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(71) Applicant: ENERGY RECOVERY, INC. [US/US]; 1717 Doolittle Drive, San Leandro, California 94577 (US).

(72) Inventors: MCLEAN, JR., James Elliott; 1717 Doolittle Drive, San Leandro, California 94577 (US). **TRUAX, Matthew Hans**; 1717 Doolittle Drive, San Leandro, California 94577 (US).

(74) Agent: NOEL, Samuel J. et al.; LOWENSTEIN SANDLER LLP, One Lowenstein Drive, Roseland, New Jersey 07068 (US).

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(54) Title: CONTROL OF REFRIGERATION AND HEAT PUMP SYSTEM ARCHITECTURES THAT INCLUDE PRESSURE EXCHANGERS

(57) Abstract: A method includes identifying, by a processing device, a first indication of a speed of operation of a pressure exchanger of a heat transfer system. The method further includes determining, based on the first indication of the speed of operation of the pressure exchanger, a target opening value of a first valve. An inlet of the first valve is coupled to a high-pressure outlet of the PX. The method further includes causing, based on the target opening value, actuation of the first valve.

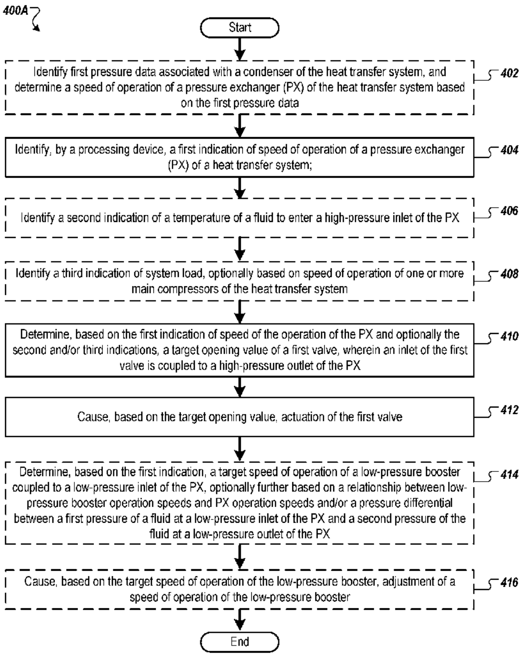

FIG. 4A

[Continued on next page]

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CONTROL OF REFRIGERATION AND HEAT PUMP SYSTEM ARCHITECTURES THAT INCLUDE PRESSURE EXCHANGERS

TECHNICAL FIELD

[0001] The present disclosure relates to control of systems, and, more particularly, control of refrigeration and heat pump systems that include pressure exchangers.

BACKGROUND

[0002] Systems use fluids at different pressures. Systems use pumps and/or compressors to increase pressure of fluid. Energy usage of a fluid handling system may be largely consumed by pumps and/or compressors increasing fluid pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The present disclosure is illustrated by way of example, and not by way of limitation in the figures of the accompanying drawings.

[0004] FIG. 1A is a schematic diagram of a fluid handling system that includes a hydraulic energy transfer system, according to some embodiments.

[0005] FIG. 1B is a schematic diagram of a fluid handling system including a hydraulic energy transfer system, according to some embodiments.

[0006] FIGS. 2A-E are exploded perspective views of pressure exchangers (PXs), according to some embodiments.

[0007] FIGS. 3A-B are schematic diagrams of fluid handling systems including PXs, according to some embodiments.

[0008] FIGS. 4A-C are flow diagrams illustrating methods for controlling fluid handling systems, according to some embodiments.

[0009] FIG. 5 is a block diagram illustrating a computer system, according to certain embodiments.

DETAILED DESCRIPTION OF EMBODIMENTS

[0010] Embodiments described herein are related to control of refrigeration and/or heat pump systems that include pressure exchangers (e.g., control of refrigeration systems, heat pump systems, pressure exchanger systems, fluid handling systems that include a pressure exchanger, heat transfer systems, control systems for carbon dioxide (CO_2) refrigeration systems integrated with rotary pressure exchanger, etc.). In particular, control modules for controlling, maintaining, adjusting, etc., operation of systems including one or more pressure exchangers are described.

[0011] Systems may use fluids at different pressures. A supply of a fluid to a system may be at lower pressure, and one or more portions of the system may operate at higher pressures. A system may include a closed loop with various fluid pressures maintained in different portions of the loop. These systems may include hydraulic fracturing (e.g., fracking or fracing) systems, desalinization systems, refrigeration systems, heat pump systems, energy generation systems, mud pumping systems, slurry pumping systems, industrial fluid systems, waste fluid systems, fluid transportation systems, etc. Pumps or compressors may be used to increase pressure of fluids of such systems.

[0012] Conventionally, heat transfer systems (e.g., refrigeration systems, heat pump systems, reversible heat pump systems, or the like) use pumps or compressors to increase the pressure of a fluid (e.g., a refrigeration fluid such as carbon dioxide (CO_2), R-744, R-134a, hydrocarbons, hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), ammonia (NH_3), refrigerant blends, R-407A, R-404A, etc.). Conventionally, separate pumps or compressors mechanically coupled to motors are used to increase pressure of the fluid in any portion of a system including an increase in fluid pressure. Pumps and compressors, especially those that operate over a large pressure differential (e.g., cause a large pressure increase in the fluid), require large quantities of energy. Conventional systems thus expend large amounts of energy increasing the pressure of the fluid (via the pumps or compressors driven by the motors). Additionally, conventional heat transfer systems decrease the pressure of the fluid through expansion valves and/or heat exchangers (e.g., condensers and/or evaporators, etc.). Conventional systems inefficiently increase pressure of fluid and decrease pressure of the fluid. This is wasteful in terms of energy used to run the conventional systems (e.g., energy used to repeatedly increase the pressure of the refrigeration fluid to cause increase or decrease of temperature of the surrounding environment).

[0013] The systems, devices, and methods of the present disclosure enable control of systems (e.g., fluid handling systems, heat transfer systems, refrigeration systems, heat pump systems, cooling systems, heating systems, etc.) including one or more pressure exchangers (PXs). In a system, a PX may be configured to exchange pressure between a first fluid (e.g., a high pressure portion of a refrigeration fluid in a refrigeration cycle) and a second fluid (e.g., a low pressure portion of the refrigeration fluid in the refrigeration cycle). The PX may receive the first fluid (e.g., a portion of the refrigeration fluid at high pressure) via a first inlet (e.g., a high pressure inlet) and a second fluid (e.g., a portion of the refrigeration fluid at a low pressure) via a second inlet (e.g., a low pressure inlet). When entering the PX, the first fluid may be of a higher pressure than the second fluid. The PX may exchange pressure between the first fluid and the second fluid. The first fluid may exit the PX via a first outlet (e.g., a low pressure outlet) and the second fluid may exit the PX via a second outlet (e.g., a high pressure outlet). When exiting the PX, the second fluid may have a higher pressure than the first fluid (e.g., pressure has been exchanged between the first fluid and the second fluid).

[0014] In some embodiments, a heat transfer system (e.g., refrigeration system, heat pump system, etc.) may target controlled operating conditions. For example, a refrigeration system may target a particular temperature of a refrigerated zone (e.g., for safe storage of perishable materials such as food, medication, scientific or research materials, or the like); a heat pump system may target a comfortable interior temperature for a home; a system may target a rate of heat exchange between the system and the environment; one or more portions of a system may target an operating temperature, pressure, fluid density, or the like; etc. Operational parameters to maintain target conditions may be dependent on many factors, e.g., ambient temperature; mass, type, and initial temperature of material in a temperature-controlled area; frequency of exchange of material and/or energy between a controlled area and the ambient environment; and the like.

[0015] In some embodiments, the PX may be operable at a range of operating speeds. For example, a rotary PX may be operable at a variety of rotational speeds, a reciprocating PX may be operable at a variety of cycle frequencies, or the like. The PX may be coupled to a motor. The motor may be configured to control an operating speed of the PX. The operating speed of the PX may have an impact on fluid flow rate, fluid pressure in various portions of the fluid handling system, etc. In some embodiments, the motor may drive the PX, e.g., if faster flow rate through the PX is targeted, the motor may speed up operation of the PX. In some embodiments, the motor may serve to inhibit the PX, e.g., if slower flow rate through the PX is targeted, the motor may inhibit motion of the PX to maintain a desired flow rate. A controller may be operatively coupled to the motor of the PX. The controller may receive data collected from one or more parts of the fluid handling system, e.g., pressure data indicative of fluid pressure associated with (e.g., in, exiting from) a condenser of the fluid handling system, flow rate data indicative of flow rate through a portion of the fluid handling system, or the like. The controller may generate a control signal for the motor based on the data received indicative of one or more operating conditions of the fluid handling system. The motor may be configured to adjust an operating speed of the PX based on the control signal.

[0016] In some embodiments, operating speed of the PX may be utilized to maintain one or more conditions of the fluid system. For example, the PX speed may be selected to maintain a target fluid pressure at a component upstream of the PX. The PX speed may further impact other conditions of the system, but may be at least partially unavailable for adjustment due to the impact of the PX speed on multiple conditions and components of the system. Additional control methods may be utilized in maintaining one or more target conditions of a fluid system, that may be further affected by an operating speed of the PX.

[0017] In some embodiments, the fluid system may include one or more control valves, that may be opened or closed to enable a target fluid flow rate. A control valve may be included in a fluid system, coupled to a high-pressure outlet of the PX. For example, a fluid may leave a high-pressure outlet of the PX, pass through an auxiliary gas cooler, and be provided to a control valve. The control valve may have an adjustable opening, that is adjusted based on one or more inputs, to maintain a target condition of the fluid system. The control valve opening may be adjusted to maintain a target travel distance of the PX.

[0018] Travel distance is a measure of fluid flow into ducts of the PX. For example, fluid may flow from a first inlet into a duct and exchange pressure with a second fluid that entered the duct from an inlet disposed at the opposite side of the duct. The fluid may then, after exchanging pressure, be removed via an outlet disposed at the same side of the duct that the fluid entered. The travel distance is a measure of how far into the duct the first fluid flows before retreating back to the outlet. Travel distance indicates a volumetric flow through the PX, e.g., based on rotational speed of the PX, number of ducts in the PX, and total duct volume of the PX. Two inlets of the PX may have their own associated travel distances. For example, in operation the PX may operate at a first low-pressure travel distance, associated with travel of a fluid provided at a low-pressure inlet of the PX, and a second high-pressure travel distance, associated with travel of a fluid provided at a high-pressure inlet of the PX. A travel distance target may be chosen based on target volume flow through the PX, target energy efficiency, target pressure exchange efficiency, target mixing of the first and second fluids, or the like.

[0019] One or more travel distances of the PX may be adjusted and/or maintained via adjusting operation of components of a fluid transfer system including the PX. For example, the low-pressure inlet travel distance (e.g., a volume of fluid provided to the PX low-pressure inlet as compared to a working volume of the PX) may be maintained by adjusting the opening of the control valve coupled to the high-pressure outlet of the PX. The working volume of the PX depends on the speed of operation of the PX. For example, in a rotary PX, as rotational speed increases, the number of ducts of the PX utilized in a period of time increases. The control valve may be configured to be controlled based on the PX speed to maintain a target low-pressure inlet travel distance in the PX. Further signals may be taken into account in setting an opening of the control valve, such as total system load (e.g., total fluid flow through the system), temperature at one or more gas coolers, etc.

[0020] In some embodiments, the fluid system may include a booster, compressor, or pump fluidly coupled to the low-pressure inlet of the PX, e.g., a low-pressure booster. The low-pressure booster may be configured to enable flow to the low-pressure inlet of the PX. The low-pressure booster may further affect ow-pressure inlet travel distance in the PX. In some embodiments, one or more parameters (e.g., a speed of operation of the PX, a target low-pressure inlet travel distance, duct volume of the PX, and parameters such as operating volume of the low-pressure booster) may be used to set a speed of operation of the low-pressure booster to achieve the target low-pressure inlet travel distance in the PX.

[0021] In some embodiments, the fluid system may control fluid flow to a low-pressure inlet of the PX via a control valve. The fluid system may not include a low-pressure booster in such a case. In some embodiments, a bulk flow of fluid (e.g., a primary heat transfer fluid flow, such as fluid passing through a main compressor, evaporator, gas cooler, condenser, or the like) may pass through bulk flow channel of a heat exchanger. The heat exchanger may be situated after a main gas cooler or main evaporator of a refrigeration or heat pump system. A portion of the output of the bulk channel of the heat exchanger may pass through a cooling valve (e.g., a controlled expansion valve) and be provided to a secondary channel of the heat exchanger, e.g., to provide cooling to the bulk fluid passing through the bulk channel of the heat exchanger. The control valve may be used to tune the subcooling achieved in the heat exchanger to the bulk fluid flow. For example, an amount fluid passed through the cooling valve may be increased to increase cooling of the bulk fluid in the heat exchanger to achieve a target subcooling, target temperature at the bulk outlet of the heat exchanger, or the like. Achieving and/or maintaining a target fluid temperature, target amount of fluid subcooling, etc., may improve energy efficiency of the system, heat transfer efficiency of the system, or the like. A target temperature drop across the heat exchanger may be enabled by adjusting an opening of the control valve to adjust the amount of cooling provided to the bulk fluid by the secondary fluid in the secondary channel of the heat exchanger.

[0022] In some embodiments, a boosterless system may further include a second control valve. The second control valve may be coupled to the high-pressure outlet of the PX, for example after an auxiliary condenser or gas cooler. The second control valve may further affect conditions of the fluid system. The second control valve may be controlled based on, for example, the opening of the first control valve, total system load, temperature at the outlet of the bulk channel in the heat exchanger, or the like.

[0023] Systems, devices, and methods of the present disclosure provide advantages over conventional solutions. Systems of the present disclosure reduce energy consumption compared to conventional systems. For example, use of a PX in a heat transfer system of the present disclosure may recover energy stored as pressure and transfer that energy back into the system, reducing the energy cost of operating the heat transfer system. Various controllers employed by the system may increase energy efficiency of the system by, for example, maximizing the transfer of pressure from the first fluid to the second fluid via the PX (e.g., by adjusting fluid flow rates, fluid pressures, PX operating speed, or the like). Systems of the present disclosure may reduce wear on components (e.g., pumps, compressors) compared to conventional systems. Introduction of a PX may reduce the pumping load on one or more pumps/compressors, e.g., may reduce a target pressure differential a compressor is to achieve. One or more controllers (e.g., control system) may improve operation of pumps and compressors by enabling operation at a target pumping speed, e.g., a pumping speed selected to meet target system output (e.g., maintain a target temperature in a heat transfer system) while protecting one or more components of the system (e.g., a minimum viable pumping speed). Systems of the present disclosure may protect one or more components from damage. For example, a compressor of the system may be sensitive to the phase of material provided to the compressor (e.g., may be configured to compress a gas, may become damaged if supplied with liquid, etc.). A controller of the system may alter one or more operating parameters of the system (e.g., a fluid flow rate, a pumping speed, PX operating speed, control valve opening, etc.) to maintain a supply of gas to the compressor (e.g., by maintaining a target value of super heat of the gas). Systems of the present disclosure may allow for more flexibility in component selection for a fluid handling system. For example, one or more controllers (e.g., control system) may be operatively coupled, and may work together to maintain one or more operating conditions. For example, a system may include multiple controllers (e.g., control system) operatively coupled to multiple components (e.g., configured to facilitate adjustment of one or more operating parameters of the components). Multiple control signals may be generated to achieve one or more target tasks, e.g., temperature of a region associated with a heat transfer system may be maintained, and load on a pump may be kept within a target range. By utilizing multiple controllers of a system, such goals may be achievable, and/or the user may be able to use a greater selection of components in the system (e.g., may include a pump with a small manufacturer recommended operating pressure range in a system where pressure at the pump can be maintained within that range for a variety of operating conditions).

[0024] Although some embodiments of the present disclosure are described in relation to pressure exchangers, energy recovery devices, and hydraulic energy transfer systems, the current disclosure can be applied to other systems and devices (e.g., pressure exchanger that is not isobaric, rotating components that are not a pressure exchanger, a pressure exchanger that is not rotary, systems that do not include pressure exchangers, etc.).

[0025] Although some embodiments of the present disclosure are described in relation to exchanging pressure between fluid used in fracing systems, desalinization systems, heat pump systems, and/or refrigeration systems, the present disclosure can be applied to other types of systems. Fluids can refer to liquid, gas, transcritical fluid, supercritical fluid, subcritical fluid, and/or combinations thereof.

[0026] In some aspects of the present disclosure, a method includes obtaining, by a processing device, a first indication of a speed of operation of a PX of a heat transfer system. The method further includes determining, based on the first indication of the speed of operation of the PX, a target opening value of a first valve, where an inlet of the first valve is coupled to a high-pressure outlet of the PX. The method further includes generating a control signal based on the target opening value. The method further includes causing actuation of the first valve to the target opening value by providing the first control signal to the valve.

[0027] In some aspects of the present disclosure, a method includes obtaining, by a processing device, a first indication of a speed of operation of a PX of a heat transfer system. The method further includes determining, based on the first indication of the speed of operation of the PX, a target speed of operation of a low-pressure booster, where an outlet of the low-pressure booster is coupled to a low-pressure inlet of the PX. The method further includes generating a first control signal based on the target speed of operation of the low-pressure booster. The method further includes providing the first control signal to the low-pressure booster. The low-pressure booster is configured to adjust a speed of operation of the low-pressure booster in view of the first control signal.

[0028] In some aspects of the present disclosure, a method includes obtaining, by a processing device, first temperature data. The first temperature data is indicative of a temperature difference between a fluid at a bulk fluid inlet of a heat exchanger and the fluid at a bulk fluid outlet of the heat exchanger. The outlet of the heat exchanger is coupled to a high-pressure inlet of a PX. The method further includes determining, based on the first temperature data, a target adjustment to a first valve coupled to the bulk fluid outlet of the heat exchanger and to a secondary fluid inlet of the heat exchanger. The method further includes generating a first control signal based on the target adjustment. The method further includes providing the first control signal to the first valve. The first valve is configured to adjust an opening of the first valve in accordance with the target adjustment based on the first control signal.

[0029] In some aspects of the present disclosure, a non-transitory machine-readable storage medium stores instructions. The instructions, when executed, case a processing device to perform any of the above methods. In some aspects of the present disclosure, a system includes memory and a processing device coupled to the memory. The processing device is configured to perform any of the above methods. In some aspects of the present disclosure, a fluid handling system includes a PX and a controller. The controller is configured to perform operations related to maintaining target conditions of the fluid handling system, in accordance with the above methods.

[0030] FIG. 1A illustrates a schematic diagram of a fluid handling system 100A (e.g., heat transfer system) that includes a hydraulic energy transfer system 110, according to certain embodiments.

[0031] In some embodiments, a hydraulic energy transfer system 110 includes a pressure exchanger (e.g., PX). The hydraulic energy transfer system 110 (e.g., PX, a collection of components including a PX, etc.) receives low pressure (LP) fluid in 120 (e.g., via a low-pressure inlet) from an LP in system 122. The hydraulic energy transfer system 110 also receives high pressure (HP) fluid in 130 (e.g., via a high-pressure inlet) from HP in system 132. The hydraulic energy transfer system 110 (e.g., PX) exchanges pressure between the HP fluid in 130 and the LP fluid in 120 to provide LP fluid out 140 (e.g., via low-pressure outlet) to LP fluid out system 142 and to provide HP fluid out 150 (e.g., via high-pressure outlet) to HP fluid out system 152. A controller 180 may cause an adjustment of flowrates of HP fluid in 130 and LP fluid out 140 by one or more flow valves, pumps, and/or compressors (not illustrated). The controllers 185 may be configured to cause various operations (e.g., of controllable components 186) to be performed. Controller 185 may be configured to cause actuation of one or more valve. Controllers 185 may be configured to cause adjustments to speed of operation of one or more components. Controllers 185 may cause other operations of controllable components 186. The controllers 185 may cause one or more valves to actuate. The controllers 185 may activate, deactivate, or adjust operation of one or more pumps (e.g., adjust an operating speed of a booster pump).

[0032] In some embodiments, the hydraulic energy transfer system 110 includes a PX to exchange pressure between the HP fluid in 130 and the LP fluid in 120. In some embodiments, the PX is substantially or partially isobaric (e.g., an isobaric pressure exchanger (IPX)). The PX may be a device that transfers fluid pressure between HP fluid in 130 and LP fluid in 120 at efficiencies (e.g., pressure transfer efficiencies, substantially isobaric) in excess of approximately 50%, 60%, 70%, 80%, 90%, or greater (e.g., without utilizing centrifugal technology). High pressure (e.g., HP fluid in 130, HP fluid out 150) refers to pressures greater than the low pressure (e.g., LP fluid in 120, LP fluid out 140). LP fluid in 120 of the PX may be pressurized and exit the PX at high pressure (e.g., HP fluid out 150, at a pressure greater than that of LP fluid in 120), and HP fluid in 130 may be at least partially depressurized and exit the PX at low pressure (e.g., LP fluid out 140, at a pressure less than that of the HP fluid in 130). The PX may operate with the HP fluid in 130 directly applying a force to pressurize the LP fluid in 120, with or without a fluid separator between the fluids. Examples of fluid separators that may be used with the PX include, but are not limited to, pistons, bladders, diaphragms, and/or the like.

