC unit **12**, heating and cooling system **50**). The heat pump **102** includes a first heat exchanger **104** and a second heat exchanger **106** that are fluidly coupled to one another via a working fluid circuit **108** or working fluid loop (e.g., one or more conduits, refrigerant circuit). The first heat exchanger **104** may be in thermal communication with (e.g., fluidly coupled to) a thermal load **110** (e.g., room, space, and/or device) serviced by the heat pump **102**, and the second heat exchanger **106** may be in thermal communication with an ambient environment **112** (e.g., atmosphere, outdoor environment) surrounding the HVAC system **100**.

[0060] In some embodiments, a first fan **116** (e.g., blower) may direct a first air flow across the first heat exchanger **104** to facilitate heat exchange between working fluid within the first heat exchanger **104** and the first air flow supplied to the thermal load **110**, while a second fan **118** may direct a second air flow across the second heat exchanger **106** to facilitate heat exchange between working fluid within the second heat exchanger **106** and the second air flow of the ambient environment **112**. Thus, the heat pump **102** may be an air-source heat pump. One or more expansion devices **120** (e.g., electronic expansion valve [EEV], bi-directional expansion valve) may be disposed along the working fluid circuit **108**, such as between the first heat exchanger **104** and the second heat exchanger **106**, and may be configured to regulate (e.g., throttle) a flow of working fluid and/or a working fluid pressure differential (e.g., between the first and second heat exchangers **104**, **106**).

[0061] The heat pump **102** also includes a compressor **130** (e.g., compressor system, positive displacement compressor) disposed along the working fluid circuit **108**. The compressor **130** is configured to direct working fluid flow through the first heat exchanger **104**, the second heat exchanger **106**, and remaining components (e.g., the expansion device(s) **120**) that may be fluidly coupled to the working fluid circuit **108**. Although one compressor **130** is shown in the illustrated embodiment, the heat pump **102** may include any suitable quantity of compressors **130**, such as two, three, four, five, six, or more than six compressors **130**. The compressor **130** may be a fixed speed compressor, a multi-stage (e.g., two stage) compressor, and/or a variable speed compressor. Additionally, the compressor **130** may be a rotary compressor, a scroll compressor, a screw compressor, or any other suitable type of compressor (e.g., high-side shell compressor, positive displacement compressor).

[0062] The compressor **130** is configured to receive working fluid (e.g., a primary flow of working fluid) via a suction conduit **132** fluidly coupled to a suction port **134** of the compressor **130** and to discharge working fluid (e.g., compressed working fluid) via a discharge conduit **136** fluidly coupled to a discharge port **138** of the compressor **130**. The compressor **130** may be fluidly coupled to a remainder of the working fluid circuit **108** via a reversing valve **150** (e.g., a switch-over valve). The reversing valve **150** is configured to adjust a flow direction of the working fluid along the working fluid circuit **108** to adjust operation of the heat pump **102** between a cooling mode and a heating mode.

[0063] In the illustrated embodiment, the reversing valve **150** is in a first configuration **152** to enable operation of the heat pump **102** in a cooling mode. That is, while in the first configuration **152**, the reversing valve **150** enables flow of the working fluid along the working fluid circuit in a first direction **154**. Accordingly, the second heat exchanger **106** receives the flow of working fluid from the compressor **130** and operates as a condenser, while the first heat exchanger **104** operates as an evaporator (e.g., to cool the first air flow directed to the thermal load **110**) and directs the working fluid toward the compressor **130**. FIG. **6** is a schematic of an embodiment of a portion of the HVAC system **100** including the heat pump **102** with the reversing valve **150** in a second configuration **160** to enable operation of the heat pump **102** in a heating mode. That is, while in the second configuration **160**, the reversing valve **150** enables flow of the working fluid along the working fluid circuit in a second direction **162**, opposite the first direction. Accordingly, the first heat exchanger **104** receives the flow of working fluid from the compressor **130** and operates as a condenser (e.g., to heat the first air flow directed to the thermal load **110**), while the second heat exchanger **106** operates as an evaporator and directs the working fluid toward the compressor **130**.

[0064] The present discussion continues with reference to FIG. **5**. As mentioned above, it may be desirable to utilize a working fluid having a low GWP with the heat pump **102**. However, certain working fluids having a low GWP may operate at lower pressures, which may complicate operation of conventional heat pumps, particularly in cold climate conditions (e.g., low temperatures in the ambient environment **112**) and/or during operation of the heat pump **102** in the heating mode. Indeed, in low ambient temperatures, a pressure of the working fluid within the second heat exchanger **106** may be reduced to a level or value that results in operation of the compressor **130** outside of an operational envelope of the compressor **130**. For example, the pressure of the working fluid within the second heat exchanger **106** (e.g., operating as an evaporator in the heating mode) may fall below a lower suction pressure threshold value of the compressor **130**, which may result in inefficient, unstable, and/or otherwise undesirable operation of the compressor **130**.

[0065] Accordingly, present embodiments of the heat pump **102** include an ejector system **200** configured to enable more effective and efficient operation of the heat pump **102** utilizing a working fluid (e.g., low GWP working fluid, R-1234ze(E), R-1234yf, low pressure working fluid, low pressure refrigerant) designed to operate at lower pressures, as well as improved (e.g., more efficient) operation of the heat pump **102** in a heating mode and in cold climate conditions. The ejector system **200** may be described as a system disposed along and/or fluidly coupled to the working fluid circuit **108**. As shown, the ejector system **200** includes an ejector **202** (e.g., two-phase ejector) fluidly coupled to the working fluid circuit **108**. The ejector **202** is fluidly coupled to the working fluid circuit **108** via a first conduit **204** (e.g., first inlet conduit, first ejector system conduit) and a second conduit **206** (e.g., second inlet conduit, second ejector system conduit). In particular, the first conduit **204** extends from a first circuit portion **208** of the working fluid circuit **108** to a chamber inlet **210** of the ejector **202**, and the second conduit **206** extends from a second circuit portion **212** of the working fluid circuit **108** to a nozzle inlet **214** of the ejector **202**. The first circuit portion **208** extends from the second heat exchanger **106** to a first expansion valve **216** (e.g., electronic expansion valve, normal mode EEV) of the working fluid circuit **108**, and the second circuit portion **212** extends from the first expansion valve **216** to the first heat exchanger **104**.

[0066] The ejector system **200** may also include a first valve **218** (e.g., solenoid valve) disposed along the first conduit **204** and/or a second valve **220** (e.g., solenoid valve) disposed along the second conduit **206** to control flow of working fluid into the ejector **202**. Further, the ejector system **200** may include an outlet conduit **222** (e.g., ejector system conduit) extending from the ejector **202** to a separator **224** (e.g., working fluid separator, gas-liquid separate) disposed along the working fluid circuit **108** (e.g., along the suction conduit **132**). The separator **224** may be configured to receive a flow (e.g., combined flow) of working fluid from the ejector **202** via the outlet conduit **222** during operation of the ejector system **200**. It should also be noted that the heat pump **102** of the illustrated embodiment includes a second expansion valve **226** (e.g., electronic expansion valve, ejector mode EEV) disposed along the working fluid circuit **108** between the second heat exchanger **106** and the reversing valve **150**. The second expansion valve **226** may be utilized in conjunction with the ejector system **200**, in some embodiments. Operation of the ejector system **200** and associated components is described in further detail below.

[0067] The HVAC system **100** may also include a controller **230** (e.g., control system, thermostat, control panel, control circuitry, automation controller) that is communicatively coupled to one or more components of the heat pump **102** and is configured to monitor, adjust, and/or otherwise control operation of one or more components of the heat pump **102**. For example, one or more control transfer devices, such as wires, cables, wireless communication devices, and the like, may communicatively couple the compressor **130**, the expansion device(s) **120**, the first and/or second valves **218**, **220**, the first and/or second fans **116**, **118**, the control device **16** (e.g., thermostat), and/or any other suitable components of the HVAC system **100** to the controller **230**. That is, the compressor **130**, the expansion device(s) **120**, the first and/or second valves **218**, **220**, the first and/or second fans **116**, **118**, and/or the control device **16** may each have one or more communication components that facilitate wired or wireless (e.g., via a network) communication with the controller **230**. In some embodiments, the communication components may include a network interface that enables the components of the HVAC system **100** to communicate via various protocols such as EtherNet/IP, ControlNet, DeviceNet, or any other communication network protocol. Alternatively, the communication components may enable the components of the HVAC system **100** to communicate via mobile telecommunications technology, Bluetooth®, near-field communications technology, and the like. As such, the controller **230**, the compressor **130**, the expansion device(s) **120**, the first and/or second fans **116**, **118**, the first and/or second valves **218**, **220**, and/or the control device **16** may wirelessly communicate data between each other. In other embodiments, operational control of certain components of the heat pump **102** may be regulated by one or more relays or switches (e.g., a 24 volt alternating current [VAC]relay).

[0068] In some embodiments, the controller **230** may be a component of or may include the control panel **82**. In other embodiments, the controller **230** may be a standalone controller, a dedicated controller, or another suitable controller included in the HVAC system **100**. In any case, the controller **230** is configured to control components of the HVAC system **100** in accordance with the techniques discussed herein. That is, the controller **230** is configured to output one or more control signals to control and/or adjust operation of components of the heat pump **102** described herein to enable operation of the heat pump **102** in the various modes described below. The controller **230** includes processing circuitry **232**, such as a microprocessor, which may execute software for controlling the components of the HVAC system **100**. The processing circuitry **232** may include multiple microprocessors, one or more "general-purpose" microprocessors, one or more special-purpose microprocessors, and/or one or more application specific integrated circuits (ASICS), or some combination thereof. For example, the processing circuitry **232** may include one or more reduced instruction set (RISC) processors.

[0069] The controller **230** may also include a memory device **234** (e.g., a memory) that may store information, such as instructions, control software, look up tables, configuration data, etc. The memory device **234** may include a volatile memory, such as random access memory (RAM), and/or a nonvolatile memory, such as read-only memory (ROM). The memory device **234** may store a variety of information and may be used for various purposes. For example, the memory device **234** may store processor-executable instructions including firmware or software for the processing circuitry **232** to execute, such as instructions for controlling components of the HVAC system **100** (e.g., heat pump **102**). In some embodiments, the memory device **234** is a tangible, non-transitory, machine-readable-medium that may store machine-readable instructions for the processing circuitry **232** to execute. The memory device **234** may include ROM, flash memory, a hard drive, or any other suitable optical, magnetic, or solid-state storage medium, or a combination thereof. The memory device **234** may store data, instructions, and any other suitable data. It should be appreciated that the controller **230** may be configured to control operation of any and/or all of the components described herein to enable and facilitate the disclosed techniques.

[0070] As mentioned above, the embodiment of the heat pump **102** illustrated in FIG. **5** is configured for operation in the cooling mode. Thus, the reversing valve **150** is in the first configuration **152** and is configured to direct working fluid from the compressor **130** to the second heat exchanger **106** in the first direction **154**. In the cooling mode, the ejector system **200** may not be utilized. In other words, the ejector system **200** may not be operated to direct a flow of working fluid through the ejector **202**. To enable operation of the heat pump **102** in the cooling mode, the controller **230** may adjust the first valve **218** and the second valve **220** to respective closed positions to block flow of working fluid to the ejector **202**. Additionally, the controller **230** may adjust the second expansion valve **226** to a fully open position, such that the second expansion valve **226** does not throttle the flow of working fluid directed to the second heat exchanger **106** from the compressor **130** (e.g., via the reversing valve **150**). The first expansion valve **216** may be controlled and/or operated to adjust (e.g., throttle, expand) the flow of working fluid from the second heat exchanger **106** to the first heat exchanger **104** as desired. Additionally, in the cooling mode, the separator **224** may operate as an accumulator to enable control of an amount of liquid working fluid circulating in the working fluid circuit **108**. The separator **224** may receive the working fluid from the first heat exchanger **104** (e.g., via the reversing valve **150**) and may discharge the working fluid (e.g., vapor working fluid) toward the compressor **130** via the suction conduit **132**.

[0071] Similarly, in the illustrated embodiment of FIG. **6**, in which the heat pump **102** is configured for operation in the heating mode (e.g., normal heating mode), the ejector system **200** may also not be utilized. Thus, in the heating mode, the controller **230** may adjust the first valve **218** and the second valve **220** to respective closed positions to block flow of working fluid to the ejector **202**, and the controller **230** may adjust the second expansion valve **226** to a fully open position, as similarly described above. Additionally, the reversing valve **150** may be adjusted to the second configuration **160** to enable flow of the working fluid from the compressor **130** to the first heat exchanger **104** (e.g., in the second direction **162**). The separator **224** may also operate as an accumulator to enable control of an amount of liquid working fluid circulating in the working fluid circuit **108** in the heating mode (e.g., normal heating mode). In particular, the separator **224** may receive the working fluid from the second heat exchanger **106** (e.g., via the reversing valve **150**) and may discharge the working fluid (e.g., vapor working fluid) toward the compressor **130** via the suction conduit **132**.