[0033] In some embodiments, PXs may be rotary devices. Rotary PXs, such as those manufactured by Energy Recovery, Inc. of San Leandro, Calif., may not have any separate valves, since the effective valving action is accomplished internal to the device via the relative motion of a rotor with respect to end covers. In some embodiments, rotary PXs operate with internal pistons to isolate fluids and transfer pressure with relatively little mixing of the inlet fluid streams. In some embodiments, rotary PXs operate without internal pistons between the fluids.

[0034] In some embodiments, PXs may be reciprocating devices. Reciprocating PXs may include a piston moving back and forth in a cylinder for transferring pressure between the fluid streams. For example, a reciprocating PX may include one or more pressure exchange chambers. The pressure exchange chambers may each include a piston. First fluid at a high pressure may be allowed into one side of a pressure exchange chamber to transfer energy (e.g., via displacement of the piston) to a second fluid at a low pressure on the opposite side of the pressure exchange chamber. The first fluid, now at a low pressure, may then be allowed to drain from the pressure exchange chamber, as the second fluid, now at a high pressure, it utilized for operation of the fluid handling system (e.g., for desalinization, fracing, refrigeration, heat transfer, or the like). Low pressure second fluid may then be allowed to fill the second side of the pressure exchange chamber, and subsequently high pressure first fluid may be introduced into the first side of the pressure exchange chamber to transfer energy to another portion of the second fluid. A reciprocating device may include many pressure exchange chambers operating in a cycle for substantially continuous flow of high pressure second fluid from the device.

[0035] In some embodiments, PXs may be hydraulic turbocharger devices. A hydraulic turbocharger PX may introduce a first fluid at a high pressure to a chamber including a first impeller. The first high pressure fluid may cause the impeller to rotate by transferring energy from the first fluid to the impeller. The first impeller may be coupled to a shaft that is further coupled to a second impeller in a separate chamber. Rotation of the first impeller may cause rotation of the second impeller. The second impeller may be in contact with a second fluid at a low pressure. Rotation of the impeller may transfer energy to the second fluid (e.g., increase pressure of the second fluid).

[0036] Any PX or multiple PXs may be used in the present disclosure, such as, but not limited to, rotary PXs, reciprocating PXs, hydraulic turbocharger PXs, or any combination thereof. In addition, the PX may be disposed on a skid separate from the other components of a fluid handling system 100A (e.g., in situations in which the PX is added to an existing fluid handling system). For example, the PX may be fastened to a structure that can be moved from one site to another. The PX may be coupled to a system (e.g., pipes of a system, etc.) that has been built on-site. The structure to which the PX is fastened may be referred to as a ‘skid.’

[0037] In some embodiments, a motor 160 is coupled to hydraulic energy transfer system 110 (e.g., to a PX). In some embodiments, the motor 160 controls the speed of a rotor of the hydraulic energy transfer system 110 (e.g., to increase pressure of HP fluid out 150, to decrease pressure of HP fluid out 150, etc.). In some embodiments, motor 160 generates energy (e.g., acts as a generator) based on pressure exchanging in hydraulic energy transfer system 110. For example, a pressure differential (e.g., a difference between the pressure of LP fluid in 120 and HP fluid in 130) may drive rotation of a rotary PX, and motor 160 may introduce resistance to that rotation to both slow the rotation and generate electricity. Alternatively, the motor may act to slow the PX without generating electricity.

[0038] The hydraulic energy transfer system 110 may include a hydraulic turbocharger or hydraulic pressure exchanger, such as a rotating PX. The PX may include one or more chambers and/or channels (e.g., 1 to 100) to facilitate pressure transfer between first and second fluids (e.g., gas, liquid, multi-phase fluid).

[0039] In some embodiments, hydraulic energy transfer system 110 may transfer energy (e.g., pressure) between two fluids of substantially different composition, phase, or the like. For example, a PX of hydraulic energy transfer system 110 may transfer pressure between a first fluid (e.g., pressure exchange fluid, such as a proppant free fluid, substantially proppant free fluid, lower viscosity fluid, fluid that has lower than a threshold amount of certain chemicals, etc.) and a second fluid that may have a higher viscosity (e.g., be highly viscous), include more than a threshold amount of certain chemicals (e.g., corrosive chemicals), and/or contain solid particles (e.g., frac fluid containing sand, proppant, powders, debris, ceramics, etc.). By transferring energy from one type of fluid to another, expensive components such as pumps may be protected from coming into contact with fluids that may be harmful to them, such as viscous, corrosive, or abrasive fluids.

[0040] In some embodiments, hydraulic energy transfer system 110 may transfer energy (e.g., pressure) between two fluids of substantially similar compositions. For example, in some conventional systems, a waste stream of the system may include fluid at a high pressure. Hydraulic energy transfer system 110 may accept as high pressure input (e.g., HP fluid in 130) the high pressure waste stream and transfer energy from that stream to a low pressure work stream (e.g., LP fluid in 120). In some systems, such as a closed refrigeration system, energy may be recovered from a high pressure portion of a fluid stream to reduce pump and/or compressor requirements on the fluid stream.

[0041] In some embodiments, LP in system 122 includes a booster (e.g., a pump and/or a compressor) to increase pressure of fluid to form LP fluid in 120 or to facilitate mass transfer of the fluid for supply to hydraulic energy transfer system 110. In some embodiments, LP in system 122 receives a gas from LP out system 142. In many embodiments, LP in system 122 receives fluid from a receiver (e.g., flash tank). The receiver may receive LP fluid out 140 output from hydraulic energy transfer system 110.

[0042] Fluid handling system 100A further includes control module 180. Control module 180 may include one or more controllers 185. Control module 180 may be configured to perform any of the methods of FIGS. 4A-C. Controllers 185 of control module 180 may receive data (e.g., measurement data) from sensors associated with fluid handling system 100A. Controllers 185 may be configured to generate control signals based on operations parameters (e.g., threshold values, designated operating ranges, target parameter values, etc.) and/or data received from the sensors. Controllers 185 may include a single device performing one or more control tasks, separate devices for each control task (e.g., each controllable component of fluid handling system 100A), several devices for performing a number of functions each, etc. For example, operations of each of the controllers 185 may be performed by a separate device, or operations of all of the controllers 185 may be performed by a single device, or a combination of separate and combined devices may be employed.

Components of control module 180 may include general computing devices, personal computers (PCs), laptops, mobile phones, tablet computers, netbook computers, microcontrollers, purpose-built controllers (e.g., hardware, circuitry, etc.), proportional integral derivative (PID) controllers (e.g., three-term controllers), a web appliance, or any other device capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken by that device. Control module 180 may include multiple controllers acting separately (e.g., without input between from one controller to another, without measurement data from one sensor feeding into multiple controllers, etc.). Control module 180 may include multiple controllers working in conjunction with one another, e.g., a target adjustment to operating parameters of the fluid handling system 110A (e.g., as reported by one or more sensor of the system) may include adjustment of operation of one or more components of the system by one or more controllers of control module 180.

[0043] Fluid handling system 100A may additionally include one or more sensors to provide sensor data (e.g., flowrate data, pressure data, velocity data, etc.) associated with the fluids of fluid handling system 100A. Controllers 185 may control one or more flow rates of fluid handling system 100A, operation of one or more components of fluid handling system 100A (e.g., operation of motor 160, operation of one or more pumps, etc.), or the like based on the sensor data. In some embodiments, controllers 185 cause one or more flow valves to actuate based on sensor data received.

[0044] The hydraulic energy transfer system 110 may be used in different types of systems, such as fracing systems, desalination systems, refrigeration systems (e.g., FIG. 1B), heat pump systems, slurry pumping systems, industrial fluid systems, waste fluid systems, fluid transportation systems, etc.

[0045] Controllers 185 of control module 185 may provide control signals to interdependent components of fluid handling system 100A. For example, controllers 185 may provide control signals to motor 160 to control an operating speed of hydraulic energy transfer system 110. An operating speed of hydraulic energy transfer system 110 may further affect conditions in other locations of fluid handling system 100A. Other components, for example valves, pumps, etc., may be operated to control conditions of fluid handling system 100A which are affected by the operating speed of hydraulic energy transfer system 110. Controllers 185 may provide signals to various controllable components 186 that are included in fluid handling system 100A. Various components of the subsystems of fluid handling system 100A may be controlled by signals provided by controllers 185 that are based on an operating speed of hydraulic energy transfer system 110.

[0046] FIG. 1B illustrates a schematic diagram of a fluid handling system 100B including a hydraulic energy transfer system 110, according to certain embodiments. Fluid handling system 100B may be, for example, a heat transfer system, a refrigeration system or a heat pump system. Fluid handling system 100B may be configured to cool and/or heat an environment (e.g., an indoor space, a refrigerator, a freezer, etc.). In some embodiments, fluid handling system 100B includes more components, less components, same routing, different routing, and/or the like than that shown in FIG. 1B. Some of the features in FIG. 1B that have similar reference numbers as those in FIG. 1A may have similar properties, functions, and/or structures as those in FIG. 1A.

[0047] Hydraulic energy transfer system 110 (e.g., PX) may receive LP fluid in 120 from LP in system 122 (e.g., low pressure lift device 128, low pressure fluid pump, low pressure booster pump, low pressure compressor, low pressure ejector, etc.) and HP fluid in 130 from HP in system 132 (e.g., condenser 138, gas cooler, heat exchanger, etc.). The hydraulic energy transfer system 110 (e.g., PX) may exchange pressure between the LP fluid in 120 and HP fluid in 130 to provide HP fluid out 150 to HP out system 152 (e.g., high pressure lift device 159, high pressure fluid pump, high pressure booster pump, high pressure compressor, high pressure ejector, etc.) and to provide LP fluid out 140 to LP out system 142 (e.g., evaporator 144, heat exchanger, etc.). The LP out system 142 (e.g., evaporator 144) may provide the fluid to compressor 178 and low pressure lift device 128. The evaporator 144 may provide the fluid to compressor 178 and/or to the low pressure lift device 128. In some embodiments a different component may provide fluid to low pressure lift device 128, evaporator 144, etc. For example, LP fluid out 140 may be provided to a receiver of flash tank. Liquid output from the flash tank may be provided to evaporator 144, and gas output of the flash tank may be provided to low pressure lift device 128. In some embodiments, additional valves, lines, pipes, fluid flow paths, etc., may provide fluid to different devices in different orders and/or combinations. The condenser 138 may receive fluid from compressor 178 and high pressure lift device 159. Controller 180 may control one or more components of fluid handling system 100B, e.g., including motor 160 and various other controllable components 186. High pressure lift device 159 may be a high pressure booster and low pressure lift device 128 may be a low pressure booster.

[0048] The fluid handling system 100B may be a closed system. LP fluid in 120, HP fluid in 130, LP fluid out 140, and HP fluid out 150 may all be a fluid (e.g., refrigerant, the same fluid) that is circulated in the closed system of fluid handling system 100B.

[0049] Fluid handling system 100B may additionally include one or more sensors configured to provide sensor data associated with the system. For example, sensors may report on properties of the fluid at various stages of the system (e.g., various components of the system) such as temperature, pressure, flow rate, density, etc. Sensors may measure properties related to the function of fluid handling system 100B, e.g., a refrigeration system may include one or more temperature sensors reporting on the temperature of the region to be refrigerated. Sensors may measure properties influencing operation of fluid handling system 100B, e.g., a heat transfer system intended to heat a region associated with condenser 138 may measure temperature proximate to evaporator 144, and may use the temperature measurements proximate to evaporator 144 to alter one or more operating parameters of fluid handling system 100B, e.g., to achieve a target output (e.g., temperature), to improve efficiency of operation, or the like.

[0050] Control module 180 may be configured to perform any of the methods described in connection with FIGS. 4A-C. Controllers 185 of control module 180 may receive sensor data from sensors (e.g., raw sensor data, preprocessed sensor data, average sensor data, data as a difference of a measured value from a target/threshold value, etc.). Controllers 185 may be configured to generate one or more control signals based on the input sensor data. Control signals may facilitate operation of adjustable components of fluid handling system 100B.

[0051] Fluid handling system 100B may include one or more valves with variable openings. For example, a fluid flow rate may be altered by adjusting an opening of a valve. Valves may be electronically adjustable, e.g., a valve may be an electronic expansions valve (EEV). A valve may be configured to adjust an opening of the valve (e.g., a percent open value) based on a control signal received from control module 180. Fluid handling system 100B may include one or more pumps, compressors, or the like. Pumps and compressors may be configured with variable run speeds (e.g., motor operation speed, pumping speeds, etc.). Pumps and compressors may be configured to adjust a speed of operation based on a control signal received from control module 180. Fluid handling system 100B may include motor 160 coupled to a PX of hydraulic energy transfer system 110. Motor 160 may be configured to adjust a speed of operation of the PX based on a signal received from control module 180. For example, motor 160 may act as a generator by transferring rotational energy of the PX to electrical energy.

[0052] FIGS. 2A-E are exploded perspective views of a rotary PX 40 (e.g., rotary pressure exchanger, rotary liquid piston compressor (LPC)), according to certain embodiments. Some of the features in one or more of FIGS. 2A-E may have similar properties, functions, and/or structures as those in one or more of FIGS. 1A-B.

[0053] PX 40 is configured to transfer pressure and/or work between a first fluid (e.g., refrigerant, particle free fluid, proppant free fluid, supercritical carbon dioxide, HP fluid in 130) and a second fluid (e.g., refrigerant, slurry fluid, frac fluid, superheated gaseous carbon dioxide, LP fluid in 120) with minimal mixing of the fluids. The rotary PX 40 may include a generally cylindrical body portion 42 that includes a sleeve 44 (e.g., rotor sleeve) and a rotor 46. The rotary PX 40 may also include two end caps 48 and 50 that include manifolds 52 and 54, respectively. Manifold 52 includes respective inlet port 56 and outlet port 58, while manifold 54 includes respective inlet port 60 and outlet port 62. In operation, these inlet ports 56, 60 enable the first and second fluids to enter the rotary PX 40 to exchange pressure, while the outlet ports 58, 62 enable the first and second fluids to then exit the rotary PX 40. In operation, the inlet port 56 may receive a high-pressure first fluid (e.g., HP fluid in 130) output from a condenser, and after exchanging pressure, the outlet port 58 may be used to route a low-pressure first fluid (e.g., LP fluid out 140) out of the rotary PX 40 to a receiver (e.g., flash tank) configured to receive the first fluid from the rotary PX 40. The receiver may form a chamber configured to separate the fluid into a gas and a liquid. Similarly, the inlet port 60 may receive a low-pressure second fluid (e.g., low pressure slurry fluid, LP fluid in 120) from a booster configured to receive a portion of the gas from the receiver and increase pressure of the gas, and the outlet port 62 may be used to route a high-pressure second fluid (e.g., high pressure slurry fluid, HP fluid out 150) out of the rotary PX 40. The end caps 48 and 50 include respective end covers 64 and 66 (e.g., end plates) disposed within respective manifolds 52 and 54 that enable fluid sealing contact with the rotor 46.

[0054] Ports of the PX are fluidly coupled to a fluid system. The fluid system may include one or more controllable components 186. The controllable components 186 are fluidly coupled to the PX, for example, by outlet port 58 and outlet port 62. The controllable components 186 may include control valves, pumps or compressors, etc. There may further be controllable components 186 that are not directly fluidly coupled to PX 40, e.g., one or more fans for providing additional heat transfer to or from a heat exchanger that is fluidly coupled to PX 40.

[0055] One or more components of the PX 40, such as the rotor 46, the end cover 64, and/or the end cover 66, may be constructed from a wear-resistant material (e.g., carbide, cemented carbide, silicon carbide, tungsten carbide, etc.) with a hardness greater than a predetermined threshold (e.g., a Vickers hardness number that is at least 1000, 1250, 1500, 1750, 2000, 2250, or more). For example, tungsten carbide may be more durable and may provide improved wear resistance to abrasive fluids as compared to other materials, such as alumina ceramics. Additionally, in some embodiments, one or more components of the PX 40, such as the rotor 46, the end cover 64, the end cover 66, and/or other sealing surfaces of the PX 40, may include an insert. In some embodiments, the inserts may be constructed from one or more wear-resistant materials (e.g., carbide, cemented carbide, silicon carbide, tungsten carbide, etc.) with a hardness greater than a predetermined threshold (e.g., a Vickers hardness number that is at least 1000, 1250, 1500, 1750, 2000, 2250, or more) to provide improved wear resistance.

[0056] The rotor 46 may be cylindrical and disposed in the sleeve 44, which enables the rotor 46 to rotate about the axis 68. The rotor 46 may have a plurality of channels 70 (e.g., ducts, rotor ducts) extending substantially longitudinally through the rotor 46 with openings 72 and 74 (e.g., rotor ports) at each end arranged symmetrically about the longitudinal axis 68. The openings 72 and 74 of the rotor 46 are arranged for hydraulic communication with inlet and outlet apertures 76 and 78 (e.g., end cover inlet port and end cover outlet port) and 80 and 82 (e.g., end cover inlet port and end cover outlet port) in the end covers 64 and 66, in such a manner that during rotation the channels 70 are exposed to fluid at high-pressure and fluid at low-pressure. As illustrated, the inlet and outlet apertures 76 and 78 and 80 and 82 may be designed in the form of arcs or segments of a circle (e.g., C-shaped).

[0057] In some embodiments, a control module 180 may be operatively coupled to the controllable components 186. In some embodiments, a single control module may be utilized in controlling some or all of the controllable components 186. In some embodiments, one or more controllable components of controllable components 186 may have a dedicated corresponding control module 180. Control module 180 may be configured to perform any methods described in connection with FIGS. 4A-C. Control module 180 may receive sensor data (e.g., revolutions per minute measured through a tachometer or optical encoder, volumetric flow rate measured through flowmeter, pressure or temperature data of fluid in the fluid handling system, etc.). Control module 180 may generate a control signal based on sensor data. Control module 180 may use the control signal to adjust operation of controllable components 186.

[0058] Controllable component 186 may include one or more control valves. Control of a control valve may include performing operations such that a target amount of fluid passes through the control valve. The opening of the valve may be openable to a range of sizes, a range of percent openings, or the like. Control module 180 may, for example, generate a control signal that causes a valve actuator to operate, moving a valve component to a target position to generate the target opening for fluid flow.

[0059] Controllable components 186 may include one or more pumps, compressors, boosters, or the like. Control module 180 may generate a control signal that causes a pump (including booster, compressor, etc.) to achieve a target operating speed (e.g., RPM of a component of the pump), a target pumping speed, or the like.

[0060] Control module 180 may determine a target set value for one or more controllable components to maintain a target performance of the fluid system. For example, control module 180 may receive sensor data and generate a control signal based on the sensor data for increasing or decreasing some property of interest in the fluid system. Control module 180 may receive sensor data of the property of interest or may receive sensor data related to the property of interest. For example, control module 180 may be configured to provide control signals to maintain a target travel distance of the PX 40 (e.g., within a threshold error), based on pressures measured in various parts of the fluid system that are indicative of travel distance of the PX 40.

[0061] An operating speed of PX 40 may be utilized to control the extent of mixing between the first and second fluids in the rotary PX 40, which may be used to improve the operability of the fluid handling system (e.g., fluid handling systems 100A-B of FIGS. 1A-B). For example, varying the volumetric flow rates of the first and/or second fluids entering the rotary PX 40 allows the operator (e.g., system operator, plant operator) to control the amount of fluid mixing within the PX 40. In addition, varying the rotational speed of the rotor 46 (e.g., via a motor) also allows the operator to control mixing. Three characteristics of the rotary PX 40 that affect mixing are: (1) the aspect ratio of the rotor channels 70; (2) the duration of exposure between the first and second fluids; and (3) the creation of a barrier (e.g., fluid barrier, piston, interface) between the first and second fluids within the rotor channels 70. First, the rotor channels 70 (e.g., ducts) are generally long and narrow, which stabilizes the flow within the rotary PX 40. In addition, the first and second fluids may move through the channels 70 in a plug flow regime with minimal axial mixing. Second, in certain embodiments, the speed of the rotor 46 reduces contact between the first and second fluids. For example, the speed of the rotor 46 (e.g., rotor speed of approximately 1200 revolutions per minute (RPM)) may reduce contact times between the first and second fluids to less than approximately 0.15 seconds, 0.10 seconds, or 0.05 seconds. Third, the rotor channel 70 (e.g., a small portion of the rotor channel 70) is used for the exchange of pressure between the first and second fluids. In some embodiments, a volume of fluid remains in the channel 70 as a barrier between the first and second fluids. All these mechanisms may limit mixing within the rotary PX 40. Moreover, in some embodiments, the rotary PX 40 may be designed to operate with internal pistons or other barriers, either complete or partial, that isolate the first and second fluids while enabling pressure transfer.