[0072] In some circumstances, operation of the ejector system **200** may enable improved performance of the heat pump **102**. For example, during operation of the heat pump **102** in a heating mode and in cold ambient conditions, a pressure of the working fluid (e.g., low GWP working fluid) within the second heat exchanger **106** may be further reduced (e.g., below a threshold level), which may cause unstable and/or unreliable operation of the compressor **130**. That is, a suction pressure of the working fluid at the compressor **130** may fall below a lower limit or threshold (e.g., stored on the memory device **234**) that may cause the compressor **130** to operate outside a specified or desired operational envelope of the compressor **130**. Accordingly, the ejector system **200** may be operated to increase a pressure of the working fluid directed to the compressor **130**.

[0073] For example, FIG. **7** is a schematic of an embodiment of a portion of the HVAC system **100** that includes the heat pump **102** with the ejector system **200**, illustrating the heat pump **102** in an ejector heating mode (e.g., alternative heating mode, second heating mode, cold ambient heating mode). In the ejector heating mode, the ejector system **200** is utilized to increase a pressure of the working fluid that is directed to the compressor **130**. To this end, the controller **230** may adjust the first expansion valve **216** to a closed position and may adjust the first valve **218** and the second valve **220** toward respective open positions. Thus, flow of the working fluid from the first heat exchanger **104** to the second heat exchanger **106** via the first expansion valve **216** may be blocked.

[0074] In the ejector heating mode, the separator **224** may operate as a flash tank and may separate working fluid into liquid working fluid and vapor working fluid. The vapor working fluid may be directed from the separator **224** to the compressor **130** via the suction conduit **132**. From the compressor **130**, the vapor working fluid may be directed to the reversing valve **150**, which is positioned in the second configuration **160**, and the reversing valve **150** may direct the vapor working fluid to the first heat exchanger **104**, as indicated by arrow **240**. Liquid working fluid within the separator **224** may be directed to the reversing valve **150**, and the reversing valve **150** may direct the liquid working fluid to the second heat exchanger **106**, as indicated by arrow **242**. Additionally, in the ejector heating mode, the second expansion valve **226** may be operated to throttle, expand, and/or otherwise adjust flow of the working fluid directed to the second heat exchanger **106**.

[0075] Working fluid discharged from the first heat exchanger **104** may flow along the second circuit portion **212** of the working fluid circuit **108** and may be diverted to the second conduit **206** of the ejector system **200**, due to the closed position of the first expansion valve **216**. The second conduit **206** may direct the working fluid through the second valve **220** and into the ejector **202** via the nozzle inlet **214** of the ejector **202**. Meanwhile, the working fluid discharged from the second heat exchanger **106** may be diverted to the first conduit **204** of the ejector system **200** to flow through the first valve **218** and into the ejector **202** via the chamber inlet **210**. Therefore, the working fluid discharged from the first heat exchanger **104** may enter the ejector **202** via the nozzle inlet **214** and be directed through a nozzle **250** of the ejector **202** as a motive fluid. The nozzle **250** of the ejector **202** may increase a velocity of the working fluid and thereby generate a lower pressure within a suction chamber **252** of the ejector **202** to draw the working fluid from the second heat exchanger **106** into the suction chamber **252** of the ejector **202** via the chamber inlet **210**. Indeed, the low pressure generated within the suction chamber **252** of the ejector **202** by the working fluid directed through the nozzle **250** (e.g., from the first heat exchanger **104**) may be lower than the pressure of working fluid within the second heat exchanger **106**, which facilitates and promotes flow of the working fluid from the second heat exchanger **106** into the suction chamber **252** of the ejector **202** via the chamber inlet **210**.

[0076] Within the suction chamber **252** of the ejector **202**, the two flows of working fluid may mix and subsequently exit the ejector **202** (e.g., as a combined flow of working fluid) via a diffuser **254** (e.g., outlet) of the ejector **202**. In this way, the flow (e.g., combined flow) of working fluid exiting the ejector **202** may have an increased pressure relative to a pressure of the working fluid discharged from the second heat exchanger **106**. The working fluid discharged by the ejector **202** may be directed to the separator **224** via the outlet conduit **222** to be separated into vapor working fluid and liquid working fluid, as discussed above. The vapor working fluid discharged by the separator **224** to the compressor **130** may have a greater pressure than the pressure of the working fluid discharged by the second heat exchanger **106**. Therefore, the compressor **130** may receive working fluid at a greater pressure than the pressure of working fluid received by the compressor **130** (e.g., from the second heat exchanger **106**) in the heating mode discussed above with reference to FIG. **6**. As will be appreciated, the increase in pressure of the working fluid may be particularly advantageous in embodiments of the heat pump **102** utilizing a low GWP working fluid having a low operating pressure. In this way, operation of the heat pump **102** in cold ambient conditions may be improved via operation of the ejector system **200**. More specifically, the heat pump **102** may be operated with an extended operating range in a heating mode, and the compressor **130** may be operated with desired operating parameters in cold climate conditions, which may enable more efficient operation of the heat pump **102** and reduced energy consumption by the compressor **130**.

[0077] As will be appreciated, the controller **230** may be configured to operate the heat pump **102** in the cooling mode in response to a call for cooling (e.g., received from a thermostat and/or control device, to cool the thermal load **110**), and the controller **230** may be configured to operate the heat pump **102** in the heating mode and/or the ejector heating mode (e.g., alternative heating mode, cold ambient heating mode) in response to a call for heating (e.g., received from a thermostat and/or control device, to heat the thermal load **110**). Additionally, in accordance with present techniques, the controller **230** may be configured to adjust operation of the heat pump **102** between the cooling mode, the heating mode, and the ejector heating mode (e.g., alternative heating mode, cold ambient heating mode) discussed above based on one or more operating conditions (e.g., operating parameters) of the heat pump **102** (e.g., cold ambient temperatures, working fluid pressure). For example, the controller **230** may be configured to adjust operation of one or more of the first expansion valve **216**, the second expansion valve **226**, the first fan **116**, the second fan **118**, the first valve **218**, the second valve **220**, and/or the compressor **130** based on feedback from one or more sensors **246**. In some embodiments, one or more of the sensors **246** may be configured to detect a flow rate, a temperature, a pressure, a phase, or other attribute of the working fluid, a temperature of the ambient environment **112**, a temperature of the thermal load **110**, another suitable operating parameter, or any combination thereof. Additionally or alternatively, the controller **230** may be configured to adjust an operating mode of the heat pump **102** based on a set point temperature of the thermal load **110**. In some embodiments, the controller **230** may be configured to operate the heat pump **102** in the heating mode or in the ejector heating mode in response to a call for heating and based on one or more operating conditions of the heat pump **102**.