[0062] In some embodiments, a speed of operation of the PX may be set (e.g., targeting the properties listed above, or other properties of interest in the fluid system). Properties of the fluid system may be affected by the PX 40 rotational speed. Control module 180 may receive an indication of PX 40 speed of operation (e.g., from a sensor, from a control signal for a controller of PX 40, etc.), and may generate control signals for controllable components 186 which are based on speed of operation of PX 40.

[0063] In some embodiments, control module 180 may receive an indication of a speed of operation of PX 40. The indication of speed of operation of PX 40 may be provided by a sensor measuring the speed of operation. The indication of speed of operation of PX 40 may be provided by a control module for a motor of PX 40, be based on the same information as a control signal for the speed of PX 40, or the like. Based on the speed of operation of PX 40, control module 180 may provide a control signal to a control valve of controllable components 186. The control valve may adjust an opening of the control valve to a target opening in response to the control signal. In some embodiments, further sensor data may be utilized, such as temperature data of a fluid, pressure data of the fluid, or the like.

[0064] In some embodiments, control module 180 may receive an indication of speed of operation of PX 40. Based on the speed of operation of PX 40, control module 180 may provide a control signal to a pump, e.g., a low-pressure booster pump. The pump may adjust a speed of operation of the pump based on the control signal. The pump speed may be selected to achieve a target travel distance of a fluid provided to a low-pressure inlet of the PX 40 (e.g., LP-IN travel distance). Further indications may be taken into account in generating the control signal, e.g., fluid temperature of a gas cooler (e.g., heat exchanger), fluid pressure of a gas cooler, or the like.

[0065] In some embodiments, control module 180 may receive temperature data of a temperature difference between a fluid at a bulk fluid inlet of a heat exchanger and the fluid at a bulk fluid outlet of the heat exchanger. A control signal may be generated by control module 180 based on the temperature difference. The control signal may cause actuation of a valve. The control signal may cause a target value of subcooling of the bulk fluid to be achieved in the heat exchanger.

[0066] FIGS. 2B-2E are exploded views of an embodiment of the rotary PX 40 illustrating the sequence of positions of a single rotor channel 70 in the rotor 46 as the channel 70 rotates through a complete cycle. It is noted that FIGS. 2B-2E are simplifications of the rotary PX 40 showing one rotor channel 70, and the channel 70 is shown as having a circular cross-sectional shape. In other embodiments, the rotary PX 40 may include a plurality of channels 70 with the same or different cross-sectional shapes (e.g., circular, oval, square, rectangular, polygonal, etc.). Thus, FIGS. 2B-2E are simplifications for purposes of illustration, and other embodiments of the rotary PX 40 may have configurations different from those shown in FIGS. 2A-2E. As described in detail below, the rotary PX 40 facilitates pressure exchange between first and second fluids (e.g., a particulate-free fluid and a slurry fluid, higher pressure refrigerant and lower pressure refrigerant, etc.) by enabling the first and second fluids to briefly contact each other within the rotor 46. In some embodiments, the PX facilitates pressure exchange between first and second fluids by enabling the first and second fluids to contact opposing sides of a barrier (e.g., a reciprocating barrier, a piston, not shown). In some embodiments, this exchange happens at speeds that result in limited mixing of the first and second fluids. The speed of the pressure wave traveling through the rotor channel 70 (as soon as the channel is exposed to the aperture 76), the diffusion speeds of the fluids, and/or the rotational speed of rotor 46 may dictate whether any mixing occurs and to what extent.

[0067] FIGS. 2B-E include controllable components 186, fluidly coupled to one or more outlets of PX 40. Controllable components 186 may be provided control signals in accordance with any of the methods of FIGS. 4A-C. FIGS. 2B-E depict various stages of operation of PX 40. Operation of PX 40 may be controlled by a control module, e.g., control module 180 of FIGS 1A-B. For example, the control module may be operatively coupled to a motor of the PX. The control module may send one or more control signals to the motor. The motor may adjust operation of PX 40, e.g., may adjust a speed of rotation of PX 40, a speed of rotation of PX 40, etc. The control module may be operatively coupled to other components of a fluid handling system that affect operation of PX 40. For example, one or more compressors that supply fluid to PX 40 may be controlled by the control module, one or more valves that supply fluid to PX 40 may be controlled by the control module, one or more valves coupled to an outlet of PX 40 may be controlled by the control module, etc. These components may include controllable components 186 of FIGS. 2B-E.

[0068] FIG. 2B is an exploded perspective view of an embodiment of a rotary PX 40 (e.g., rotary LPC), according to certain embodiments. In FIG. 2B, the channel opening 72 is in a first position. In the first position, the channel opening 72 is in fluid communication with the aperture 78 in end cover 64 and therefore with the manifold 52, while the opposing channel opening 74 is in hydraulic communication with the aperture 82 in end cover 66 and by extension with the manifold 54. The rotor 46 may rotate in the clockwise direction indicated by arrow 84. In operation, low-pressure second fluid 86 (e.g., low pressure slurry fluid) passes through end cover 66 and enters the channel 70, where it contacts the first fluid 88 at a dynamic fluid interface 90. The second fluid 86 then drives the first fluid 88 out of the channel 70, through end cover 64, and out of the rotary PX 40. However, because of the short duration of contact, there is minimal mixing between the second fluid 86 (e.g., slurry fluid) and the first fluid 88 (e.g., particulate-free fluid). In some embodiments, low pressure second fluid 86 contacts a first side of a barrier (e.g., a piston, not shown) disposed in channel 70 that is in contact (e.g., on an opposing side of the barrier) by first fluid 88. The second fluid 86 drives the barrier which pushes first fluid 88 out of the channel 70. In such embodiments, there is negligible mixing between the second fluid 86 and the first fluid 88.

[0069] FIG. 2C is an exploded perspective view of an embodiment of a rotary PX 40 (e.g., rotary LPC), according to certain embodiments. In FIG. 2C, the channel 70 has rotated clockwise through an arc of approximately 90 degrees. In this position, the opening 74 (e.g., outlet) is no longer in fluid communication with the apertures 80 and 82 of end cover 66, and the opening 72 is no longer in fluid communication with the apertures 76 and 78 of end cover 64. Accordingly, the low-pressure second fluid 86 is temporarily contained within the channel 70.

[0070] FIG. 2D is an exploded perspective view of an embodiment of a rotary PX 40 (e.g., rotary LPC), according to certain embodiments. In FIG. 2D, the channel 70 has rotated through approximately 60 degrees of arc from the position shown in FIG. 2B. The opening 74 is now in fluid communication with aperture 80 in end cover 66, and the opening 72 of the channel 70 is now in fluid communication with aperture 76 of the end cover 64. In this position, high-pressure first fluid 88 enters and pressurizes the low-pressure second fluid 86, driving the second fluid 86 out of the rotor channel 70 and through the aperture 80.

[0071] FIG. 2E is an exploded perspective view of an embodiment of a rotary PX 40 (e.g., rotary LPC), according to certain embodiments. In FIG. 2E, the channel 70 has rotated through approximately 270 degrees of arc from the position shown in FIG. 2B. In this position, the opening 74 is no longer in fluid communication with the apertures 80 and 82 of end cover 66, and the opening 72 is no longer in fluid communication with the apertures 76 and 78 of end cover 64. Accordingly, the first fluid 88 is no longer pressurized and is temporarily contained within the channel 70 until the rotor 46 rotates another 90 degrees, starting the cycle over again.

[0072] FIGS. 3A-B are schematic diagrams of fluid handling systems 300A-B including PXs and one or more controllers (e.g., control system, controllers 185 of control module 180 of FIG. 1A), according to certain embodiments. Some of the features in one or more of FIGS. 3A-B may have similar properties, functions, and/or structures as those in one or more of FIGS. 1A-B and/or one or more of FIGS. 2A-E (e.g., features that have similar names and/or reference numbers). Systems of one or more of FIGS. 3A-B may be used to perform the methods of one or more of FIGS. 4A-C.

[0073] FIGS. 3A-B depict various fluid handling system architectures (fluid handling systems 300A-B) and various controllers, according to certain embodiments. The depicted architectures are example architectures, e.g., depicted architectures highlight operations of controllers of the fluid handling systems. Any of the controllers depicted in FIGS. 3A-D may be included in any combination in any architecture design of a fluid handling system. For example, a controller performing operations such as controller 390 of FIG. 3A may be included in an architecture that doesn't include a low-pressure booster pump (e.g., the architecture depicted in FIG. 3B), a controller performing operations such as controller 394 controlling a bypass valve of FIG. 3B may be included in an architecture similar to that depicted in FIG. 3A, etc. A fluid handling system including any controller depicted herein (e.g., any controller adjusting operation of a component of a fluid handling and/or energy transfer system including a PX based on sensor data from the system), alone or in any combination, is within the scope of this disclosure. Controllers may be isolated components (e.g., each controller may be a separate device), controllers may be combined components (e.g., operations of two or more controllers may be performed by the same device, control system), etc. Controllers may provide control signals in response to various inputs, e.g., sensor data provided to the controllers. Controllers may provide control signals to adjust properties of the fluid handling systems, e.g., to adjust values of one or more conditions of the fluid handling systems such that the condition values satisfy one or more threshold conditions.

[0074] In some embodiments, devices of fluid handling systems 300A-B of FIGS. 3A-B may communicate via wired connections. In some embodiments, devices of fluid handling systems 300A-B may communicate wirelessly. In some embodiments, device depicted in FIGS. 3A-B may communicate via a network. For example, controllers of FIGS. 3A-B may receive sensor data via a network and may transmit control signals via the network. In some embodiments, devices of fluid handling systems 300A-B of FIGS. 3A-B may communicate via one or more wired networks. In some embodiments, devices of fluid handling systems 300A-B of FIGS. 3A-B may communicate via one or more wireless networks (e.g., personal area networks, wireless local area networks, etc.). In some embodiments, devices of fluid handling systems 300A-B may communicate via some wired and some wireless networks.

[0075] In some embodiments, controllers of fluid handling systems 300A-B may be PID controllers. Controllers of fluid handling systems 300A-B may calculate an error value (e.g., the difference between a target set point and a measured value). Controllers of fluid handling systems 300A-B may apply a correction (e.g., generate a control signal) based on proportional, integral, and derivative terms of the error value. For example, the proportional term may be based on the difference between the set point value and the measured value, the integral term may be based on past values of the error term integrated over time, and the derivative term may be based on a predicted future trend of the error term based on the current rate of change of the error term. In some embodiments, controllers of fluid handling systems 300A-B may be computing devices. Controllers of fluid handling systems 300A-B may be implemented as software (e.g., executed by a general purpose computing device), hardware, or a combination of hardware and software. In some embodiments, operation of controllers of fluid handling systems 300A-B may include receiving one or more adjustable settings, parameters, etc. For example, the response (e.g., magnitude of output signal, value of an adjustment instruction included in a control signal, etc.) of a controller may be of variable strength (e.g., for a given difference between a measured value and a target value of a measured property, a controller may have a range of possible output values, and implementation of one of the range of outputs may be responsive to one or more settings and/or parameters of the controller). In some embodiments, a controller may have an associated lookup table, and for a given input (e.g., a difference between a set point and a measured value), the controller may produce an output in accordance with the table. In some embodiments, a controller may perform a calculation including an adjustable parameter (e.g., a user-adjustable parameter, and adjustable setting, etc.), and in response to an input, the controller may generate an output based on the input. In some embodiments, parameters and/or settings of controllers may be selected/adjusted by a user. In some embodiments, parameters and/or settings of a controller may be adjusted by a computer-implemented method, e.g., of the controller, of an associated computing device, or the like.

[0076] In some embodiments, performance of a controller may be tracked (e.g., measured and stored for analysis over time). If a controller causes overshoot (e.g., if a component of a fluid handling system over-corrects responsive to receiving a control signal from the controller, if the measured property value passes through a target value before settling within a threshold of the target value, etc.) above a threshold value (e.g., a percent of the difference between the initial value and the target value, above a threshold value of frequency and/or severity of overshoot, etc.), sensitivity of the controller (e.g., strength of response to a measurement different from a target property value) may be decreased. For example, a controller may generate a control signal responsive to receiving a measurement different from a set point (e.g., a difference between a set point and a measured value exceeding a threshold). The controller may later receive a measurement different from the set point but in the opposite direction (e.g., the control signal may have intended to correct a measured value lower than a set point, and the subsequent measurement may be higher than the set point). Responsiveness of the controller (e.g., a parameter of a calculation that determines the strength of an output relative to an input difference between a set point and a measured value, a table entry determining the severity of action instructed in a control signal based on an input from a sensor, etc.) may be adjusted to reduce the likelihood of an overshoot in future operations. Adjustment to a controller setting may be global, e.g., a parameter or table may be updated such that all future control signals are generated according to the update. Adjustment to a controller setting may not apply globally, e.g., one or more lookup table values may be adjusted while others are left unadjusted (e.g., a lookup table value associated with a range of differences between a set point and a measured value may be adjusted, a lookup table value associated with one or more differences for a range of measured values may be adjusted, etc.), a parameter for use in some situations may be updated (e.g., a list of parameters may be applied for different measured values, different set point values, different values of a difference between a measured value and a set point, etc.), or the like.

[0077] Similarly, if a controller is not sensitive enough (e.g., if property values in the system are slower than desired to reach values within a threshold value of a target value), response of the controller may be increased. For example, a controller may receive a measurement different than a set point (e.g., a controller may be configured to receive pressure measurements from a pressure gauge and may receive a measurement that is different from a set point pressure value by at least a threshold amount). The controller may generate a control signal responsive to receiving the measurement (e.g., the controller may generate a control signal for a valve to open to adjust pressure at the pressure gauge). The controller may subsequently receive a measurement that the pressure has not reached the set point (e.g., the action taken by the valve responsive to the control signal was not sufficient to reduce the difference between the set point and the measured value below a threshold). One or more settings/parameters of the controller may be adjusted to increase the response of the controller (e.g., increase the output signal generated based on an input signal of a given strength, increase the severity of instructions included in a control signal associated with a given difference between a set point and a measured value, etc.) to an input.

[0078] In some embodiments, determining an update to the sensitivity and/or response (e.g., an update to a parameter or setting dictating the strength or severity of an output) of a controller may be performed by a machine learning model. A machine learning model may be trained with input including a target property value, a measured property value, a response of the controller (e.g., a control signal), and/or a result of a component of the system acting on an instruction received by the controller. The machine learning model, once trained, may be configured to receive as input a measured property value and a target value and generate as output an indication of an appropriate action (e.g., a control signal) to be taken by one or more components of the fluid handling system. For example, a machine learning model may be provided with historical data as training data. The machine learning model may be provided with one or more historical property values associated with a property to be corrected in a fluid handling system (e.g., one or more set point values and one or more measured values generated before and after a component of the system performs an action as instructed by a controller) as training input. The machine learning model may further be provided with historical property values after an adjustment to correct the measured property values is made (e.g., one or more measured values, measured after a control signal was generated for one or more components of the system). The machine learning model may be provided with one or more historical control signals (or data indicative of the control signals) as target output. Once trained, the machine learning model may receive as input current property values (e.g., one or more set point values, one or more measured values, etc.) and generate as output a control signal (or data associated with a control signal) that is predicted to bring the one or more measured property values within a threshold difference value of the one or more set point values.

[0079] Fluid handling systems 300A-B may be heat transfer systems. Fluid handling systems 300A-B may be refrigeration systems. Fluid handling systems 300A-B may be heat pump systems. Fluid handling systems 300A-B may be reversible heat pump systems. A reversible heat pump system may include components not pictured in FIGS. 3A-B, for example, a reversing valve (e.g., a 4-way valve to reverse flow). A reversible heat pump system may reverse direction of flow of a coolant fluid in one or more portions of the fluid handling system, e.g., flow through a condenser and/or an evaporator (e.g., outdoor heat exchanging unit and/or indoor heat exchanging unit) may be reversed. A reversible heat pump system may not reverse direction of flow in one or more portions of the fluid handling system, e.g., flow through a compressor or pump may not be reversed. A reversible heat pump system may include additional flow paths, additional valves, etc., utilized for example when flow is reversed. Though additional components and flow paths associated with a reversible heat pump system are not depicted in FIGS. 3A-B, reversible heat pump systems including such components are within the scope of this disclosure.

[0080] FIG. 3A is a schematic diagram of a fluid handling system 300A including a PX 310 and controllers 390, 391, 392, and 393, according to some embodiments. System 300A may be configured to control various components of the system based on sensor data received from sensors of the system. System 300A may be configured to determine an opening of one or more valves based at least in part on a speed of operation of PX 310. System 300A may be configured to determine a speed of operation of one or more pumps (e.g., low pressure booster 314) based at least in part on a speed of operation of PX 310.

[0081] PX 310 may be a rotary pressure exchanger. In some embodiments, PX 310 is an isobaric or substantially isobaric pressure exchanger. PX 310 may be configured to exchange pressure between a first fluid and a second fluid. PX 310 may be configured to exchange pressure between a high pressure first fluid (e.g., provided to the PX 310 at a high-pressure inlet, labeled HP-IN) and a low pressure second fluid (e.g., provided to the PX 310 at a low-pressure inlet, LP-IN). PX 310 may decrease the pressure of the first fluid (e.g., for output from PX 310 at a low-pressure outlet, LP-OUT) and increase the pressure of the second fluid (e.g., for output from PX 310 at a high-pressure outlet, HP-OUT). In some embodiments, PX 310 is coupled to a motor (e.g., rotation of a rotor of PX 310 is controlled and/or adjusted by motor). In some embodiments, a controller (e.g., controller 390, controller 391, controller 392, controller 393) receives sensor data from one or more sensors. Controllers may receive sensor data from one or more sensors and generate one or more control signals based on the received sensor data. In some embodiments, mass flow (e.g., of the first fluid, of the second fluid, etc.) through PX 310 may be related to a speed of operation of PX 310 (e.g., a speed of rotation of a rotor of a rotary PX). In some embodiments, pressure of fluid (e.g., the first fluid, the second fluid, etc.) in various components of a fluid handling system (e.g., fluid handling systems 300A-B) may be related to a speed of operation of PX 310.

[0082] In some embodiments, PX 310 is configured to receive the first fluid at a high pressure (e.g., HP fluid in 130 of FIGS. 1A-B) via a high pressure inlet. In some embodiments, PX 310 is configured to receive the second fluid at a low pressure (e.g., LP fluid in 120 of FIGS. 1A-B) via a low pressure inlet. Although there is a reference to "high pressure" and "low pressure," "high pressure" and "low pressure" may be relative to one another and may not connote certain pressure values (e.g., the pressure of the HP fluid in 130 is higher than the pressure of LP fluid in 120). PX 310 may exchange pressure between the first fluid and the second fluid. PX 310 may provide the first fluid via a low pressure outlet (e.g., LP fluid out 140) and may provide the second fluid via a high pressure outlet (e.g., HP fluid out 150). In some embodiments, the first fluid provided via the low pressure outlet is at a low pressure and the second fluid provided via the high pressure outlet is at a high pressure. PX 310 may act as a high pressure expansion valve, e.g., fluid that flows through PX 310 (e.g., from a high pressure inlet to a low pressure outlet) may expand. PX 310 may transfer pressure from one fluid stream to another, increasing the pressure of one fluid stream. PX 310 may act as both an isentropic (or substantially isentropic) expansion device and a compressor, which may cause transfer of heat, may facilitate one or more operations of a refrigeration cycle, or the like. The compression process of PX 310 may be substantially isenthalpic.

[0083] In some embodiments, the first fluid may be a refrigerant fluid in a supercritical state (e.g., supercritical CO_2). In some embodiments, the first fluid may be a refrigerant fluid in a liquid state (e.g., liquid CO_2). In some embodiments, the second fluid may be a refrigerant fluid in a gaseous state (e.g., gaseous CO_2). In some embodiments, the second fluid may be a refrigerant fluid in a two-phase mixture (e.g., a liquid-gas mixture of CO_2). In some embodiments, the second fluid may be a refrigerant fluid in a liquid state (e.g., liquid CO_2).

[0084] In some embodiments, fluid handling system 300A includes a main gas cooler 329 (e.g., a condenser), an auxiliary gas cooler 327, an evaporator 318, and a main compressor 322. In some embodiments, main gas cooler 329 and/or auxiliary gas cooler 327 may or may not act as condensers, e.g., the fluid handling system may be operated at pressures and temperatures such that fluid does or does not condense in the gas coolers. Any embodiment discussed herein may include a gas cooler that may or may not act as a condenser in one or more applications. In some embodiments, e.g., above the critical point of a fluid, the thermodynamic distinction between gas and liquid of a fluid disappears, and fluid (e.g., fluid in a condenser) may exist in a super critical state (e.g., both input and output fluid of a condenser may be in a supercritical state, on of input or output fluid of a condenser may be in a supercritical state, neither fluids may be in a supercritical state, etc.). In some embodiments, fluid handling system 300A is a refrigeration system. For example, evaporator 318 may facilitate absorption of heat by system 300A from a heat source (e.g., a refrigerated area, a cold reservoir, etc.) to a refrigeration fluid. The heat may be rejected to a heat sink (e.g., the environment, a hot reservoir, etc.) via the main gas cooler 329 and/or auxiliary gas cooler 327. In some embodiments, the refrigeration fluid facilitates heat transfer from an environment associated with the evaporator 318 to an environment associated with the main gas cooler 329. Main compressor 322 of fluid handling system 300A may increase corresponding pressure of the refrigeration fluid along a flow path between the evaporator 318 and the main gas cooler 329. In some embodiments, the refrigeration fluid is CO_2 or another refrigeration fluid. The refrigeration fluid may flow substantially in a cycle (e.g., from gas cooler 329 to PX 310 to evaporator 318 to main compressor 322 to gas cooler 329, etc.).

[0085] In some embodiments, fluid handling system 300A is a heat pump system. For example, heat may be rejected by fluid at main gas cooler 329 into a target region to be heated (e.g., for heating the interior space of a building). Heat may be absorbed from the environment by the fluid of fluid handling system 300A at evaporator 318 for transfer to the environment of main gas cooler 329. In some embodiments, fluid handling system 300A may be a reversible heat pump.

[0086] In some embodiments, fluid handling system 300A includes a low-pressure booster (e.g., LP booster 314) and/or a high-pressure booster (not shown). Both LP booster 314 and an HP booster may be configured to increase (e.g., “boost”) pressure of the second fluid. For instance, LP booster 314 may increase pressure of the first fluid output from evaporator 318 (e.g., evaporator 318 may receive a low-pressure second fluid from the PX 310 and output a fluid to LP booster 314). An HP booster may increase pressure of the second fluid output by the PX 310 via the high-pressure outlet. The second fluid may be coupled from the HP-OUT of the PX 310, to an auxiliary gas cooler 327, then to flash tank 313. The second fluid may be coupled to flash tank 313 via auxiliary high-pressure valve 368. Auxiliary high-pressure valve 368 may be a control valve, e.g., may be configured to be set to a range of openings to enable control of fluid flow through the valve. Alternatively, the second fluid may be provided to combine with fluid output from main compressor 322 (e.g., upstream of an inlet of the main gas cooler 329) to be provided to the main gas cooler 329. LP booster 314 may be configured to increase pressure less than a threshold value (e.g., LP booster 314 may operate over a pressure differential that is less than a threshold amount, fluid handling system 300A may transfer pressure via PX 310 to reduce pressure differential at LP booster 314, etc.). For example, LP booster 314 may increase pressure of the second fluid by approximately 10-100 psi, by approximately 30-80 psi, by approximately 40-60 psi, by approximately 50 psi, by any range contained therein, etc. The second fluid may experience pressure loss (e.g., parasitic loss) as the second fluid flows from the LP booster 314 to the second inlet (e.g., low pressure inlet) of the PX 310. LP booster 314 may be configured to increase pressure of fluid to a target value, e.g., a value chosen for system operation, a value associated with another pressure in the system (e.g., pressure of a fluid associated with a low pressure outlet of the PX).

[0087] An HP booster may increase pressure of the second fluid between the second outlet of the PX 310 and an inlet of the main gas cooler 329 or auxiliary gas cooler 327. An HP booster may increase pressure less than a threshold value (e.g., HP booster may operate over a small pressure differential). For example, HP booster may increase pressure of the second fluid by approximately 10-100 psi, by approximately 30-80 psi, by approximately 40-60 psi, by approximately 50 psi, by any range contained therein, etc. HP booster may increase pressure of the second fluid to the inlet pressure of the coupled gas cooler. The HP booster may increase the pressure of a fluid to a target value (e.g., a value chosen for system operation, a measured pressure value to match output of main compressor 322, or the like). In some embodiments, the HP booster may be coupled to an outlet of a gas cooler/condenser. In some embodiments, fluid exiting a gas cooler is in a liquid state. Thus, in some embodiments, the HP booster pumps liquid from the outlet of a gas cooler (e.g., liquid discharged from the gas cooler) to the high pressure inlet of the PX 310. The HP booster may increase the pressure of the liquid output from the condenser to the high pressure inlet of the PX 310.

[0088] In some embodiments, main compressor 322 increases pressure of fluid more than a threshold amount (e.g., main compressor 322 may operate over a pressure differential that is greater than a threshold amount, that is greater than the pressure differential LP booster 314 operates over, or the like). For example, main compressor 322 may increase pressure of the fluid by approximately 100-1200 psi, by approximately 500-1100 psi, by approximately 800-1000 psi, by approximately 900 psi, by at least 100 psi, by at least 500 psi, any included range, or the like. In some embodiments, operations of main compressor 322 may be performed by more than one physical device, e.g., multiple compressors, multiple pumps, or the like. Multiple compressors performing operations of main compressor 322 may be arranged in parallel, in series, or a combination of arrangements. Any discussion of main compressor 322 may be generalized to include multiple devices, e.g., by summing energy consumed or calculating total fluid flow through the compressor system taking into account arrangement, specifications, and operating speeds of each compressor of the compressor system.

[0089] Fluid handling system 300A may include one or more sensors. The one or more sensors measure property values associated with the system. For example, one or more temperature sensors may measure temperature of a flowing fluid, of the environment, of hot and/or cold sinks associated with the system, etc. One or more pressure gauges may measure pressure of a fluid of fluid handling system 300A. One or more flow meters may measure flow (e.g., mass flow) of fluid through fluid handling system 300A. One or more density meters (e.g., two phase fluid density meters, two phase density meters, etc.) may measure density of a fluid of fluid handling system 300A. Other sensors (e.g., meters) may measure additional property values, e.g., work performed by various components, heat flow through the system, power consumed by components of the system, total fluid flow through various portions of the system, etc. Depicted in FIG. 3A are gauge 380 and gauge 384.

[0090] Fluid handling system 300A includes controllers 390, 391, 392, and 393. Controllers of fluid handling system 300A may be PID controllers. Controllers of fluid handling system 300A may perform operations based on a known relationship between sensor data and control output, e.g., via a lookup table, functional form of the relationship, or the like.

[0091] Controller 390 is operatively coupled to PX 310. Controller 390 may receive one or more measurements from gauge 380. Controller 390 may receive pressure measurements of fluid from gauge 380. Controller 390 may receive measurements as raw measurement data, as preprocessed measurement data, as averaged (e.g., boxcar averaged) measurement data, or the like. In some embodiments, controller 390 may receive additional measurement data, e.g., from one or more other sensors associated with fluid handling system 300A. Controller 390 may receive ambient temperature data, e.g., of the environment in the vicinity of main gas cooler 329 and/or auxiliary gas cooler 327 (for instance, in the case of a refrigeration system) or the environment in the vicinity of evaporator 318 (for instance, in the case of a heat pump system). Controller 390 may receive sensor data from PX 310, e.g., data indicative of a speed of operation of PX 310, etc. Controller 390 may be configured to generate one or more control signals based on received measurement data. Controller 390 may provide control signals to a device configured to adjust a speed of operation of PX 310, such as a motor coupled to PX 310 (e.g., coupled to a rotor of PX 310).

[0092] A motor or other speed adjusting device may be configured to adjust operation of PX 310 (e.g., by adjusting a speed of operation of the motor) responsive to receiving a control signal from controller 390. Gauge 380 may provide an indication of pressure of fluid in main gas cooler 329. Controller 390 may generate a control signal directed at achieving and/or maintaining a target pressure of main gas cooler 329. The target pressure of main gas cooler 329 may be modified by ambient temperature (e.g., heat sink temperature for rejected heat), for example to achieve optimal energy efficiency, heat transfer, refrigeration, or the like. For example, increasing a speed of operation of PX 310 may increase a flow rate of fluid through PX 310. Increasing a speed of operation of PX 310 may decrease fluid pressure of main gas cooler 329, a pressure measured by gauge 380, etc.

[0093] In some embodiments, a target pressure of main gas cooler 329 may be chosen to maximize heat transfer of the system, maximize heat transfer between main gas cooler 329 and the environment, maximize energy efficiency of the system, maximize a coefficient of performance (COP, e.g., a ratio between heat transferred by the system and power expended by pumps/compressors of the system), or the like.

[0094] In some embodiments, a device for adjusting PX speed may act to operate, actuate, or accelerate PX 310. For example, a motor may drive PX 310. A motor may draw power from a power source to drive PX 310. In some embodiments, a motor may act like a generator. For example, PX 310 may be driven by fluid of fluid handling system 300A (e.g., driven by a pressure differential in the fluid, driven by one or more pumps and/or compressors of the system, etc.). A motor may impart additional resistance to operation of PX 310 (e.g., resistance to rotation of a rotor of a rotary PX), which may cause a speed of operation of PX 310 to decrease. A motor may generate electrical power (e.g., may convert rotational energy of PX 310 into electrical energy).

[0095] Controller 391 is operatively coupled to auxiliary cooling component 302. Auxiliary cooling component 302 may be a device configured to increase heat transfer between auxiliary gas cooler 327 and the surrounding environment. For example, auxiliary gas cooler 327 may reject heat to the ambient atmosphere, and cooling component 302 may be a fan that increases transfer of heat from auxiliary gas cooler 327 to the atmosphere. Auxiliary cooling component 302 may be a heat exchanger coupled to auxiliary gas cooler 327 or another type of component that increases heat transfer away from auxiliary gas cooler 327.

[0096] In some embodiments, controller 391 may receive a data measurement from gauge 384. Gauge 384 may provide a temperature measurement of a fluid temperature of auxiliary gas cooler 327. Gauge 384 may provide a temperature measurement of a fluid temperature of fluid output from auxiliary gas cooler 327. Controller 391 may generate a control signal based on data provided by gauge 384. Controller 391 may generate a control signal to achieve a target temperature of a fluid output by the auxiliary gas cooler 327. Controller 391 may generate a control signal to adjust operation of auxiliary cooling component 302. For example, controller 391 may adjust a speed of operation of a fan to achieve a target temperature (e.g., within a threshold) of fluid at the outlet of auxiliary gas cooler 327.

[0097] Controller 392 is operatively coupled to auxiliary high-pressure valve 368. Controller 392 may receive a signal from PX 310 indicative of a speed of operation of PX 310. The signal from PX 310 may be a signal from a sensor measuring a speed of operation of PX 310. The signal from PX 310 may be a signal from a component of PX 310 or a component coupled to PX 310, such as a motor of PX 310. The signal indicative of the speed of operation of PX 310 may be provided by controller 390, e.g., a control signal may be provided to PX 310 to adjust operation of PX 310, and the control signal may be provided to controller 392 for use by controller 392 in additional operations.

[0098] Controller 392 may generate a control signal for auxiliary high-pressure valve 368 based on PX 310 operating speed. The auxiliary high-pressure valve may be opened or closed to a target opening size, target opening value, etc. The target opening size may be selected to achieve a target travel distance of a fluid in the PX 310. For example, the target opening size may be selected to achieve a target LP-IN travel distance of a fluid provided to the low-pressure inlet of the PX. Travel distance may be or include a measure of flow through the PX 310 as compared to operating volume (e.g., duct volume, duct volume modified by operating speed, etc.) of the PX 310. Travel distance may describe a portion of the operating volume of the PX 310 that is filled or displaced by an incoming fluid. A value or range of travel distance may be targeted, e.g., the optimized efficiency of system 300A, optimizes heat transfer, or the like. In some embodiments, a target LP-IN travel distance may be around 100%, 90%-110%, 80%-120%, 70%-130%, or any included or other range.

[0099] Controller 392 may further receive additional sensor data. The additional sensor data may be utilized in determining an opening of the auxiliary high-pressure valve 368. Additional sensor data may include gas cooler temperature (e.g., provided by gauge 380). Additional sensor data input may include an indication of system load. System load, as used herein, is the total flow of fluid through system 300A. System load may be determined based on a speed of operation of main compressor 322, e.g., by taking into account a volume swept per rotation of main compressor 322 and an operating rotational speed of main compressor 322. A control signal provided by controller 392 to auxiliary high-pressure valve 368 may further depend on the additional sensor data provided to controller 392.

[00100] Controller 393 is operatively coupled to low-pressure booster 314. Controller 393 may provide control signals to low-pressure booster 314 to adjust an operating speed of low-pressure booster 314. A speed of operation of the low-pressure booster 314 may be determined based on a target LP-IN travel distance of PX 310. Controller 393 may receive sensor data indicative of a speed of operation of PX 310. Controller 393 may generate a control signal for low-pressure booster 314 based on the speed of operation of PX 310.

[00101] In some embodiments, a controller (e.g., a central controller, a system controller, which may be combined with one or more of controllers 390 through 393) receives sensor data indicative of a temperature of a refrigerated space (e.g., the cold reservoir proximate evaporator 318) and/or a temperature of a heated space (e.g., the hot reservoir proximate main gas cooler 329). The controller may control LP booster 314, auxiliary cooling component 302, auxiliary high-pressure valve 368, PX 310, and/or main compressor 322 based on sensor data received from one or more sensors of the fluid handling system 300A (e.g., one or more fluid flowrate sensors, temperature sensors, pressure sensors, etc.). In some embodiments, one or more sensors (e.g., pressure sensors, flow sensors, temperature sensors, etc.) are disposed proximate inlets and/or outlets of the various components of the fluid handling system 300A (e.g., fluids discharged from various components). In some embodiments, one or more sensors are disposed internal to the components of the fluid handling system 300A. In some embodiments, a pressure sensor may be disposed proximate the inlet of the main compressor 322 and an additional pressure sensor may be disposed proximate the outlet of the main compressor 322. In some embodiments, a temperature sensor may be disposed proximate the inlet of the evaporator 318 and another temperature sensor may be disposed proximate the outlet of the evaporator 318 (e.g., for measuring temperature of fluid discharged from evaporator 318). In some embodiments, a temperature sensor may be disposed internal to the main gas cooler 329 and/or auxiliary gas cooler 327. In some embodiments, a flow sensor may be located at each of the inlets and outlets of the PX 310 to measure a flow of the first fluid and the second fluid into and out of the PX 310.

[00102] In some embodiments, evaporator 318 is a heat exchanger to provide corresponding thermal energy from an environment (e.g., a medium of an environment) to a fluid of fluid handling system 300A. For example, evaporator 318 may receive heat (e.g., thermal energy) from air of the environment and provide the heat to the fluid. In some embodiments, the environment is a refrigerated space such as the inside of a refrigerator or freezer, an interior space (e.g., of a building or vehicle), or any other space that is to be kept cool. For example, the environment can be the interior of a freezer or refrigeration section at a supermarket or warehouse. In some embodiments, evaporator 318 may absorb heat from the environment to be provided to main gas cooler 329, e.g., heating the region around main gas cooler 329 may be a target outcome of fluid handling system 300A.

[00103] In some embodiments, fluid handling system 300A may include a secondary evaporator. Fluid handling system 300A may further include secondary components corresponding to any components of evaporator 318, e.g., input and output lines, valves, gauges, controllers, etc. In some embodiments, the secondary evaporator receives a portion of flow of fluid directed to evaporator 318. For example, the secondary evaporator may receive a portion of the flow from the low pressure outlet of PX 310. In some embodiments, a secondary evaporator may target a different temperature than evaporator 318 (e.g., the evaporators may be associated with refrigeration systems with different target temperatures, such as a refrigerator and freezer). In some embodiments, the two evaporators (e.g., evaporator 318 and the secondary evaporator) may be operated at different fluid pressures. Fluid output by one or more of the secondary evaporators may be directed to one or more components (e.g., valves, expansions valves, pumps, compressors, or the like) to alter the pressure of the output fluid such that the pressures are substantially similar when the output streams of the two evaporators are combined.

[00104] In some embodiments, main gas cooler 329 and/or auxiliary gas cooler 329 is a heat exchanger to provide thermal energy from the fluid of fluid handling system 300A to another environment. For example, main gas cooler 329 may reject heat (e.g., thermal energy) to air of an outside (e.g., exterior) environment. In some embodiments, main gas cooler 329 exchanges thermal energy (e.g., rejects heat) to an outside space. For example, main gas cooler 329 may be placed outside a supermarket or warehouse building (e.g., on a roof of the building) and reject heat to the outside environment. In another example, main gas cooler 329 may be placed in the ground and facilitate the transfer of thermal energy between the fluid and the ground. In some embodiments, main gas cooler 329 rejects heat to an interior space while evaporator 318 absorbs heat from an exterior space (e.g., as in a heat pump configuration that is providing heating to the interior space). Thermal energy rejected from main gas cooler 329 may be used to heat an enclosed (e.g., substantially enclosed) space.

[00105] In some embodiments, fluid handling system 300A may include an auxiliary gas cooler 327. In some embodiments, the auxiliary condenser receives the second fluid from the high pressure outlet of PX 310, and main gas cooler 329 receives output from main compressor 322. In some embodiments, the auxiliary gas cooler 327 is a heat exchanger that exchanges thermal energy (e.g., heat) between the second fluid and a medium of an environment. In some embodiments, the auxiliary gas cooler 327 exchanges thermal energy between the second fluid and the same environment with which the main gas cooler 329 exchanges thermal energy. In other embodiments, the auxiliary condenser exchanges thermal energy between the second fluid and a different environment with which the main gas cooler 329 exchanges thermal energy. In some embodiments, the auxiliary gas cooler 327 operates at a temperature different than main gas cooler 329.

[00106] Fluid handling system 300A further includes high-pressure valve 304. High-pressure valve 304 may be a controllable valve. High-pressure valve 304 may be utilized in determining a portion of output of main gas cooler 329 to be provided to PX 310. High-pressure valve 304 may be utilized in determining a portion of output of main gas cooler 329 to be provided to flash tank 313. High-pressure valve 304 may be set to maintain a target high-pressure in travel distance of the PX 310. Control of high-pressure valve 304 may include determining pressure of the working fluid and providing a control signal to high-pressure valve 304 based on the pressure. Pressure of fluid provided to high-pressure valve 304 (e.g., measured by gauge 380) may be used in determining a control signal to provide to high-pressure valve 304. Indications of operation of PX 310 may further be utilized in determining a control signal to provide to high-pressure valve 304, in determining a target opening of high-pressure valve 304, etc. For example, a speed of operation of PX 310 may be received by a controller and utilized in generating a control signal for causing actuation of high-pressure valve 304. In another example, whether or not PX 310 is to be operated (e.g., based on ambient conditions proximate main gas cooler 329) may be used in determining one or more operating parameters (e.g., opening percentage) of high—pressure valve 304.

[00107] Fluid handling system 300A further includes flash gas valve 320. Fluid handling system 300A may include a flash gas valve 320 to regulate a flow of gas on a flash gas bypass flow path. In some embodiments, flash gas valve 320 is a bypass valve that regulates a flow of gas from a gas outlet of the flash tank 313 to be combined with output of the evaporator 318. In some embodiments, the flow of gas from the flash tank 313 flows along the flash gas bypass flow path to bypass the evaporator 318. In some embodiments, the flash gas flow path is between flash tank 313 and a location downstream of an outlet of the evaporator 318. The gas flowing along the flash gas bypass flow path may be combined with output of the evaporator 318. The flash gas valve 320 may cause gas collected in the flash tank 313 to expand (e.g., decrease in pressure) as the gas flows toward the main compressor 322. The flash gas valve 320 may, in some embodiments, be an adjustable valve. In some embodiments, the flash gas valve 320 is caused to actuate by a controller based on sensor data.