[0078] In some embodiments, the controller **230** may be configured to initialize operation of the heat pump **102** in the ejector heating mode described above with reference to FIG. **7** and/or transition operation of the heat pump **102** from the heating mode described above with reference to FIG. **6** to the ejector heating mode based on one or more operating conditions of the heat pump **102**. That is, in some embodiments, the controller **230** may be configured to operate the heat pump **102** in the ejector heating mode, instead of in the heating mode, to provide heating to the thermal load **110** based on (e.g., in response to) one or more operating conditions of the heat pump **102**. The one or more operating conditions of the heat pump **102** may be detected by one or more of the sensors **246** described above. For example, in some embodiments, the controller **230** may be configured to operate the heat pump **102** in the ejector heating mode described above based on (e.g., in response to) a determination that a temperature of the ambient environment **112** detected by one of the sensors **246** is below a threshold (e.g., predetermined) temperature (e.g., threshold temperature value, stored on the memory device **234**). The threshold temperature may be indicative of and/or may correspond to a low ambient condition (e.g., low ambient temperature condition, cold climate conditions) in which the heat pump **102** may operate with improved efficiency (e.g., reduced energy consumption) via operation of the ejector system **200**. For example, when the temperature of the ambient environment **112** is below the threshold temperature and the heat pump **102** operates to provide heating to the thermal load **110**, the pressure of the working fluid exiting the second heat exchanger **106** operating as an evaporator may be lower than a desired or target suction pressure (e.g., lower limit pressure) of the compressor **130**. Accordingly, the heat pump **102** may operate with the ejector system **200** in the ejector heating mode to enable an increase in the pressure of the working fluid directed to the suction port **134** of the compressor **130** to enable operation of the compressor **130** within an operational envelope and with improved efficiency (e.g., reduced energy consumption).

[0079] As another example, the controller **230** may be configured to operate the heat pump **102** in the ejector heating mode based on (e.g., in response to) a pressure drop and/or pressure differential across the heat pump **102**. To this end, the controller **230** may be configured to determine a pressure differential across the heat pump **102** via data and/or feedback received from one or more of the sensors **246** indicative of pressures within the heat pump **102** (e.g., working fluid circuit **108**). For example, the controller **230** may be configured to determine the pressure differential based on data indicative of a first pressure of the working fluid at the first heat exchanger **104** and a second pressure of the working fluid at the second heat exchanger **106**. Additionally or alternatively, the controller **230** may be configured to determine the pressure differential based on data indicative of a first pressure of the working fluid at the suction port **134** of the compressor **130** and a second pressure of the working fluid at the discharge port **138** of the compressor **130**. Based on (e.g., in response to) a determination that the pressure differential (e.g., measured pressure differential, detected pressure differential, differential pressure) of the working fluid across the heat pump **102** is equal to or greater than a threshold pressure differential (e.g., stored on the memory device **234**, threshold pressure differential value), the controller **230** may initialize and/or transition operation of the heat pump **102** to the ejector heating mode. Accordingly, the heat pump **102** may operate with the ejector system **200** in the ejector heating mode to enable an increase in the pressure of the working fluid directed to the suction port **134** of the compressor **130** to reduce the pressure differential across the heat pump **102** and thereby enable operation of the compressor **130** with improved efficiency (e.g., reduced energy consumption).

[0080] In some embodiments, the controller **230** may be configured to operate the heat pump **102** in the ejector heating mode (e.g. instead of the heating mode) based on and/or in response to other operating parameters of the heat pump **102** (e.g., detected by one or more of the sensors **246**). For example, the controller **230** may be configured to operate the heat pump **102** in the ejector heating mode, instead of the heating mode, in response to a determination that a coil temperature of the second heating exchanger **106** (e.g., evaporator) is less than a threshold temperature value, in response to a determination that a pressure of the working fluid at the suction port **134** (e.g., suction pressure) of the compressor **130** is less than a corresponding threshold value (e.g., threshold suction pressure value, lower limit suction pressure value, first threshold pressure value), in response to a determination that a pressure of the working fluid at the second heat exchanger **106** (e.g., evaporation pressure) is less than a corresponding threshold value (e.g., threshold evaporation pressure value, lower limit evaporation pressure value, second threshold pressure value), in response to a determination that a pressure of the working fluid at the discharge port **138** of the compressor **130** (e.g., discharge pressure) is greater than a corresponding threshold value (e.g., threshold discharge pressure value, upper limit discharge pressure value, third threshold pressure value), in response to a determination that a pressure of the working fluid at the first heat exchanger **104** (e.g., condensing pressure) is greater than a corresponding threshold value (e.g., threshold condensing pressure value, upper limit condensing pressure value, fourth threshold pressure value), or any combination thereof.

[0081] It will be appreciated that operation of the ejector system **200** in the ejector heating mode may also enable improved (e.g., more efficient) operation of the compressor **130** by increasing mass flow of the working fluid directed through the compressor **130**. Indeed, by increasing a pressure of the working fluid directed to the suction port **134** of the compressor **130** via operation of the ejector system **200**, the working fluid directed into the compressor **130** may have a greater density, which cause an increase in mass flow of the working fluid directed into the compressor **130**. In this way, a capacity of the heat pump **102** may be increased, and a displacement of the demand of the compressor **130** may be reduced, which enables operation of the compressor **130** with reduced energy consumption.

[0082] FIGS. **8-10** are schematics of an embodiment of a portion of the HVAC system **100** that includes the heat pump **102** with the ejector system **200**. The illustrated embodiments of FIGS. **8-10** include similar elements and element numbers as those described above with reference to FIGS. **5-7**. Additionally, the heat pump **102** (e.g., ejector system **200**) includes an intermediate heat exchanger **280**. The intermediate heat exchanger **280** is disposed along the second conduit **206** upstream of the nozzle inlet **214** of the ejector **202** and downstream of the second circuit portion **212** (e.g., relative to a flow of working fluid through the second conduit **206**, downstream of the second valve **220**). The intermediate heat exchanger **280** is also disposed along the suction conduit **132** upstream of the compressor **130** (e.g., suction port **134**) and downstream of the separator **224** (e.g., relative to a flow of working fluid through the suction conduit **132**. The intermediate heat exchanger **280** may have any suitable configuration configured to enable transfer of heat between two flows of working fluid. For example, the intermediate heat exchanger **280** may be a brazed plate heat exchanger.