[00108] Fluid handling system 300A may include an expansion valve 316. In some embodiments, expansion valve 316 is disposed along a flow path between flash tank 313 and evaporator 318, e.g., coupled between flash tank 313 and evaporator 318. Expansion valve 316 may be an adjustable valve (e.g., an electronic expansion valve, a thermostatic expansions valve, a ball valve, a gate valve, a poppet valve, etc.). Expansion valve 316 may be controllable by a user (e.g., a technician, an operator, an engineer, etc.) or by a controller (e.g., a controller similar in design and/or function to one or more of controllers 390-393). In some embodiments, the expansion valve 316 is caused to actuate by a controller based on sensor data (e.g., pressure sensor data, flowrate sensor data, temperature sensor data, etc.). In some embodiments, expansion valve 316 is a thermal expansion valve. Expansion valve 316 may actuate (e.g., open and/or close) based on temperature data associated with the evaporator 318 (e.g., temperature of liquid in the evaporator, temperature of gas in the evaporator, temperature of fluid entering the evaporator, temperature of fluid exiting the evaporator, etc.). For example, a pressure-sensitive component (e.g., sensing bulb) of the expansion valve 316 may increase or decrease pressure on a diaphragm of the expansion valve 316, causing a poppet valve coupled to the diaphragm to open or close, thus causing more or less flow of fluid to the evaporator 318, causing more or less expansion of the fluid. The pressure-sensitive component of the expansion valve may be positioned proximate to the downstream end of the evaporator 318 (e.g., proximate the outlet of the evaporator 318, outside evaporator 318, inside evaporator 318, or the like) and may be fluidly coupled to the diaphragm via a fluid line (e.g., a sensing capillary). In some embodiments, expansion valve 316 is controlled and actuated entirely based on electronic commands (e.g., from a controller).

[00109] Described herein are references to “first fluid” and “second fluid.” In some embodiments, the first fluid and the second fluid are the same type of fluid (e.g., are a refrigeration fluid flowing in a fluid handling system). “First fluid” may refer to fluid flowing through the PX 310 from the high pressure inlet to the low pressure outlet of the PX 310 and/or fluid flowing to or from the high pressure inlet and/or the low pressure outlet of the PX 310. “Second fluid” may refer to fluid flowing through the PX 310 from the low pressure inlet to the high pressure outlet of the PX 310 and/or fluid flowing to or from the low pressure inlet and/or the high pressure outlet of the PX 310.

[00110] In some embodiments, system 300A is a heat pump system capable of heating and cooling an environment (e.g., an indoor space). In some examples, one of main gas cooler 329 or evaporator 318 is an outdoor unit and the other of main gas cooler 329 or evaporator 318 is an indoor unit. In some examples, main gas cooler 329 is the outdoor unit (e.g., condensing unit) and evaporator 318 is the indoor unit (e.g., disposed in the air handler). The flow of fluid through the main gas cooler 329 and the evaporator 318 may be reversible (e.g., via a reversing valve coupled to the main compressor 322). The reversing valve may cause fluid flow exiting the main compressor 322 to be switchable between being directed towards the inlet of main gas cooler 329 (e.g., outdoor unit) or towards the inlet of the evaporator 318 (e.g., indoor unit). In some embodiments, one or more valves and piping may be used to cause fluid flow to be directed in the same direction through all of the components (e.g., one or more the PX 310, LP booster 314, an HP booster, main compressor 322, and/or the like) while reversing fluid flow through the main gas cooler 329 and evaporator 318.

[00111] The transfer of thermal energy (e.g., heat transfer) of the system 300A may be reversible in some embodiments. For example, in some implementations of system 300A, the main gas cooler 329 can absorb heat (e.g., provide corresponding thermal energy from the corresponding environment to the refrigeration fluid) and the evaporator 318 can reject heat (e.g., provide corresponding thermal energy from the refrigeration fluid to the corresponding environment). Thus, in some embodiments, main gas cooler 329 can be an evaporator (e.g., a single component may operate in some modes as an evaporator and some modes as a condenser) and evaporator 318 can be a condenser (e.g., a single component may operate in some modes as a condenser and some modes as an evaporator). In some embodiments, system 300A includes one or more valves (e.g., a reversing valve, diversion valve(s), etc.) to reverse the function of system 300A (e.g., reverse the flow of thermal energy facilitated by system 300A). In some embodiments, one or more flows of refrigeration fluid (e.g., to/from the PX 310, to/from the HP booster, to/from the LP booster 314, to/from the main compressor 322, to/from the main gas cooler 329, and/or to/from the evaporator 318) may be reversed and/or diverted. For example, in some embodiments, one or more reversing or diversion valves included in system 300A in some embodiments can direct fluid from the main compressor 322 toward the evaporator 318. Similar valves may direct fluid from the main gas cooler 329 toward the compressor 322.

[00112] Reversibility of system 300A may be controlled (e.g., via one or more controllers, via a programmable thermostat disposed in the indoor space, via user input, etc.). For example, a controller may determine (e.g., based on temperature data, based on user input, based on a schedule) whether to use system 300A to heat an indoor space or to cool an indoor space. In some embodiments, a controller may cause one or more valves (e.g., reversing valve, diversion valve(s), etc.) to actuate to cause fluid flow through main gas cooler 329 and evaporator 318 to reverse. For example, a controller may cause a valve to actuate to cause refrigeration fluid to flow from the main compressor 322 to the evaporator 318. In such embodiments, the evaporator 318 may act as a condenser (e.g., the refrigeration fluid may condense inside the evaporator 318) and the evaporator 318 may provide corresponding thermal energy from the refrigeration fluid to the corresponding environment (e.g., the evaporator 318 may reject heat). In some examples, a controller may cause a valve to actuate to cause refrigeration fluid to flow from the main gas cooler 329 to the main compressor 322. In such embodiments, the main gas cooler 329 may act as an evaporator (e.g., the refrigeration fluid may evaporate inside the main gas cooler 329) and the main gas cooler 329 may provide corresponding thermal energy from the corresponding environment to the refrigeration fluid (e.g., the main gas cooler 329 may absorb heat). In embodiments where the function of system 300A is reversible (e.g., reversible between heating and cooling an indoor space), evaporator 318 may be an interior heat exchanger (e.g., disposed within an interior space, disposed in an air handler system providing airflow to an indoor space) and the main gas cooler 329 may be an exterior heat exchanger (e.g., disposed outside the interior space). Any system of the present disclosure may be a reversible system, e.g., may be a heat pump capable of heating and cooling an interior space.

[00113] In some embodiments, a system described herein is a heat pump system capable of heating an environment (e.g., an indoor space). In such a heat pump system, the main gas cooler 329 is placed indoors and the evaporator 318 is placed outdoors. In a heat pump system, the evaporator absorbs heat from the ambient and vaporize the two phase refrigerant fluid flowing through the evaporator before sending it to the inlet of the compressor. In some embodiments, to switch from refrigeration or air-cooling system to a heat pump system, a reversing valve may be used to cause the fluid flow exiting the main compressor 322 to be switchable between being directed towards the inlet of the outdoor unit or towards the inlet of the indoor unit. In some embodiments, one or more valves and piping may be used to cause fluid flow to be directed in the same direction through all of the components (e.g., one or more the PX 310, LP booster 314, HP booster, main compressor 322, and/or the like) while switching the fluid flow from indoor unit to outdoor unit.

[00114] The direction of transfer of thermal energy (e.g., heat transfer) of the system 300A may be reversible in some embodiments. For example, in refrigeration / air-conditioning / air cooling implementations of system 300A, the main gas cooler 329 placed outdoors rejects heat (e.g., provide corresponding thermal energy from the refrigeration fluid to the corresponding environment) and the evaporator 318 can absorbs heat (e.g., provide corresponding thermal energy from the corresponding environment to the refrigeration fluid). While in heat pump implementation of system 300A, the main gas cooler 329 placed indoors rejects heat to its indoor environment and evaporator 318 absorbs heat from its outdoor environment. In some embodiments, system 300A includes one or more valves (e.g., a reversing valve, diversion valve(s), etc.) to reverse the function of system 300A (e.g., reverse the flow of thermal energy facilitated by system 300A). In some embodiments, one or more flows of refrigeration fluid (e.g., to/from the PX 310, to/from the HP booster, to/from the LP booster 314, to/from the main compressor 322, to/from the main gas cooler 329, and/or to/from the evaporator 318) may be reversed and/or diverted. In some examples, one or more reversing or diversion valves included in system 300A in some embodiments can direct fluid from the main gas cooler 322 toward the outdoor unit. Similar valves may direct fluid from the main compressor 322 to the indoor unit.

[00115] Reversibility of system 300A may be controlled (e.g., via a controller of system 300A, via a programmable thermostat disposed in the indoor space, via user input, etc.). In some examples, the controller may determine (e.g., based on temperature data, based on user input, based on a schedule) whether to use system 300A to heat an indoor space or to cool an indoor space. In some embodiments, the controller may cause one or more valves (e.g., reversing valve, diversion valve(s), etc.) to actuate to cause fluid flow through the system to reverse. In embodiments where the function of system 300A is reversible (e.g., reversible between heating and cooling an indoor space), evaporator 318 may be an interior heat exchanger (e.g., disposed within an interior space, disposed in an air handler system providing airflow to an indoor space) and the main gas cooler 329 may be an exterior heat exchanger (e.g., disposed outside the interior space). In other embodiments the evaporator 318 may be an outdoor heat exchanger and main gas cooler 329 may be an indoor heat exchanger.

[00116] In some embodiments, the systems described herein (e.g., systems of one or more of FIGS. 3A-B can be used to heat an interior and/or enclosed space, to cool an interior and/or enclosed space, and/or selectively (e.g., reversibly) heat and cool a space.

[00117] FIG. 3B is a schematic diagram of a fluid handling system 300B that includes a pressure exchanger (PX 310) without a low-pressure booster, according to some embodiments. In some embodiments, features that have reference numbers that correspond to reference numbers in other figures include similar properties, structures, and/or functionality as those described in other figures. In some embodiments, optional components described in connection with FIG. 3A (e.g., secondary evaporator, a system of compressors in place of main compressor 322, etc.) may also be optional components for fluid handling system 300B. In some examples, features of fluid handling system 300B have similar properties, structures, and/or functionality as fluid handling system 300A of FIG. 3A.

[00118] Fluid handling system 300B may be configured to provide heat transfer (e.g., refrigeration) via circulation of a working fluid (e.g., CO_2). Fluid handling system 300B may be configured to perform operations to adjust one or more components of fluid handling system 300B based on sensor data generated by sensors of fluid handling system 300B. In some embodiments, fluid handling system 300B may perform operations to achieve and/or maintain a target temperature of a bulk fluid output from a heat exchanger, e.g., heat exchanger 315. In some embodiments, fluid handling system 300B may receive temperature data from one or more temperature sensors indicative of temperatures of a fluid of fluid handling system 300B. Fluid handling system 300B may actuate one or more valves (e.g., bypass high-pressure valve 348) based on the temperature data. Fluid handling system 300B may adjust one or more components to achieve and/or maintain a target fluid temperature, target fluid subcooling, or the like.

[00119] Fluid handling system 300B may include a bypass high-pressure valve 348. Bypass high-pressure valve 348 may be an expansion valve or a flow control valve. In some embodiments, bypass high-pressure valve 348 selectively regulates a flow of fluid from the outlet of main gas cooler 329 (e.g., fluid discharged by main gas cooler 329) to heat exchanger 315, auxiliary gas cooler 327, and/or flash tank 313 (e.g., receiver) in parallel with the PX 310. In some embodiments, bypass high-pressure valve 348 can be actuated to selectively regulate the flow of fluid. Bypass high-pressure valve 348 may selectively provide a portion of fluid output by the main gas cooler 329 to the flash tank 313. For example, high-pressure bypass valve 348 can be actuated to be further opened to flow more fluid from the main gas cooler 329 to the flash tank 313, or bypass high-pressure valve 348 can be actuated to be further closed to flow less fluid from the main gas cooler 329 to the flash tank 313. The fluid may expand as the fluid flows through bypass high-pressure valve 348, causing a decrease in pressure and/or temperature of the fluid. In some embodiments, controller 394 may cause the bypass high-pressure valve 348 to actuate (e.g., open or close) based on sensor data received from one or more sensors of fluid handling system 300B.

[00120] In some embodiments, main gas cooler 329 may act as a condenser. In some embodiments, the fluid handling system may be operated at pressured and temperatures where fluid does or does not condense in main gas cooler 329. Any embodiment discussed herein may include a condenser that may act as a gas cooler in one or more applications.

[00121] Fluid handling system 300B may include a flash tank 313 (e.g., receiver). In some embodiments, flash tank 313 is a receiver configured to receive a flow of fluid (e.g., first fluid) output from the low pressure outlet of the PX 310. Flash tank 313 may form a chamber to collect the first fluid from the first outlet of the PX 310. Flash tank 313 may receive the first fluid in a two-phase state (e.g., liquid and gas), transcritical fluid, supercritical fluid, subcritical fluid, and/or combinations thereof. In some embodiments, flash tank 313 is a tank constructed of welded sheet metal. Flash tank 313 may include one or more flash tank inlets for receiving fluid and one or more flash tank outlets for discharging fluid (e.g., a gas outlet and a liquid outlet). The first fluid (at a low pressure) may separate into gas and liquid inside the flash tank 313 (e.g., indicated by the liquid surface depicted in FIG. 3B). The liquid of the first fluid may settle in the bottom of the flash tank 313 while the gas of the first fluid may rise to the top of the flash tank 313. The liquid may flow from flash tank 313 towards evaporator 318 (e.g., via expansion valve 316). The chamber of flash tank 313 may be maintained at a set pressure. The pressure may be set by a user (e.g., an operator, a technician, an engineer, etc.) and/or by a controller. In some embodiments, the pressure of the flash tank 313 is controlled by one or more valves (e.g., expansion valve 316, flash gas valve 320, a pressure regulator valve, a safety valve, etc.). In some embodiments, the flash tank 313 includes at least one pressure sensor (e.g., pressure transducer). In some embodiments, a liquid level of flash tank 313 may be monitored (e.g., to prevent liquid from being routed through flash gas valve 320).

[00122] Fluid handling system 300B may include an expansion valve 316. In some embodiments, expansion valve 316 is disposed along a flow path between flash tank 313 and evaporator 318, e.g., coupled between flash tank 313 and evaporator 318. Expansion valve 316 may be an adjustable valve (e.g., an electronic expansion valve, a thermostatic expansions valve, a ball valve, a gate valve, a poppet valve, etc.). Expansion valve 316 may be controllable by a user (e.g., a technician, an operator, an engineer, etc.) or by a controller (e.g., a controller sharing one or more features with controller 394). In some embodiments, the expansion valve 316 is caused to actuate by a controller based on sensor data (e.g., pressure sensor data, flowrate sensor data, temperature sensor data, etc.). In some embodiments, expansion valve 316 is a thermal expansion valve. Expansion valve 316 may actuate (e.g., open and/or close) based on temperature data associated with the evaporator 318 (e.g., temperature of liquid in the evaporator, temperature of gas in the evaporator, temperature of fluid entering the evaporator, temperature of fluid exiting the evaporator, etc.). For example, a pressure-sensitive component (e.g., sensing bulb) of the expansion valve 316 may increase or decrease pressure on a diaphragm of the expansion valve 316, causing a poppet valve coupled to the diaphragm to open or close, thus causing more or less flow of fluid to the evaporator 318, causing more or less expansion of the fluid. The pressure-sensitive component of the expansion valve may be positioned proximate to the downstream end of the evaporator 318 (e.g., proximate the outlet of the evaporator 318, outside evaporator 318, inside evaporator 318, or the like) and may be fluidly coupled to the diaphragm via a fluid line (e.g., a sensing capillary). In some embodiments, expansion valve 316 is controlled and actuated entirely based on electronic commands.

[00123] Fluid handling system 300B may include a flash gas valve 320 to regulate a flow of gas on a flash gas bypass flow path. In some embodiments, flash gas valve 320 is a bypass valve that regulates a flow of gas from a gas outlet of the flash tank 313 to be combined with output of the evaporator 318. In some embodiments, the flow of gas from the flash tank 313 flows along the flash gas bypass flow path to bypass the evaporator 318. In some embodiments, the flash gas flow path is between flash tank 313 and a location downstream of an outlet of the evaporator 318. The gas flowing along the flash gas bypass flow path may be combined with output of the evaporator 318. The flash gas valve 320 may cause gas collected in the flash tank 313 to expand (e.g., decrease in pressure) as the gas flows toward the main compressor 322. The flash gas valve 320 may, in some embodiments, be an adjustable valve. In some embodiments, the flash gas valve 320 is caused to actuate by a controller based on sensor data.

[00124] In some embodiments, fluid handling system 300B may further include one or more additional heat exchangers, e.g., heat exchanger 315, for exchanging heat between fluid in different portions of fluid handling system 300B. For example, fluid handling system 300B may include heat exchanger for exchanging heat between fluid output by main gas cooler 329 and fluid output by flash tank 313. Heat exchanger 315 may be used to exchange heat between fluid output by main gas cooler 329 and fluid expanded through bypass high-pressure valve 348. A first flow path including one or more fluid channels through the heat exchanger may be coupled between an outlet of main gas cooler 329 and both a high pressure inlet of PX 310 and bypass high-pressure valve 348. A second flow path including one or more fluid channels through the heat exchanger may be coupled between an outlet of bypass high-pressure valve 348 and a low-pressure inlet of PX 310. The heat exchanger may be configured to exchange heat between the fluid traveling along the first flow path and fluid traveling along the second flow path. The fluid being cooled (e.g., the fluid along the main fluid path, the fluid coupled directly to the main gas cooler 329 and/or main compressor 322, etc.) may pass through a bulk fluid channel of the heat exchanger 315, via a bulk fluid inlet and bulk fluid outlet. The heat exchanger may transfer heat from the main gas cooler 329 output fluid to the bypass high-pressure valve 348 output fluid. Fluid may expand through bypass high-pressure valve 348, decreasing in temperature and/or pressure. The cooler expanded fluid may be utilized as a heat sink for the bulk fluid in heat exchanger 315.

[00125] Heat exchanger 315 may be configured to achieve cooling of the bulk fluid passing through the bulk fluid channel of heat exchanger 315. Heat exchanger 315 may be configured to achieve a target value of subcooling of the bulk fluid passing through heat exchanger 315. Subcooling refers to a cooling of a fluid below the temperature at which the fluid condenses to a liquid, for fluids with a liquid/gas transition. Subcooling may be measured by measuring a temperature of the fluid, e.g., by temperature gauge 386. Heat exchanger 315 may target a temperature drop across the heat exchanger 315, e.g., measured by temperature gauge 386 after the bulk fluid flows through heat exchanger 315 and temperature gauge 388 before the bulk fluid flows through heat exchanger 315.

[00126] Controller 394 may provide a control signal to operate bypass high-pressure valve 348. Controller 394 may receive temperature data from one or more temperature sensors, e.g., temperature gauge 386 and/or temperature gauge 388. Controller 394 may generate a control signal for bypass high-pressure valve 348 based on the sensor data. Controller 394 may generate a control signal to cause actuation of bypass high-pressure valve 348 to a target opening. Controller 394 may generate a control signal to target a temperature of bulk fluid output by heat exchanger 315, a target level of subcooling of bulk fluid in heat exchanger 315, etc.

[00127] In another example, fluid handling system 300B may include a heat exchanger including a first flow path coupled between output of flash tank 313 and the output stream of evaporator 318, and a second flow path coupled before a low pressure inlet of PX 310. The heat exchanger may facilitate the transfer of heat from near the inlet of PX 310 to fluid output from flash tank 313. The transfer of heat via the heat exchanger may improve operation similarly as the previous example heat exchanger, e.g., may vaporize liquid and/or increase superheat of the output stream of evaporator 318, may increase COP by increasing density of fluid flowing through PX 310, etc.

[00128] In another example, fluid handling system 300B may include a heat exchanger, including a first flow path coupled between an outlet of flash tank 313 and an output stream of evaporator 318, and a second flow path coupled between a high pressure outlet of PX 310 and an inlet of flash tank 313. Heat may be provided to the output of flash tank 313. Advantages provided may be similar to previously discussed heat exchangers.

[00129] In some embodiments, fluid handling system 300B may include an auxiliary high-pressure valve 369. Auxiliary high-pressure valve 369 may control flow though auxiliary gas cooler 327. Auxiliary high-pressure valve 369 may be coupled to bypass high-pressure valve 348, e.g., the two high-pressure valves may be along the same fluid flow path. Auxiliary high-pressure valve 369 may have an effect on a travel distance of PX 310, e.g., low-pressure inlet travel distance. Controller 395 may provide control signals to auxiliary high-pressure valve 369.

[00130] Controller 395 may receive input indicative of an opening of bypass high-pressure valve 348. Auxiliary high-pressure valve 369 may be provided a control signal such that flow through the auxiliary high-pressure valve 369 corresponds to flow through bypass high-pressure valve 348 based on the opening of bypass high-pressure valve 348. Various properties of fluid handling system 300B, e.g., properties of the components disposed between bypass high-pressure valve 348 and auxiliary high-pressure valve 369, may further be utilized in determining a target opening for auxiliary high-pressure valve 369. The signal provided to controller 395 indicative of an opening of bypass high-pressure valve 348 may be provided by bypass high-pressure valve 348, a sensor associated with bypass high-pressure valve 348, controller 394 that provided control signals to bypass high-pressure valve 348, or the like. Controller 395 may determine a target opening of bypass high-pressure valve 348 based on signals from temperature gauge 386 and/or temperature gauge 388 and determine an opening of auxiliary high-pressure valve 369 based on the determine opening of bypass high-pressure valve 348. Controller 395 may receive temperature data from one or more of temperature gauge 386 or temperature gauge 388 and determine an opening of auxiliary high-pressure valve 369 based on the temperature data. Controller 395 may further receive data indicating total system load of fluid handling system 300B. Total system load may be determine based on specifications (e.g., swept volume) and operating speed of main compressor 322.