[0083] FIG. **8** illustrates the heat pump **102** having the ejector system **200** and the intermediate heat exchanger **280** configured for operation in an ejector heating mode. Thus, the first expansion valve **216** may be in a closed position, and the separator **224** may operate as a flash tank to separate working fluid into liquid working fluid and vapor working fluid. Additionally, the first valve **218** and the second valve **220** may be in respective open positions. Accordingly, working fluid may flow from the first heat exchanger **104** through the ejector system **200** and from the second heat exchanger **106** through the ejector system **200** in a manner similar to that described above with reference to FIG. **7**. However, prior to entering the ejector **202** via the nozzle inlet **214**, the working fluid discharged from the first heat exchanger **104** may flow (e.g., along the second conduit **206**) through the intermediate heat exchanger **280** and may exchange heat with a flow of vapor working fluid directed from the separator **224** to the compressor **130** via the suction conduit **132**. More specifically, heat may be transferred from the working fluid directed along the second conduit **206** to the nozzle inlet **214** of the ejector **202** to the working fluid directed to the compressor **130**. In this way, the temperature of the working fluid directed to the nozzle inlet **214** of the ejector **202** may be reduced, which may enable recovery of expansion losses in the heat pump **102** and thereby enhance the coefficient of performance of the heat pump **102**, such as embodiments of the heat pump **102** utilizing certain low GWP and low-pressure working fluids (e.g., R1234ze(E), R1234yf). Accordingly, energy consumption of the heat pump **102** may be reduced, which further enables a reduction in greenhouse gas emissions.

[0084] FIG. **9** illustrates the heat pump **102** having the ejector system **200** and the intermediate heat exchanger **280** configured for operation in a heating mode (e.g., normal heating mode), and FIG. **10** illustrates the heat pump **102** having the ejector system **200** and the intermediate heat exchanger **280** configured for operation in a cooling mode. The heat pump **102** having the ejector system **200** and the intermediate heat exchanger **280** may operate in the heating mode and the cooling mode in a manner similar to that described above with reference to FIGS. **5** and **6**. For example, in the heating mode, the reversing valve **150** may be adjusted to the second configuration **160** to enable flow of working fluid along the working fluid circuit **108** in the second direction **162**. In the cooling mode, the reversing valve **150** may be adjusted to the first configuration **152** to enable flow of working fluid along the working fluid circuit **108** in the first direction **154**. Additionally, in both the heating mode and the cooling mode, the controller **230** may adjust the first valve **218** and the second valve **220** to respective closed positions to block flow of working fluid through the ejector system **200**. The controller **230** may also adjust the second expansion valve **226** to a fully open position. In both the heating mode and the cooling mode, the separator **224** may operate and function as an accumulator, as similarly described above.

[0085] FIGS. **11-13** are schematics of an embodiment of a portion of the HVAC system **100** that includes the heat pump **102** with the ejector system **200**. The illustrated embodiments of FIGS. **11-13** include similar elements and element numbers as those described above with reference to FIGS. **5-7**. Additionally, the separator **224** includes an internal heat exchanger **300** disposed within a shell **302** (e.g., housing, enclosure) of the separator **224**. For example, the internal heat exchanger **300** may include one or more conduits (e.g., coils, tubes) extending through the shell **302** of the separator **224**. The internal heat exchanger **300** is fluidly coupled to the second conduit **206** and is disposed upstream of the nozzle inlet **214** of the ejector **202** and downstream of the second circuit portion **212** (e.g., relative to a flow of working fluid through the second conduit **206**, downstream of the second valve **220**). Therefore, during operation of the ejector system **200**, the internal heat exchanger **300** may enable transfer of heat between a flow of working fluid directed along the second conduit **206** and working fluid within the shell **302** of the separator **224**.

[0086] FIG. **11** illustrates the heat pump **102** having the ejector system **200** and the separator **224** with the internal heat exchanger **300** configured for operation in an ejector heating mode. As discussed above, the first expansion valve **216** may be in a closed position, and the separator **224** may operate as a flash tank to separate working fluid into liquid working fluid and vapor working fluid in the ejector heating mode. The first valve **218** and the second valve **220** may be in respective open positions in the ejector heating mode. Thus, working fluid may flow from the first heat exchanger **104**, along the second conduit **206**, and through the ejector system **200**, and working fluid may flow from the second heat exchanger **106**, along the first conduit **204**, and through the ejector system **200** in a manner similar to that described above with reference to FIG. **7**. Prior to entering the ejector **202** via the nozzle inlet **214**, the working fluid discharged from the first heat exchanger **104** may flow along the second conduit **206** and through the internal heat exchanger **300** disposed within the shell **302** of the separator **224** to exchange heat with the working fluid within the shell **302** (e.g., external to the internal heat exchanger **300**) of the separator **224**. More specifically, heat may be transferred from the working fluid directed through the internal heat exchanger **300** and to the nozzle inlet **214** of the ejector **202** to the working fluid within the shell **302** of the separator **224**. In this way, the temperature of the working fluid directed to the nozzle inlet **214** of the ejector **202** may be reduced, which may enable recovery of expansion losses in the heat pump **102** and thereby enhance the coefficient of performance of the heat pump **102**, such as embodiments of the heat pump **102** utilizing certain low GWP and low-pressure working fluids (e.g., R1234ze(E), R1234yf). Accordingly, energy consumption of the heat pump **102** may be reduced, which further enables a reduction in greenhouse gas emissions. Moreover, the internal heat exchanger **300** may enable compositional shifts for certain working fluids, such as zeotropic refrigerant blends, during operation of the ejector **202** in the ejector heating mode. Such compositional shifts may enable more efficient operation of the ejector **202**.

[0087] FIG. **12** illustrates the heat pump **102** having the ejector system **200** and the internal heat exchanger **300** configured for operation in a heating mode (e.g., a normal heating mode), and FIG. **13** illustrates the heat pump **102** having the ejector system **200** and the internal heat exchanger **300** configured for operation in a cooling mode. The heat pump **102** having the ejector system **200** and the internal heat exchanger **300** may operate in the heating mode and the cooling mode in a manner similar to that described above with reference to FIGS. **5** and **6**. For example, in the heating mode, the reversing valve **150** may be adjusted to the second configuration **160** to enable flow of working fluid along the working fluid circuit **108** in the second direction **162**. In the cooling mode, the reversing valve **150** may be adjusted to the first configuration **152** to enable flow of working fluid along the working fluid circuit **108** in the first direction **154**. Additionally, in both the heating mode and the cooling mode, the controller **230** may adjust the first valve **218** and the second valve **220** to respective closed positions to block flow of working fluid through the ejector system **200**. The controller **230** may also adjust the second expansion valve **226** to a fully open position. In both the heating mode and the cooling mode, the separator **224** may operate and function as an accumulator, as similarly described above.

[0088] FIGS. **14-16** are schematics of an embodiment of a portion of the HVAC system **100** that includes the heat pump **102** with the ejector system **200**. The illustrated embodiments of FIGS. **14-16** include similar elements and element numbers as those described above with reference to FIGS. **5-7**. In addition to the first expansion valve **216** and the second expansion valve **226**, the working fluid circuit **108** also includes a third expansion valve **320**. The third expansion valve **320** is disposed along the second circuit portion **212** (e.g., between the first heat exchanger **104** and the second conduit **206** of the ejector system **200**). As will be appreciated, incorporation of the first expansion valve **216** and the third expansion valve **320** may be beneficial and/or suitable for embodiments of the heat pump **102** configured as a split system (e.g., residential heating and cooling system **50**).

[0089] FIG. **14** illustrates the heat pump **102** having the ejector system **200** and the third expansion valve **320** configured for operation in an ejector heating mode. As discussed above, the first expansion valve **216** may be in a closed position, and the separator **224** may operate as a flash tank to separate working fluid into liquid working fluid and vapor working fluid in the ejector heating mode. Additionally, the first valve **218** and the second valve **220** may be in respective open positions in the ejector heating mode. The third expansion valve **320** may also be in an open position (e.g., fully open position), in some embodiments. Thus, working fluid may flow from the first heat exchanger **104**, along the second conduit **206**, and through the ejector system **200** and from the second heat exchanger **106**, along the first conduit **204**, and through the ejector system **200** in a manner similar to that described above with reference to FIG. **7**. The two flows of working fluid may mix within the suction chamber **252** of the ejector **202** and may exit the ejector **202** at a greater pressure than a pressure of the working fluid within the second heat exchanger **106**. The working fluid discharged by the ejector **202** may be directed to the separator **224** via the outlet conduit **222** to be separated into vapor working fluid and liquid working fluid, and the vapor working fluid discharged by the separator **224** to the compressor **130** may be greater than the pressure of the working fluid discharged by the second heat exchanger **106**. The increase in pressure of the working fluid directed to the compressor **130** may be particularly advantageous in embodiments of the heat pump **102** utilizing a low GWP working fluid having a low operating pressure. In this way, operation of the heat pump **102** in cold ambient conditions may be improved via operation of the ejector system **200** (e.g., extended operating range in a heating mode, operation of the compressor **130** within an operational envelope).

[0090] FIG. **15** illustrates the heat pump **102** having the ejector system **200** and the third expansion valve **320** configured for operation in a heating mode (e.g., a normal heating mode), and FIG. **16** illustrates the heat pump **102** having the ejector system **200** and the third expansion valve **320** configured for operation in a cooling mode. Additionally, in both the heating mode and the cooling mode, the controller **230** may adjust the first valve **218** and the second valve **220** to respective closed positions to block flow of working fluid through the ejector system **200**. The controller **230** may also adjust the second expansion valve **226** to a fully open position. In both the heating mode and the cooling mode, the separator **224** may operate and function as an accumulator, as similarly described above.

[0091] In the heating mode, the first expansion valve **216** may be operated (e.g., via the controller **230**) to control flow (e.g., throttling, expansion) of the working fluid from the first heat exchanger **104** to the second heat exchanger **106**, and the third expansion valve **320** may be adjusted to a fully open position. In this way, the working fluid directed from the first heat exchanger **104** and along the second circuit portion **212** may remain in a liquid phase until the working fluid flows through the first expansion valve **216** positioned proximate the second heat exchanger **106**. As a result, a pressure drop and heat losses of the working fluid directed along the second circuit portion **212** may be reduced in the heating mode.

[0092] In the cooling mode, the third expansion valve **320** may be operated (e.g., via the controller **230**) to control flow (e.g., throttling, expansion) of the working fluid from the second heat exchanger **106** to the first heat exchanger **104**, and the first expansion valve **216** may be adjusted to a fully open position. In this way, the working fluid directed from the second heat exchanger **106** and along the first circuit portion **208** and the second circuit portion **212** may remain in a liquid phase until the working fluid flows through the third expansion valve **320** positioned proximate the first heat exchanger **104**. As a result, a pressure drop and heat losses of the working fluid directed along the first circuit portion **208** and the second circuit portion **212** may be reduced in the cooling mode.

[0093] FIGS. **17** and **18** are schematics of an embodiment of a portion of the HVAC system **100** that includes the heat pump **102** with the ejector system **200**. The illustrated embodiments of FIGS. **17** and **18** include similar elements and element numbers as those described above with reference to FIGS. **5-7**. In the illustrated embodiments, the working fluid circuit **108** includes a check valve **340** configured to block flow of working fluid from the first heat exchanger **104** to the second heat exchanger **106** (e.g., along the first circuit portion **208**). FIG. **17** illustrates the heat pump **102** configured for operation in a cooling mode, and FIG. **18** illustrates the heat pump **102** configured for operation in a heating mode (e.g., ejector heating mode). The first expansion valve **216** may be utilized to control flow of the working fluid from the second heat exchanger **106** to the first heat exchanger **104** and the second expansion valve **226** may be adjusted toward a fully open position in the cooling mode. Additionally, working fluid may not flow through the ejector system **200** in the cooling mode. To this end, the second valve **220** may be adjusted to a closed position in the cooling mode. In the heating mode, the ejector system **200** may be operated to direct working fluid from the first heat exchanger **104** and the second heat exchanger **106** to the ejector system **200** (e.g., through the ejector **202**) and toward the separator **224**, as similarly discussed above. The separator **224** may operate in the cooling mode and the heating mode as similarly described above.

[0094] FIGS. **19** and **20** are schematics of an embodiment of a portion of the HVAC system **100** that includes the heat pump **102** with the ejector system **200**. The illustrated embodiments of FIGS. **19** and **20** include similar elements and element numbers as those described above with reference to FIGS. **5-7**. In the illustrated embodiments, the working fluid circuit **108** also includes an additional reversing valve **360** configured to adjust flows of working fluid to the ejector **202**. FIG. **19** illustrates the heat pump **102** configured for operation in a cooling mode (e.g., ejector cooling mode), and FIG. **20** illustrates the heat pump **102** configured for operation in the heating mode (e.g., ejector heating mode). The separator **224** may operate as a flash tank in both the cooling mode and the heating mode in the illustrated embodiments. Additionally, the additional reversing valve **260** may be adjusted to a first configuration **362** in the cooling mode and a second configuration **364** in the heating mode to adjust the respective flows of working fluid directed to the nozzle inlet **214** and the chamber inlet **210** of the ejector **202**, as shown. More specifically, in the first configuration **362**, the additional reversing valve **360** is configured to direct working fluid from the second heat exchanger **106** to the nozzle inlet **214** of the ejector **202** and to direct working fluid from the first heat exchanger **104** to the chamber inlet **210** of the ejector **202**. In the second configuration **364**, the additional reversing valve **360** is configured to direct working fluid from the second heat exchanger **106** to the chamber inlet **210** of the ejector **202** and to direct working fluid from the first heat exchanger **104** to the nozzle inlet **214** of the ejector **202**.