[00131] In some embodiments, fluid handling system 300B may include a PX high pressure valve and/or a PX on/off valve. The PX high pressure valve may control a flow of a fluid output from the high pressure outlet of the PX. The PX high pressure valve may be coupled between the high pressure outlet of the PX and an inlet of flash tank 313. Expanding the fluid through the PX high pressure valve into flash tank 313 may alter the ratio of gas to liquid of the fluid in flash tank 313. The PX on/off valve may control a flow of high pressure fluid from an outlet of main gas cooler 329 to the high pressure inlet of PX 310. The PX high pressure valve and/or the PX on/off valve may be controlled by one or more controllers. The valves may be controlled based on measurements received from one or more sensors. For example, the PX high pressure valve may be adjusted based on a sensor reporting on the gas to liquid ratio in flash tank 313.

[00132] In some embodiments, one or more components of fluid handling system 300B and/or fluid handling system 300A may be provided as a retrofit, as an addition to an existing fluid handling system, as an upgrade package, or the like. For example, a refrigeration system may not include PX 310, LP booster 314, one or more high-pressure valves, or the like. All fluid input to main gas cooler 329 in the refrigeration system may pass through main compressor 322. Components including PX 310, an associated motor, controllers 390-395, high-pressure valves, etc., may be added to a system, e.g., for increasing energy efficiency of the system by introduction of PX 310 (e.g., for energy recovery, for pressure transfer, etc.).

[00133] In some embodiments, a PX system (e.g., fluid handling system 300A, fluid handling system 300B, etc.) may be included in a system with additional components. The additional components (e.g., parent rack) may include sufficient components to perform operations of the fluid handling system without use of various components included in FIGS. 3A-B, e.g., PX 310, auxiliary gas cooler 327, LP booster 314, auxiliary high-pressure valves 368 and 369, bypass high-pressure valve 348, etc. In some embodiments, operations of the fluid handling system may be performed such that PX 310 and associated components are bypassed, e.g., in favor of components of the parent rack. One or more sensors may determine whether operation of PX 310 and associated components is to be performed. For example, under certain combinations of target conditions, ambient conditions, fluid conditions, etc., PX 310 may not provide sufficient value to justify operation of the PX 310 and associated components. Under such conditions, PX 310 may be bypassed and the parent rack may be utilized for operations performed by PX 310 and other components described in connection with FIGS. 3A-B.

[00134] In some embodiments, temperature of fluid between main gas cooler 329 and a HP-IN of PX 310 may be utilized to determine whether to operate PX 310. A diversion to the parent rack for bypassing PX 310 may be disposed in the fluid path between main gas cooler 329 and HP-IN of PX 310, along with one or more associated valves. Valves directing fluid flow to PX 310 may be operated based on the temperature of the fluid provided to HP-IN of PX 310. In some embodiments, one or more valves may be included for safety, e.g., if a sensor detects a condition that may damage one or more components of the fluid handling system, the safety valves may close to prevent or reduce damage to the one or more components of the system.

[00135] FIGS. 4A-C are flow diagrams illustrating methods 400A-C for controlling fluid handling systems (e.g., one or more of fluid handling systems 300A-B of FIGS. 3A-B), according to some embodiments. In some embodiments, methods 400A-C are performed by processing logic that includes hardware (e.g., circuitry, dedicated logic, programmable logic, microcode, processing device, etc.), software (such as instructions run on a processing device, a general purpose computer system, or a dedicated machine), firmware, microcode, or a combination thereof. In some embodiments, methods 400A-C are performed, at least in part, by one or more controllers (e.g., control module 180 of FIGS. 1A-B, controllers 390-395 of FIGS. 3A-B). In some embodiments, a non-transitory storage medium stores instructions that when executed by one or more processing devices (e.g., of control module 180 of FIGS. 1A-B, controllers 390-395 of FIGS. 3A-B), cause the processing device to perform methods 400A-C.

[00136] For simplicity of explanation, methods 400A-C are depicted and described as a series of operations. However, operations in accordance with this disclosure can occur in various orders and/or concurrently and with other operations not presented and described herein. Furthermore, in some embodiments, not all illustrated operations are performed to implement methods 400A-C in accordance with the disclosed subject matter. In addition, those skilled in the art will understand and appreciate that methods 400A-C are could alternatively be represented as a series of interrelated states via a state diagram or events.

[00137] FIG. 4A is a flow diagram of a method 400A for providing control of one or more components of a fluid handling system, according to some embodiments. The fluid handling system of method 400A may be a heat transfer system, a heat pump system, a refrigeration system, and/or the like (e.g., one or more of the architectures discussed in connection with one or more of FIGS. 3A-B).

[00138] At block 402, processing logic optionally identifies first pressure data associated with a condenser of a heat transfer system. The processing logic may determine a speed of operation of a PX (e.g., PX 310 of FIG. 3A) of the heat transfer system based on the first pressure data. The condenser may be a gas cooler in embodiments, e.g., main gas cooler 329 of FIG. 3A.

[00139] At block 404, processing logic identifies a first indication of speed of operation of a pressure exchanger (PX) of a heat transfer system. Identifying the first indication of speed of operation may include receiving sensor data from a sensor measuring a speed of operation (e.g., rotational speed of a rotor) of the PX. Identifying the first indication of speed of operation may include receiving a control signal directed to adjust a speed of operation of the PX. Identifying the first indication of speed may include receiving sensor data upon which a control signal for the speed of operation of the PX is based.

[00140] At block 406, processing logic optionally identifies a second indication of a temperature of a fluid to enter a high-pressure inlet of the PX. At block 408, processing logic optionally identifies a third indication of system load, optionally based on speed of operation of one or more compressors of the heat transfer system. The one or more compressors may be main compressors, e.g., the one or more compressors may drive fluid between an evaporator (e.g., heat source) and condenser (e.g., heat sink) of the heat transfer system. System load, as used herein, indicates a total amount of fluid (e.g., refrigeration fluid) transferred through the system (e.g., mass flow through the main compressor or main compressor set). System load may further be based on specifications of the system and/or main compressor, e.g., fluid pressure, fluid pressure at the main compressor, operating volume (e.g., swept volume of fluid displaced in one stroke or rotation) of the main compressor, etc.

[00141] At block 410, processing logic determines, based on the first indication of speed of operation of the PX, a target opening value of a first valve. An inlet of the first valve is coupled to a high-pressure outlet of the PX. The inlet of the first valve may be configured to receive fluid output by the high-pressure outlet of the PX, e.g., the first valve may be directly fluidly coupled to the high-pressure outlet of the PX. Determining the target opening of the first valve may be further based on additional data, e.g., the second indication of temperature of a high-pressure inlet of the PX and/or third indication of system load.

[00142] At block 412, processing logic causes, based on the target opening value, actuation of the first valve. Actuation of the first valve may adjust the opening of the first valve to the target value.

[00143] At block 414, processing logic optionally determines, based on the first indication, a target speed of operation of a low-pressure booster. The low-pressure booster (e.g., an outlet of the low-pressure booster) may be coupled to a low-pressure inlet of the PX. The target speed of operation of the low-pressure booster may further be based on a relationship between low-pressure booster operations speeds and PX operation speeds. The relationship may be enumerated, e.g., codified, recorded in a lookup table, or the like. The relationship may be functional, formulaic, or the like. Determining the target speed of operation of the low-pressure booster may further be based on a measured pressure differential between a first pressure of a fluid at a low-pressure inlet of the PX and a second pressure of the fluid at a low-pressure outlet of the PX. Processing logic may receive data of the pressure differential for determining the target speed of operation of the low-pressure booster.

[00144] At block 416, processing logic optionally causes, based on the target speed of operation of the low-pressure booster, adjustment of a speed of operation of the low-pressure booster. Adjustment of the speed of operation of the low-pressure booster (and any adjustments or component actions described in FIGS. 4A-C) may be performed by providing, by processing logic of a controller, a control signal to the low-pressure booster to cause the adjustment to the speed of operation of the low-pressure booster.

[00145] FIG. 4B is a flow diagram of a method 400B (e.g., via controller 393 of FIG. 3A) for adjusting operation of a fluid handling system including a low-pressure booster, according to some embodiments. At block 420, processing logic optionally identifies first pressure data associated with a condenser of a heat transfer system. At block 422, processing logic optionally determines a speed of operation of the PX based on the first pressure data. Operations of blocks 420 and 422 may share features with operations of block 402 of FIG. 4A.

[00146] At block 424, processing logic obtains a first indication of the speed of operation of the PX of the heat transfer system. Operations of block 424 may share features with operations of block 404.

[00147] At block 426, processing logic determines a target speed of operation of a low-pressure booster. An outlet of the low-pressure booster is fluidly coupled to provide fluid to a low-pressure inlet of the PX. The target speed of operation of the low-pressure booster is based on the speed of operation of the PX. The target speed of operation of the low-pressure booster may further be based on a relationship between the low-pressure booster operation speeds and PX operations speeds. The relationship may be a functional relationship, recorded in a look-up table, etc. The target speed of operation of the low-pressure booster may further be based on a target low-pressure inlet travel distance of the PX. The target speed of operation of the low-pressure booster may further be based on specifications of the low-pressure booster and/or PX, e.g., operating volumes of the booster and PX, pumping efficiencies of the booster and PX, swept volume of the booster, duct volume of the PX, etc.

[00148] At block 428, processing logic causes an adjustment to a speed of operation of the low-pressure booster. The adjustment may be based on the target speed of operation of the low-pressure booster. The adjustment may cause the low-pressure booster to be operated at the target speed. The adjustment may be performed by providing a control signal indicative of the target speed of operation to the low-pressure booster (e.g., a motor of the low-pressure booster).

[00149] At block 430, processing logic optionally identifies an indication of a temperature of an auxiliary gas cooler of the heat transfer system. An inlet of the auxiliary gas cooler may be configured to receive fluid from a high-pressure outlet of the PX (e.g., the auxiliary gas cooler may be coupled in a fluid flow path of a fluid handling system directly after a high-pressure outlet of the PX). At block 432, processing logic optionally adjusts operation of a cooling component of the auxiliary gas cooler based on the second indication. The cooling component may be a fan, coolant pump, or another component configured to increase heat transfer from the fluid of the fluid handling system at the auxiliary gas cooler to the surrounding environment.

[00150] FIG. 4C is a flow diagram of a method 400C (e.g., via controller 394 of FIG. 3B) for adjusting operation of a boosterless PX system, based on sensor data of the PX system, according to some embodiments. At block 440, processing logic identifies first temperature data indicative of a temperature difference between a fluid at a bulk inlet of a heat exchanger and the fluid at a bulk outlet of the heat exchanger. The bulk outlet of the heat exchanger is coupled to the bulk inlet of the heat exchanger via one or more channels of the heat exchanger, e.g., channels passing through the heat exchanger for facilitating the exchange of thermal energy between the bulk fluid and a secondary fluid. The bulk outlet of the heat exchanger may be fluidly coupled to a high-pressure inlet of a PX. The bulk outlet of the heat exchanger may be directly coupled to a high-pressure inlet of a PX, e.g., the high-pressure inlet of the PX may be configured to receive fluid from the bulk outlet of the heat exchanger.

[00151] At block 442, processing logic determines a target adjustment of a first valve. The determination may be made based on the first temperature data. The first valve may be fluidly coupled to the bulk outlet of the heat exchanger and to a cooling fluid inlet (e.g., secondary inlet) of the heat exchanger. The first valve may be fluidly coupled between the bulk outlet of the heat exchanger and the cooling fluid inlet of the heat exchanger. The cooling fluid inlet may be configured to receive output of the bulk outlet of the heat exchanger via the first valve. Determining the target adjustment to the first valve may include determining that a value of subcooling of the bulk fluid in the heat exchanger does not meet a threshold value. Determining the target adjustment to the first value may include determining that the target adjustment is predicted to adjust the value of subcooling of the bulk fluid to be within a threshold value of the target level of subcooling. The adjustment may be based on a relationship between fluid flow (e.g., mass flow) to the cooling inlet (e.g., an amount of cooling fluid provided to the secondary channels of the heat exchanger) and subcooling of the bulk fluid.

[00152] At block 444, processing logic causes, based on the target adjustment to the first valve, actuation of the first valve. The actuation may be to the target position of the first valve.

[00153] At block 446, processing logic optionally determines, based on the opening of the first valve, a target adjustment to a second valve. The second valve may be fluidly coupled to a high-pressure outlet of the PX. The second valve may be fluidly coupled between a high-pressure outlet of the PX and an inlet to a flash tank. The second valve may be fluidly coupled to an outlet of a gas cooler, e.g., an auxiliary gas cooler. The second valve and the gas cooler may be arranged in the fluid path between the high-pressure outlet of the PX and an inlet of the flash tank (e.g., receiver). The target adjustment to the second valve may further be based on mass flow through the first and second valves, e.g., a lookup table that includes correspondences between openings in the first and second valves and mass flows through the first and second valves. The target adjustment to the second valve may further be based on a total system load of a heat transfer system including the PX (e.g., total fluid flow through a main compressor, total fluid flow through an evaporator or condenser, etc.). The target adjustment to the second valve may further be based on temperature data indicative of the temperature of the fluid at the bulk outlet of the heat exchanger.

[00154] At block 448, processing logic optionally causes, based on the target opening of the second valve, actuation of the second valve.

[00155] FIG. 5 is a block diagram illustrating a computer system 500, according to some embodiments. In some embodiments, the computer system 500 is a client device. In some embodiments, the computer system 500 is a controller device (e.g., server, control module 180 of FIGS 1A-B, controllers 390-395 of FIGS. 3A-B, etc.).

[00156] In some embodiments, computer system 500 is connected (e.g., via a network, such as a Local Area Network (LAN), an intranet, an extranet, or the Internet) to other computer systems. Computer system 500 operates in the capacity of a server or a client computer in a client-server environment, or as a peer computer in a peer-to-peer or distributed network environment. In some embodiments, computer system 500 is provided by a personal computer (PC), a tablet PC, a Set-Top Box (STB), a Personal Digital Assistant (PDA), a cellular telephone, a web appliance, a server, a network router, switch or bridge, or any device capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken by that device. Further, the term "computer" shall include any collection of computers that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methods described herein.

[00157] In some embodiments, the computer system 500 includes a processing device 502, a volatile memory 504 (e.g., Random Access Memory (RAM)), a non-volatile memory 506 (e.g., Read-Only Memory (ROM) or Electrically-Erasable Programmable ROM (EEPROM)), and/or a data storage device 516, which communicates with each other via a bus 508.

[00158] In some embodiments, processing device 502 is provided by one or more processors such as a general purpose processor (such as, for example, a Complex Instruction Set Computing (CISC) microprocessor, a Reduced Instruction Set Computing (RISC) microprocessor, a Very Long Instruction Word (VLIW) microprocessor, a microprocessor implementing other types of instruction sets, or a microprocessor implementing a combination of types of instruction sets) or a specialized processor (such as, for example, an Application Specific Integrated Circuit (ASIC), a Field Programmable Gate Array (FPGA), a Digital Signal Processor (DSP), a PID controller, or a network processor). In some embodiments, processing device 502 is provided by one or more of a single processor, multiple processors, a single processor having multiple processing cores, and/or the like.

[00159] In some embodiments, computer system 500 further includes a network interface device 522 (e.g., coupled to network 574). In some embodiments, the computer system 500 includes one or more input/output (I/O) devices. In some embodiments, computer system 500 also includes a video display unit 510 (e.g., a liquid crystal display (LCD)), an alphanumeric input device 512 (e.g., a keyboard), a cursor control device 514 (e.g., a mouse), and/or a signal generation device 520. Computer system 500 may include signal input device 515, e.g., for receiving signals from other devices. For example, signal input device 515 may facilitate reception by computer system 500 of measurement data from sensors associated with a fluid handling system. Signal generation device 520 may be utilized to generate and/or send control signals for sending instructions to one or more components of a fluid handling system. Signal generation device 520 may send control signals to various high-pressure valves, booster pumps, cooling components, PX components, etc.

[00160] In some implementations, data storage device 518 (e.g., disk drive storage, fixed and/or removable storage devices, fixed disk drive, removable memory card, optical storage, network attached storage (NAS), and/or storage area-network (SAN)) includes a non-transitory computer-readable storage medium 524 on which stores instructions 526 encoding any one or more of the methods or functions described herein, and for implementing methods described herein. Control module 527 (e.g., including any of controllers 390-395 of FIGS. 3A-B) may be included in instructions 526.

[00161] In some embodiments, instructions 526 also reside, completely or partially, within volatile memory 504 and/or within processing device 502 during execution thereof by computer system 500, hence, volatile memory 504 and processing device 502 also constitute machine-readable storage media, in some embodiments.

[00162] While computer-readable storage medium 524 is shown in the illustrative examples as a single medium, the term "computer-readable storage medium" shall include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) that store the one or more sets of executable instructions. The term "computer-readable storage medium" shall also include any tangible medium that is capable of storing or encoding a set of instructions for execution by a computer that cause the computer to perform any one or more of the methods described herein. The term "computer-readable storage medium" shall include, but not be limited to, solid-state memories, optical media, and magnetic media.

[00163] The methods, components, and features described herein may be implemented by discrete hardware components or may be integrated in the functionality of other hardware components such as ASICS, FPGAs, DSPs or similar devices. In addition, the methods, components, and features may be implemented by firmware modules or functional circuitry within hardware devices. Further, the methods, components, and features may be implemented in any combination of hardware devices and computer program components, or in computer programs.

[00164] Unless specifically stated otherwise or clear from context, terms such as “actuating,” “adjusting,” “causing,” “controlling,” “determining,” “identifying,” “providing,” “receiving,” “generating,” “obtaining,” or the like, refer to actions and processes performed or implemented by computer systems that manipulates and transforms data represented as physical (electronic) quantities within the computer system registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices. Also, the terms "first," "second," "third," "fourth," etc. as used herein are meant as labels to distinguish among different elements and may not have an ordinal meaning according to their numerical designation.

[00165] Examples described herein also relate to an apparatus for performing the methods described herein. This apparatus may be specially constructed for performing the methods described herein, or it may include a general purpose computer system selectively programmed by a computer program stored in the computer system. Such a computer program may be stored in a computer-readable tangible storage medium.

[00166] The methods and illustrative examples described herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used in accordance with the teachings described herein, or it may prove convenient to construct more specialized apparatus to perform methods described herein and/or each of their individual functions, routines, subroutines, or operations. Examples of the structure for a variety of these systems are set forth in the description above.

[00167] The preceding description sets forth numerous specific details, such as examples of specific systems, components, methods, and so forth, in order to provide a good understanding of several embodiments of the present disclosure. It will be apparent to one skilled in the art, however, that at least some embodiments of the present disclosure may be practiced without these specific details. In other instances, well-known components or methods are not described in detail or are presented in simple block diagram format in order to avoid unnecessarily obscuring the present disclosure. Thus, the specific details set forth are merely exemplary. Particular implementations may vary from these exemplary details and still be contemplated to be within the scope of the present disclosure. Descriptions of systems herein may include descriptions of one or more optional components. Components may be included in combinations not specifically discussed in this disclosure, and still be within the scope of this disclosure. For example, any of controllers 390-395 of FIGS. 3A-D, alone or in any combination, may be included in a fluid handling system that is within the scope of this disclosure.

[00168] Reference throughout this specification to “one embodiment” or “an embodiment” means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, the appearances of the phrase “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment. In addition, the term “or” is intended to mean an inclusive “or” rather than an exclusive “or.” When the term “about,” “substantially,” or "approximately" is used herein, this is intended to mean that the nominal value presented is precise within ±10%. Also, the terms "first," "second," "third," "fourth," etc. as used herein are meant as labels to distinguish among different elements and can not necessarily have an ordinal meaning according to their numerical designation.

[00169] The terms "over," "under," "between," "disposed on," "before," "after," and "on" as used herein refer to a relative position of one material layer or component with respect to other layers or components. For example, one layer disposed on, over, or under another layer may be directly in contact with the other layer or may have one or more intervening layers. Moreover, one layer disposed between two layers may be directly in contact with the two layers or may have one or more intervening layers. Similarly, unless explicitly stated otherwise, one feature disposed between two features may be in direct contact with the adjacent features or may have one or more intervening layers or components.

[00170] Although the operations of the methods herein are shown and described in a particular order, the order of the operations of each method may be altered so that certain operations may be performed in an inverse order or so that certain operation may be performed, at least in part, concurrently with other operations. In another embodiment, instructions or sub-operations of distinct operations may be in an intermittent and/or alternating manner.