[0095] FIGS. **21** and **22** are schematics of an embodiment of a portion of the HVAC system **100** that includes the heat pump **102** with the ejector system **200**. The illustrated embodiments of FIGS. **21** and **22** include similar elements and element numbers as those described above with reference to FIGS. **5-7**, **8-10**, **19**, and **20**. In the illustrated embodiments, the working fluid circuit **108** also includes the additional reversing valve **360**, and the ejector system **200** includes the intermediate heat exchanger **280**. FIG. **21** illustrates the heat pump **102** configured for operation in a cooling mode (e.g., ejector cooling mode), and FIG. **22** illustrates the heat pump **102** configured for operation in the heating mode (e.g., ejector heating mode). The separator **224** may operate as a flash tank in both the cooling mode and the heating mode in the illustrated embodiments. Additionally, the additional reversing valve **260** may be adjusted to the first configuration **362** in the cooling mode and the second configuration **364** in the heating mode to adjust the respective flows of working fluid directed to the nozzle inlet **214** and the chamber inlet **210** of the ejector **202**, as discussed above. The intermediate heat exchanger **280** may also operate as similarly discussed above.

[0096] As set forth above, embodiments of the present disclosure may provide one or more technical effects useful for enabling operation of a heat pump system in cold climate conditions. Indeed, implementation of the disclosed heat pump system (e.g., energy efficient heat pump) with the ejector system may enable operation of a compressor within an operational envelope of the compressor with the heat pump system configured to circulate low GWP and/or low-pressure working fluids, particularly during operation of the heat pump system in a heating mode in low ambient temperature conditions. The present techniques also enable operation of the heat pump across a wider operating range in low ambient temperature conditions. As a result, the present techniques enable utilization of heat pumps (e.g., without auxiliary heating systems, such as furnaces) with low GWP working fluids to satisfy greater demands (e.g., heating demands) with improved efficiency, reduced energy consumption, and reduced greenhouse gas emissions. It should be understood that the technical effects and technical problems in the specification are examples and are not limiting. Indeed, it should be noted that the embodiments described in the specification may have other technical effects and can solve other technical problems.

[0097] While only certain features and embodiments have been illustrated and described, many modifications and changes may occur to those skilled in the art, such as variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, such as temperatures and pressures, mounting arrangements, use of materials, colors, orientations, and so forth, without materially departing from the novel teachings and advantages of the subject matter recited in the claims. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the disclosure.

[0098] Furthermore, in an effort to provide a concise description of the exemplary embodiments, all features of an actual implementation may not have been described, such as those unrelated to the presently contemplated best mode, or those unrelated to enablement. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation specific decisions may be made. Such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure, without undue experimentation.

[0099] The techniques presented and claimed herein are referenced and applied to material objects and concrete examples of a practical nature that demonstrably improve the present technical field and, as such, are not abstract, intangible or purely theoretical. Further, if any claims appended to the end of this specification contain one or more elements designated as "means for [perform]ing [a function] . . . " or "step for [perform]ing [a function] . . . ", it is intended that such elements are to be interpreted under 35 U.S.C. 112(f). However, for any claims containing elements designated in any other manner, it is intended that such elements are not to be interpreted under 35 U.S.C. 112(f).

1. An energy efficient heat pump for a heating, ventilation, and air conditioning (HVAC) system, comprising:

a working fluid circuit configured to circulate a working fluid, wherein the working fluid circuit comprises a compressor, a first heat exchanger, a second heat exchanger, and a reversing valve, wherein the reversing valve is configured to adjust a flow direction of the working fluid through the working fluid circuit; and

an ejector system comprising an ejector configured to receive a first flow of the working fluid from the working fluid circuit as a suction fluid, receive a second flow of the working fluid from the working fluid circuit as a motive fluid, and direct a combined flow of the first flow of the working fluid and the second flow of the working fluid toward the compressor.

2. The energy efficient heat pump of claim **1**, wherein:

the working fluid circuit comprises an expansion valve, a first circuit portion extending from the second heat exchanger to the expansion valve, and a second circuit portion extending from the expansion valve to the first heat exchanger; and

the ejector system comprises:

a first conduit extending from the first circuit portion to the ejector and configured to direct the first flow of the working fluid from the first circuit portion to a chamber inlet of the ejector; and

a second conduit extending from the second circuit portion to the ejector and configured to direct the second flow of the working fluid from the second circuit portion to a nozzle inlet of the ejector.

3. The energy efficient heat pump of claim **2**, wherein:

the working fluid circuit comprises a suction conduit extending from the reversing valve to a suction port of the compressor and a gas-liquid separator disposed along the suction conduit; and

the ejector system comprises an outlet conduit extending from a diffuser of the ejector to the gas-liquid separator, wherein the outlet conduit is configured to direct the combined flow of the first flow of the working fluid and the second flow of the working fluid from the ejector to the gas-liquid separator.

4. The energy efficient heat pump of claim **3**, wherein the gas-liquid separator is configured to separate the combined flow of the first flow of the working fluid and the second flow of the working fluid into vapor working fluid and liquid working fluid, and the working fluid circuit is configured to direct the vapor working fluid from the gas-liquid separator to the compressor and to direct the liquid working fluid from the gas-liquid separator to the reversing valve.

5. The energy efficient heat pump of claim **2**, wherein the ejector system comprises a first valve disposed along the first conduit and a second valve disposed along the second conduit.

6. The energy efficient heat pump of claim **5**, wherein the first heat exchanger is configured to place the working fluid in a first heat exchange relationship with a supply air flow directed across the first heat exchanger, and the second heat exchanger is configured to place the working fluid in a second heat exchange relationship with an ambient air flow directed across the second heat exchanger.

7. The energy efficient heat pump of claim **6**, comprising a controller communicatively coupled to the reversing valve, the expansion valve, the first valve, and the second valve, wherein the controller is configured to output one or more control signals to:

adjust the reversing valve to a first configuration, open the expansion valve, and close the first valve and the second valve to operate the energy efficient heat pump in a cooling mode;

adjust the reversing valve to a second configuration, open the expansion valve, and close the first valve and the second valve to operate the energy efficient heat pump in a heating mode; and

adjust the reversing valve to the second configuration, close the expansion valve, and open the first valve and the second valve to operate to the energy efficient heat pump in an ejector heating mode of the energy efficient heat pump.