[00171] It is to be understood that the above description is intended to be illustrative, and not restrictive. Many other embodiments will be apparent to those of skill in the art upon reading and understanding the above description. The scope of the disclosure should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which each claim is entitled.

CLAIMS

What is claimed is:

1. A method comprising:

identifying, by a processing device, a first indication of a speed of operation of a pressure exchanger (PX) of a heat transfer system;

determining, based on the first indication of the speed of operation of the PX, a target opening value of a first valve, wherein an inlet of the first valve is coupled to a high-pressure outlet of the PX; and

causing, based on the target opening value, actuation of the first valve.

2. The method of claim 1 further comprising identifying a second indication of a temperature of a fluid coupled to a high-pressure inlet of the PX, wherein the causing of the actuation of the first valve is further based on the second indication.

3. The method of claim 1, further comprising identifying a third indication of system load, wherein determining the target opening value of the first valve is further based on the system load.

4. The method of claim 3, wherein system load is determined based on a speed of operation of one or more compressors of the heat transfer system.

5. The method of claim 1, further comprising:

determining, based on the first indication of the speed of operation of the PX, a target speed of operation of a low-pressure booster, wherein an outlet of the low-pressure booster is coupled to a low-pressure inlet of the PX; and

causing, based on the target speed of operation of the low-pressure booster, adjustment of a speed of operation of the low-pressure booster.

6. The method of claim 5, wherein determining the target speed of operation of the low-pressure booster is based on a relationship between low-pressure booster operation speeds and PX operation speeds.

7. The method of claim 5, further comprising determining a pressure differential between a first pressure of a fluid at a low-pressure inlet of the PX and a second pressure of the fluid at a low-pressure outlet of the PX, wherein the determining of the target speed of operation of the low-pressure booster is further based on the pressure differential.

8. The method of claim 1, further comprising:

identifying first pressure data associated with a condenser of the heat transfer system; and

determining the speed of operation of the PX based on the first pressure data.

9. A method, comprising:

obtaining, by a processing device, a first indication of a speed of operation of a pressure exchanger (PX) of a heat transfer system;

determining, based on the first indication of the speed of operation of the PX, a target speed of operation of a low-pressure booster, wherein an outlet of the low-pressure booster is coupled to provide fluid to a low-pressure inlet of the PX; and

causing, based on the target speed of operation of the low-pressure booster, an adjustment to a speed of operation of the low-pressure booster.

10. The method of claim 9, wherein determining the target speed of operation of the low-pressure booster is based on a relationship between low-pressure booster operation speeds and PX operation speeds.

11. The method of claim 9, wherein determining the target speed of operation of the low-pressure booster comprises obtaining a target travel distance for fluid provided to a low pressure inlet of the PX, wherein the target speed of operation of the low-pressure booster is based on an operating volume of the low-pressure booster, an operating volume of the PX, and the target travel distance.

12. The method of claim 9, further comprising:

identifying a second indication of a temperature of an auxiliary gas cooler of the heat transfer system, wherein an inlet of the auxiliary gas cooler is configured to receive fluid from a high-pressure outlet of the PX; and adjusting operation of a cooling component of the auxiliary gas cooler based on the second indication.

13. The method of claim 9, further comprising:

identifying first pressure data associated with a condenser of the heat transfer system; and

determining the speed of operation of the PX based on the first pressure data.

14. The method of claim 9, further comprising:

determining, based on the first indication of the speed of operation of the PX, a target opening value of a first valve, wherein an inlet of the first valve is fluidly coupled to a high-pressure outlet of the PX; and

causing, based on the target opening value, actuation of the first valve.

15. A method, comprising:

identifying, by a processing device, first temperature data indicative of a temperature difference between a bulk fluid at a first inlet of a heat exchanger and the bulk fluid at a first outlet of the heat exchanger, fluidly coupled to the first inlet by one or more fluid channels of the heat exchanger, wherein the outlet of the heat exchanger is fluidly coupled to a high-pressure inlet of a pressure exchanger (PX);

determining, based on the first temperature data, a target adjustment of a first valve fluidly coupled to the first outlet of the heat exchanger and to a secondary fluid inlet of the heat exchanger; and

causing, based on the target adjustment, actuation of the first valve.

16. The method of claim 15, wherein determining the target adjustment to the first valve comprises:

determining that a value of subcooling of the bulk fluid in the heat exchanger does not meet a threshold subcooling value; and

determining that the target adjustment to the first valve is predicted to adjust the value of subcooling of the bulk fluid such that the subcooling satisfies the target subcooling condition.

17. The method of claim 16, wherein the determining that the target adjustment to the first valve is predicted to adjust the value of subcooling of the bulk fluid is based on a relationship between flow to the secondary fluid inlet and subcooling of the bulk fluid.

18. The method of claim 15, further comprising:

determining, based on an opening of the first valve in view of the target adjustment of the first valve, a target adjustment of a second valve, an inlet of the second valve being fluidly coupled to a high-pressure outlet of the PX; and

causing, based on the target opening of the second valve, actuation of the second valve.

19. The method of claim 18, wherein the determining of the target adjustment of the second valve comprises determining an opening of the second valve that provides a mass flow through the second valve that corresponds to a mass flow through the first valve based on the opening of the first valve.

20. The method of claim 18, further comprising obtaining a system load of a heat transfer system comprising the PX, wherein determining a target opening of the second valve is further based on the system load.

21. The method of claim 18, further comprising obtaining second temperature data indicative of the temperature of the fluid at the first outlet of the heat exchanger, wherein determining a target opening of the second valve is further based on the second temperature data.

22. A non-transitory machine-readable storage medium storing instructions which, when executed, cause a processing device to perform any of the methods of claims 1-21.

23. A system, comprising memory and a processing device coupled to the memory, wherein the processing device is configured to perform any of the methods of claims 1-21.

24. A system, comprising:

a pressure exchanger (PX);

a first condenser;

a first valve;

a heat exchanger comprising:

a bulk inlet fluidly coupled to an outlet of the first condenser,

a bulk outlet fluidly coupled to both the first valve and a high-pressure inlet of the PX, and

a secondary inlet fluidly coupled to the first valve;

a first temperature sensor configured to provide first temperature data associated with a temperature different of a bulk fluid at the bulk inlet of the heat exchanger and the bulk outlet of the heat exchanger; and

a first controller operatively coupled to the first valve, wherein the first controller is configured to actuate the first valve based on the first temperature data.

25. A system, comprising:

a pressure exchanger (PX);

a first valve fluidly coupled to a high-pressure outlet of the PX; and

a first controller operatively coupled to the first valve, wherein the first controller is configured to cause actuation of the first valve based on a speed of operation of the PX.

26. A system, comprising:

a pressure exchanger (PX);

a low-pressure booster comprising an outlet that is fluidly coupled to a low-pressure inlet of the PX; and

a first controller operatively coupled to the low-pressure booster, wherein the first controller is configured to cause, based on a speed of operation of the PX, adjustment of a speed of operation of the low-pressure booster.

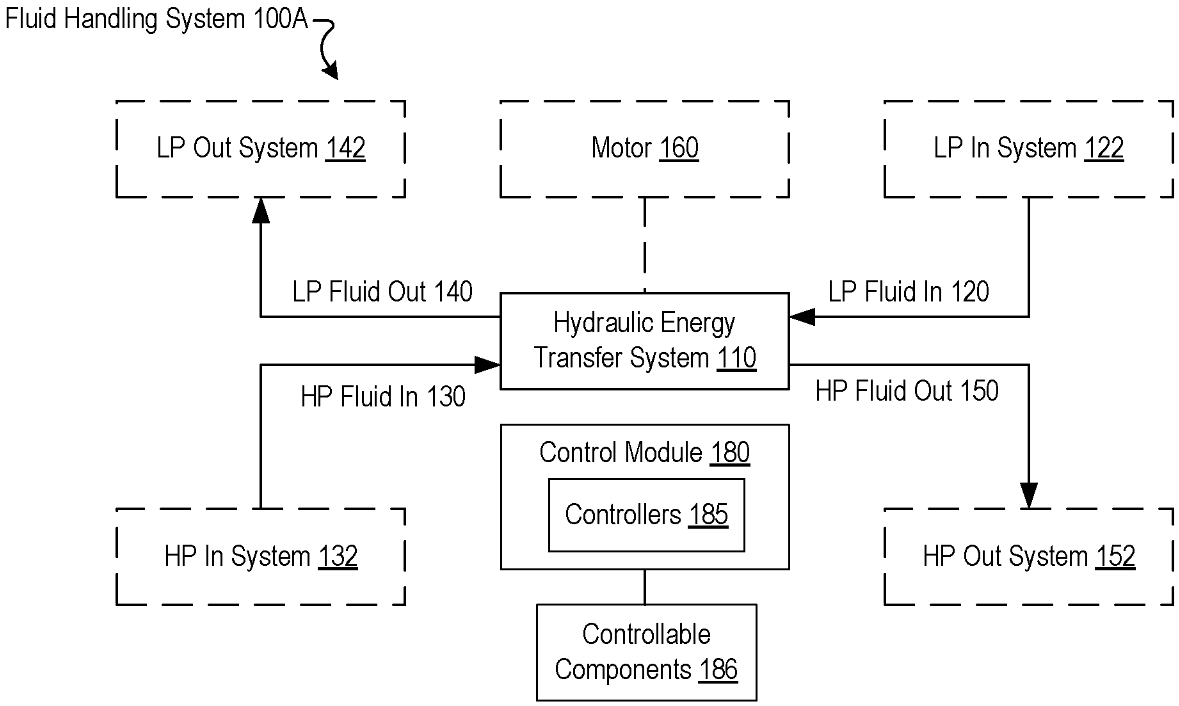

Fluid Handling System 100A
LP Out System 142
Motor 160
LP In System 122
LP Fluid Out 140
LP Fluid In 120
Hydraulic Energy Transfer System 110
HP Fluid In 130
HP Fluid Out 150
Control Module 180
Controllers 185
HP In System 132
HP Out System 152
Controllable Components 186

FIG. 1A

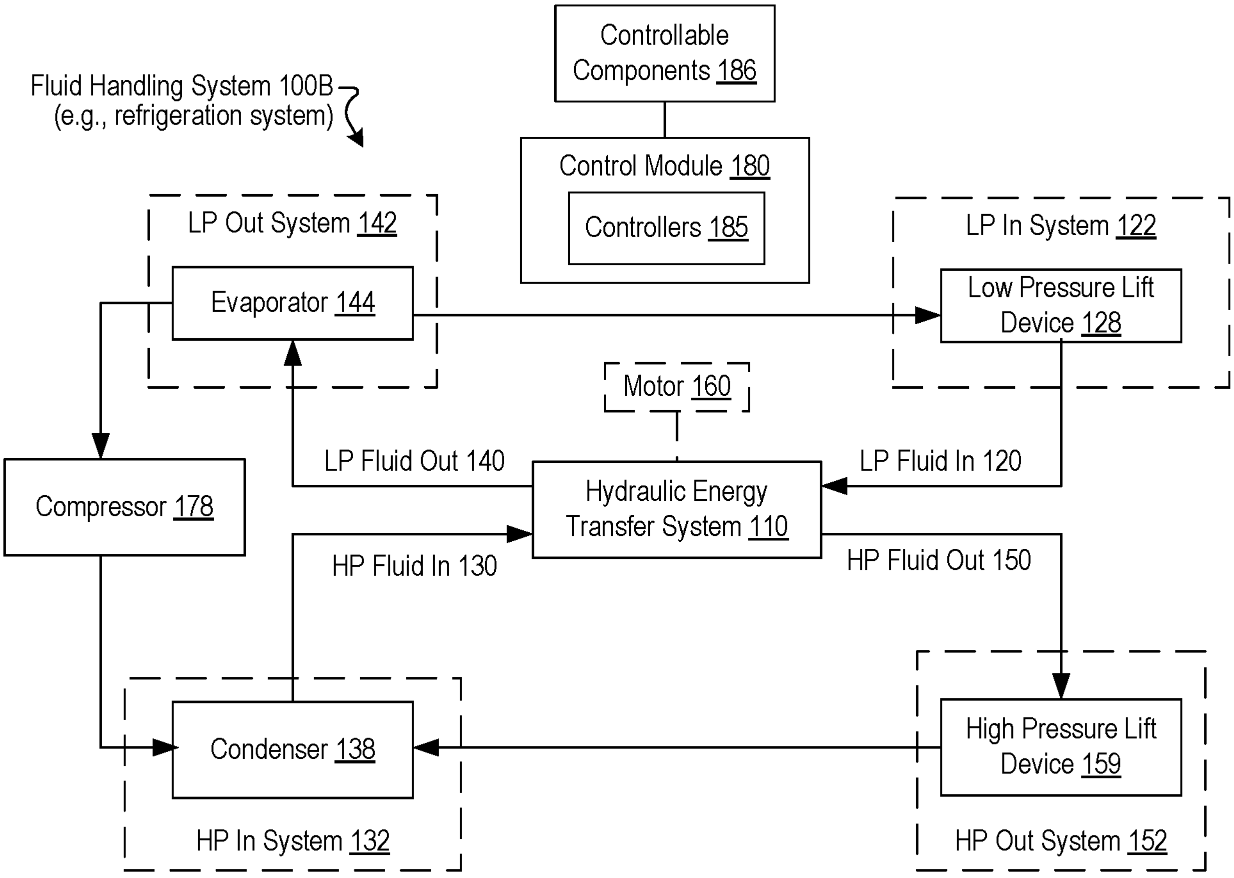

Fluid Handling System 100B (e.g., refrigeration system)
Controllable Components 186
Control Module 180
Controllers 185
LP Out System 142
Evaporator 144
LP In System 122
Low Pressure Lift Device 128
Motor 160
Compressor 178
LP Fluid Out 140
LP Fluid In 120
Hydraulic Energy Transfer System 110
HP Fluid In 130
HP Fluid Out 150
Condenser 138
HP In System 132
High Pressure Lift Device 159
HP Out System 152

FIG. 1B

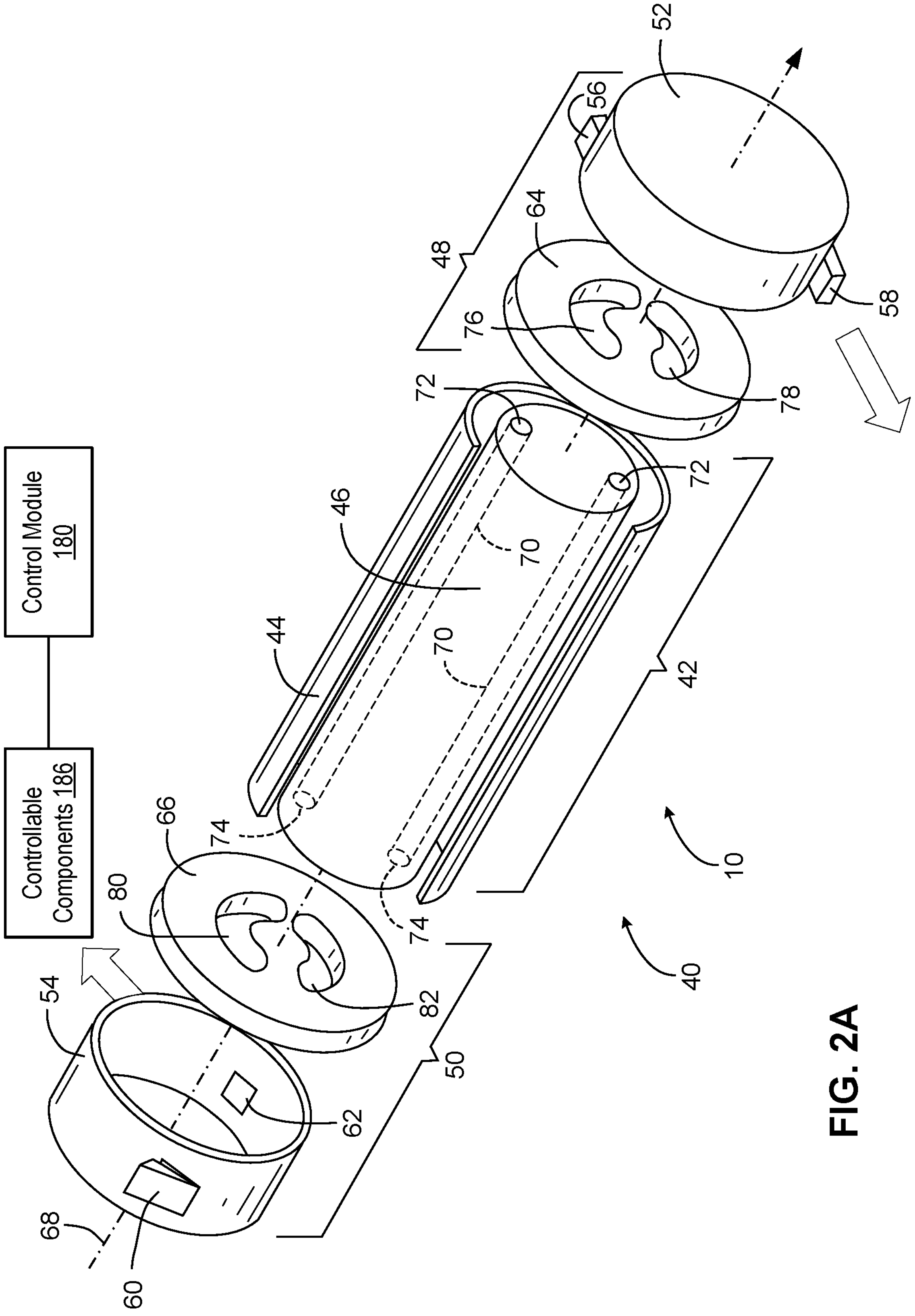

Control Module 180
Controllable Components 186
52
56
48
64
58
76
78
72
72
46
70
70
44
42
66
74
74
80
82
10
40
54
50
62
68
60