8. The energy efficient heat pump of claim **7**, wherein the controller is configured to operate the energy efficient heat pump in the ejector heating mode based on data received from one or more sensors of the energy efficient heat pump, wherein the data is indicative of one or more operating parameters of the energy efficient heat pump.

9. The energy efficient heat pump of claim **8**, wherein the one or more operating parameters comprises a first pressure of the working fluid within the working fluid circuit and a second pressure of the working fluid within the working fluid circuit, and the controller is configured to:

determine a pressure differential of the working fluid based on the first pressure and the second pressure;

compare the pressure differential to a threshold pressure differential value; and

in response to a determination that the pressure differential is equal to or greater than the threshold pressure differential value, operate the energy efficient heat pump in the ejector heating mode.

10. The energy efficient heat pump of claim **8**, wherein the one or more operating parameters comprises a temperature of an ambient environment, and the controller is configured to:

compare the temperature of the ambient environment to a threshold temperature value; and

in response to a determination that the temperature of the ambient environment is less than the threshold temperature value, operate the energy efficient heat pump in the ejector heating mode.

11. The energy efficient heat pump of claim **2**, wherein:

the ejector system comprises an intermediate heat exchanger disposed along the second conduit upstream of the ejector, relative to a direction of the second flow of the working fluid from the second circuit portion to the nozzle inlet of the ejector; and

the working fluid circuit comprises a suction conduit extending from the reversing valve to a suction port of the compressor and a gas-liquid separator disposed along the suction conduit, wherein the gas-liquid separator is configured to receive the combined flow of the first flow of the working fluid and the second flow of the working fluid from the ejector, and the gas-liquid separator is configured to direct vapor working fluid toward the suction port of the compressor,

wherein the intermediate heat exchanger is disposed along the suction conduit between the gas-liquid separator and the suction port of the compressor, and the intermediate heat exchanger is configured to place the second flow of the working fluid in a heat exchange relationship with the vapor working fluid.

12. An energy efficient heat pump, comprising:

a working fluid circuit configured to circulate a working fluid therethrough, wherein the working fluid circuit comprises a first heat exchanger configured to exchange heat between the working fluid and a supply air flow, a second heat exchanger configured to exchange heat between the working fluid and an ambient air flow, and a reversing valve configured to adjust a flow direction of the working fluid along the working fluid circuit;

an ejector system comprising an ejector, a first conduit configured to direct the working fluid from the working fluid circuit to the ejector, a second conduit configured to direct the working fluid from the working fluid circuit to the ejector, and an outlet conduit configured to direct the working fluid from the ejector toward a compressor of the working fluid circuit;

a plurality of valves configured to control flow of the working fluid along the working fluid circuit and through the ejector system; and

a controller communicatively coupled to the plurality of valves and configured to adjust respective positions of the plurality of valves based on an operating mode of the energy efficient heat pump.

13. The energy efficient heat pump of claim **12**, wherein the controller is configured to adjust the respective positions of the plurality of valves to block flow of the working fluid through the ejector system in a cooling mode of the energy efficient heat pump, block flow of the working fluid through the ejector system in a heating mode of the energy efficient heat pump, and enable flow of the working fluid through the ejector system in an alternative heating mode of the energy efficient heat pump.

14. The energy efficient heat pump of claim **13**, wherein the plurality of valves comprises:

a first valve disposed along the first conduit;

a second valve disposed along the second conduit; and

an expansion valve disposed along the working fluid circuit between the first heat exchanger and the second heat exchanger,

wherein the first conduit extends from the working fluid circuit between the second heat exchanger and the expansion valve, and the second conduit extends from the working fluid circuit between the first heat exchanger and the expansion valve.

15. The energy efficient heat pump of claim **14**, wherein the controller is configured to close the first valve and the second valve and to open the expansion valve in the cooling mode and in the heating mode, and the controller is configured to open the first valve and the second valve and to close the expansion valve in the alternative heating mode.

16. The energy efficient heat pump of claim **13**, wherein the working fluid circuit comprises a compressor and a gas-liquid separator, and, in the alternative heating mode, the gas-liquid separator is configured to receive the working fluid from the ejector via the outlet conduit and separate the working fluid into vapor working fluid and liquid working fluid, the working fluid circuit is configured to direct the vapor working fluid from the gas-liquid separator to the compressor, and the working fluid circuit is configured to direct the liquid working fluid from the gas-liquid separator to the reversing valve.

17. The energy efficient heat pump of claim **13**, wherein the controller is configured to operate the energy efficient heat pump in the alternative heating mode in response to a determination that a detected ambient temperature is less than a threshold temperature value.

18. An energy efficient heat pump, comprising:

a first heat exchanger disposed along a working fluid circuit and configured to transfer heat from a working fluid to a supply air flow in a heating mode of the energy efficient heat pump and in an alternative heating mode of the energy efficient heat pump;

a second heat exchanger disposed along the working fluid circuit and configured to transfer heat from an ambient air flow to the working fluid in the heating mode and in the alternative heating mode;

a gas-liquid separator disposed along the working fluid circuit;

an ejector system, comprising:

an ejector comprising a nozzle inlet, a chamber inlet, and an outlet;

a first conduit comprising a first valve, wherein the first conduit is configured to direct a first flow of the working fluid from the working fluid circuit to the chamber inlet of the ejector;

a second conduit comprising a second valve, wherein the second conduit is configured to direct a second flow of the working fluid from the working fluid circuit to the nozzle inlet of the ejector; and

an outlet conduit configured to direct a combined flow of the first flow of the working fluid and the second flow of the working fluid from the outlet of the ejector to the gas-liquid separator; and

a controller configured to adjust the first valve and the second valve to respective closed positions in the heating mode of the energy efficient heat pump and to adjust the first valve and the second valve to respective open positions in the alternative heating mode of the energy efficient heat pump.

19. The energy efficient heat pump of claim **18**, wherein the first conduit is configured to direct the first flow of the working fluid from the second heat exchanger to the chamber inlet of the ejector in the alternative heating mode, and the second conduit is configured to direct the second flow of the working fluid from the first heat exchanger to the nozzle inlet of the ejector in the alternative heating mode.

20. The energy efficient heat pump of claim **18**, wherein the controller is configured to operate the energy efficient heat pump in the alternative heating mode instead of the heating mode in response to a determination that a detected ambient temperature is less than a threshold temperature value, in response to a determination that a pressure differential of the working fluid across the working fluid circuit is equal to or greater than a threshold pressure differential value, or both.

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