FIG. 2A

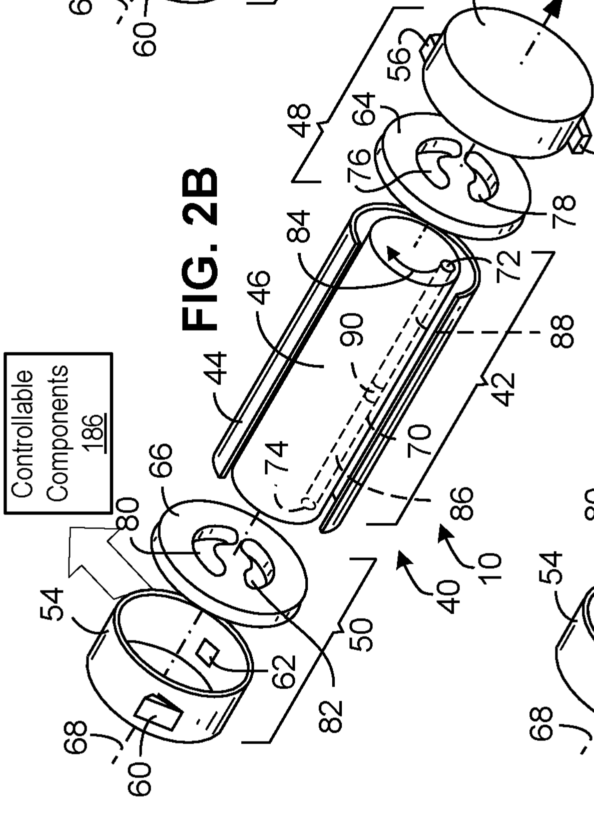


FIG. 2B

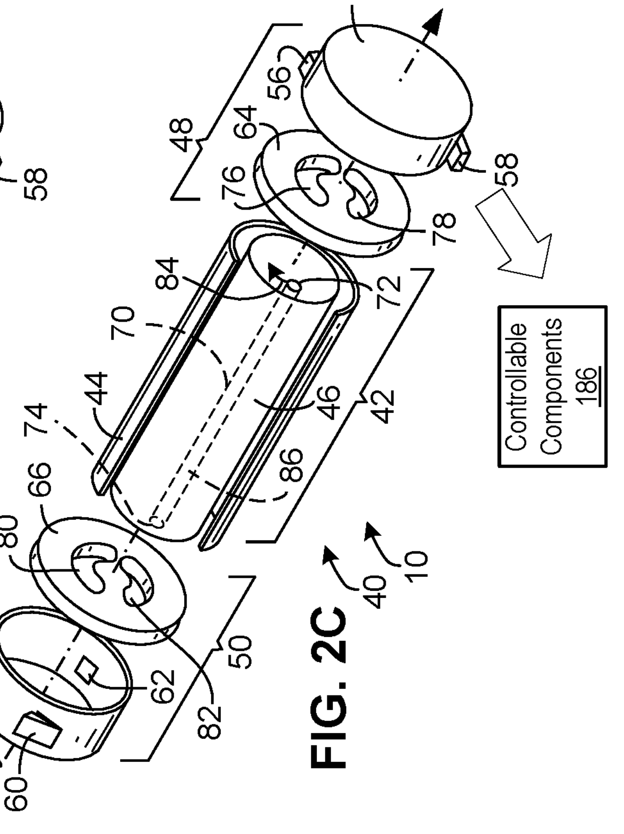


FIG. 2C

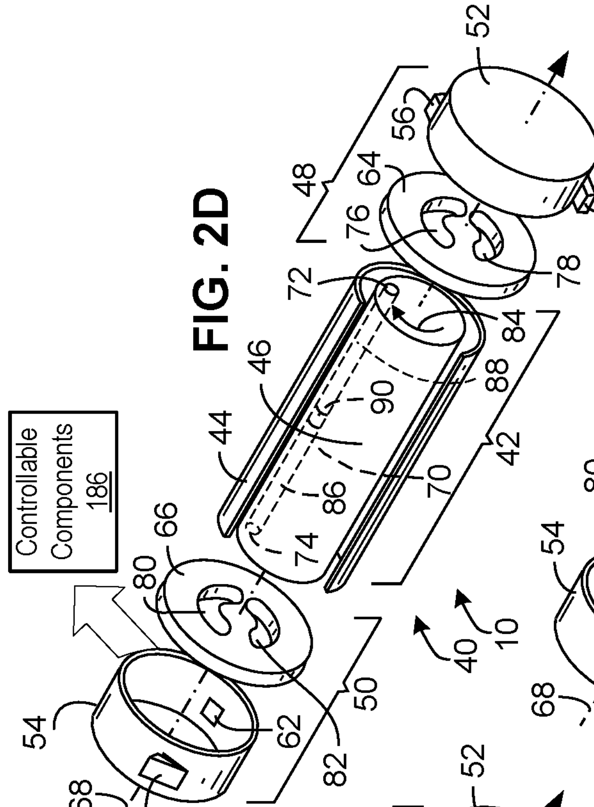


FIG. 2D

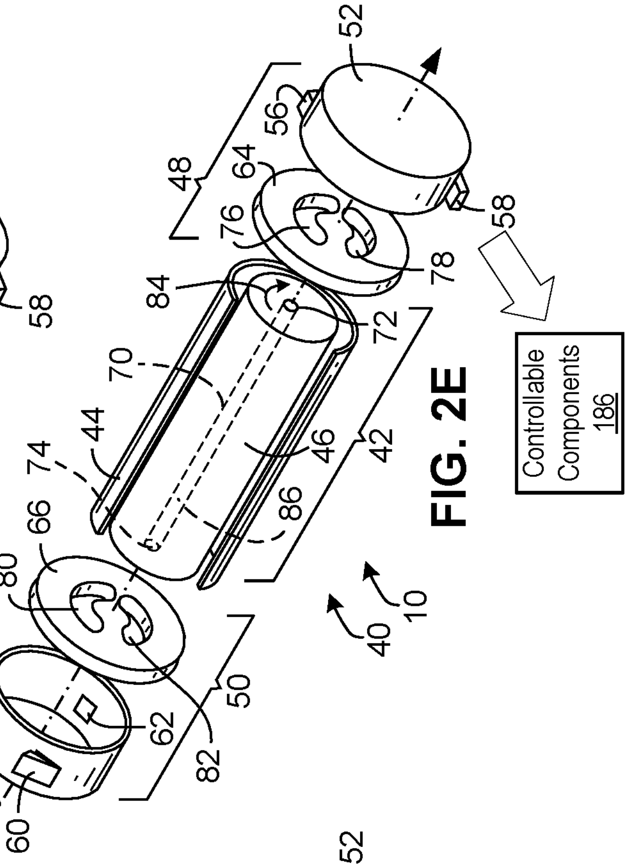


FIG. 2E

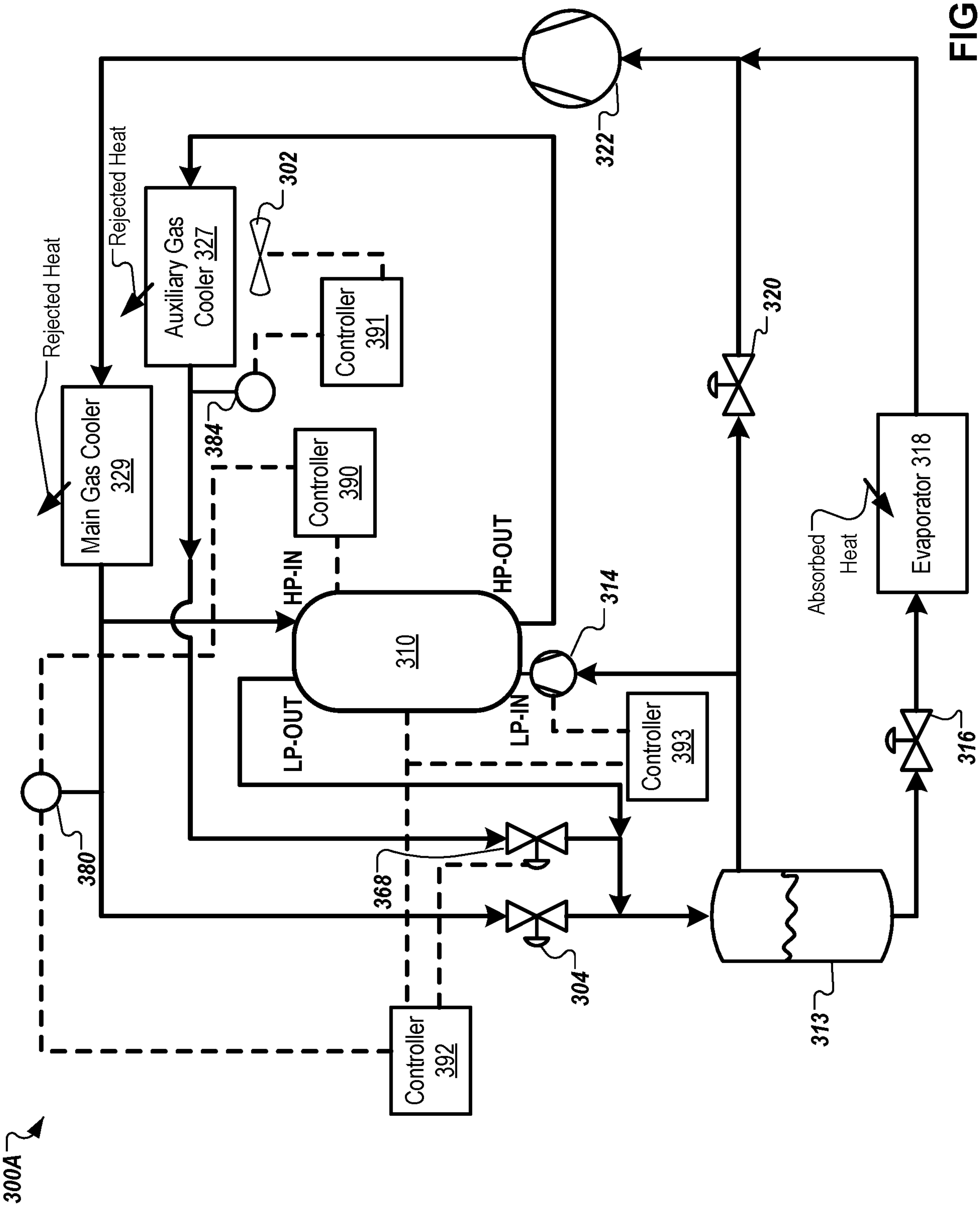

300A
Main Gas Cooler 329
Rejected Heat
Auxiliary Gas Cooler 327
Rejected Heat
302
Controller 391
Controller 390
384
HP-IN
HP-OUT
310
LP-OUT
LP-IN
314
Controller 393
322
320
Evaporator 318
Absorbed Heat
316
313
380
368
304
Controller 392

FIG. 3A

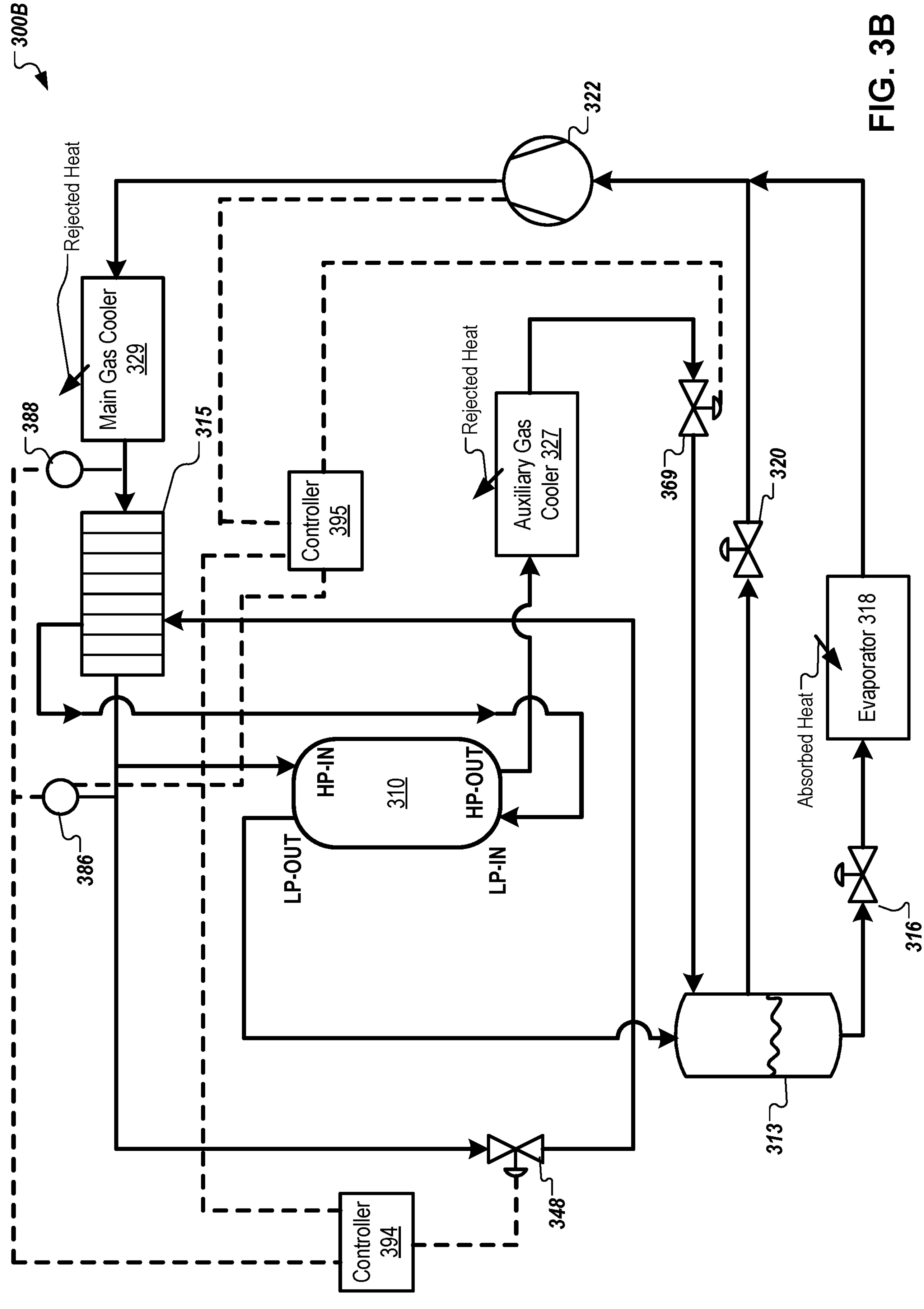

300B
Rejected Heat
Main Gas Cooler 329
388
315
Controller 395
Rejected Heat
Auxiliary Gas Cooler 327
322
369
320
Evaporator 318
Absorbed Heat
316
HP-IN
310
HP-OUT
LP-OUT
LP-IN
386
313
348
Controller 394

FIG. 3B

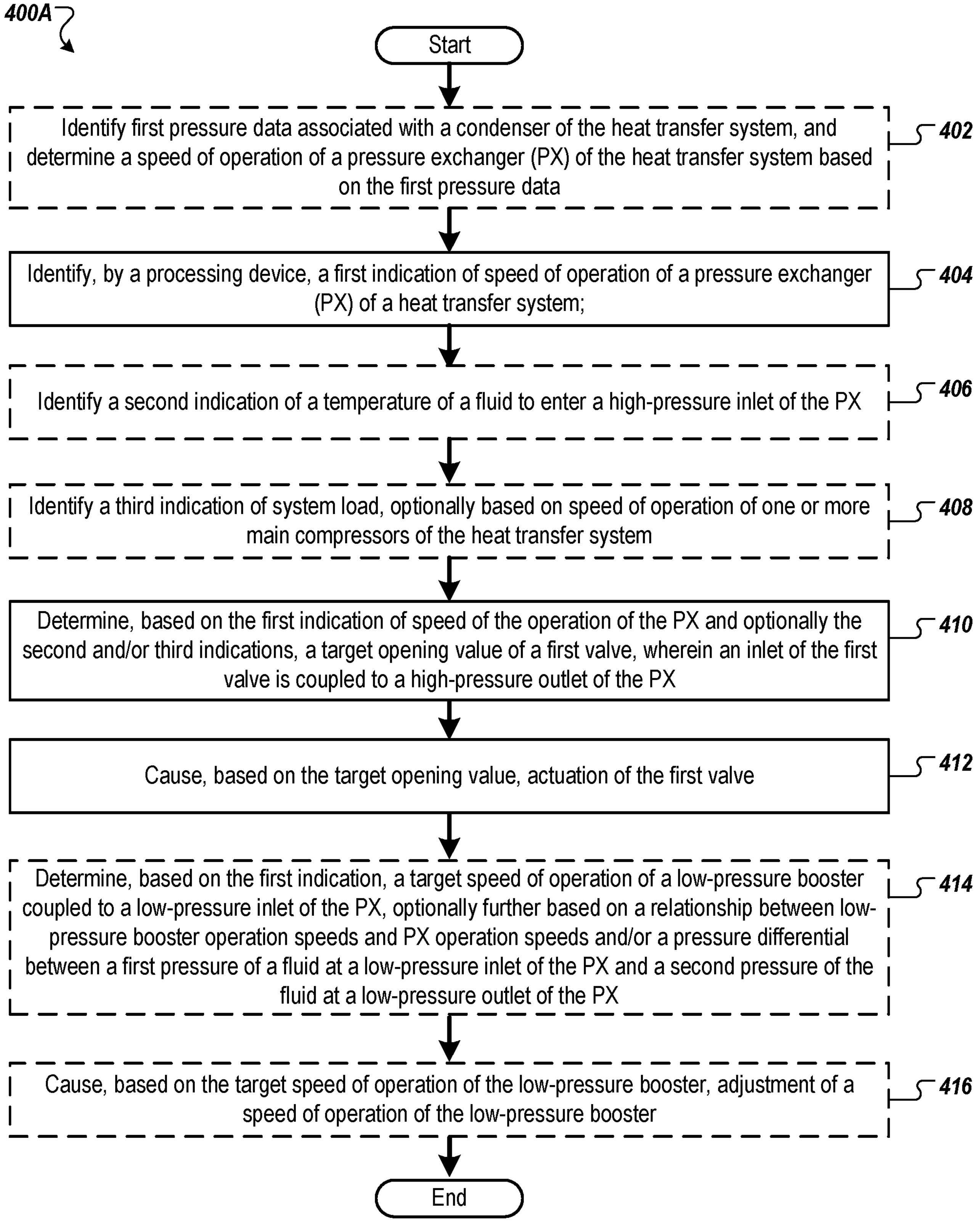

400A
Start
Identify first pressure data associated with a condenser of the heat transfer system, and determine a speed of operation of a pressure exchanger (PX) of the heat transfer system based on the first pressure data
402
Identify, by a processing device, a first indication of speed of operation of a pressure exchanger (PX) of a heat transfer system;
404
Identify a second indication of a temperature of a fluid to enter a high-pressure inlet of the PX
406
Identify a third indication of system load, optionally based on speed of operation of one or more main compressors of the heat transfer system
408
Determine, based on the first indication of speed of the operation of the PX and optionally the second and/or third indications, a target opening value of a first valve, wherein an inlet of the first valve is coupled to a high-pressure outlet of the PX
410
Cause, based on the target opening value, actuation of the first valve
412
Determine, based on the first indication, a target speed of operation of a low-pressure booster coupled to a low-pressure inlet of the PX, optionally further based on a relationship between low-pressure booster operation speeds and PX operation speeds and/or a pressure differential between a first pressure of a fluid at a low-pressure inlet of the PX and a second pressure of the fluid at a low-pressure outlet of the PX
414
Cause, based on the target speed of operation of the low-pressure booster, adjustment of a speed of operation of the low-pressure booster
416
End

FIG. 4A

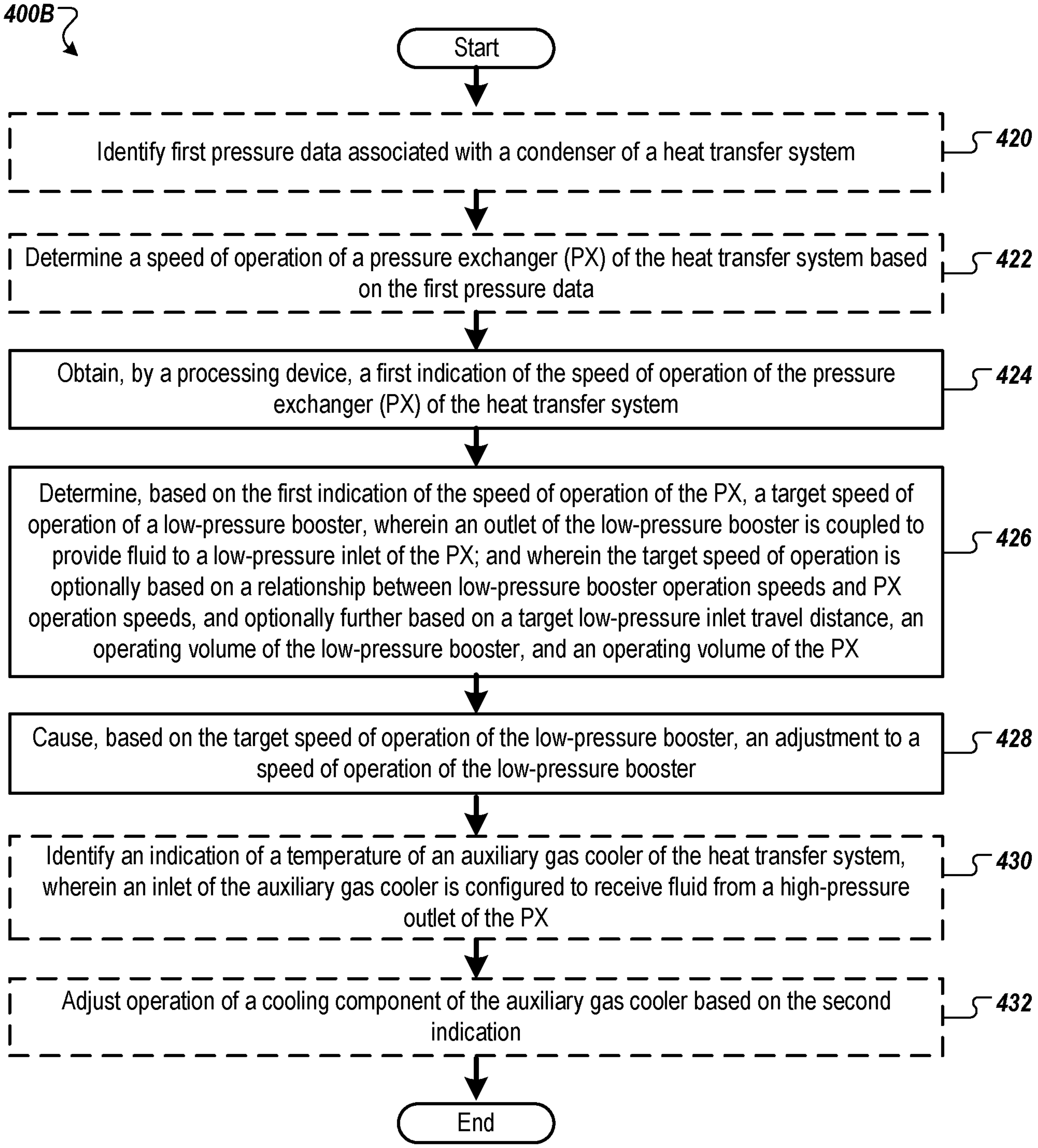
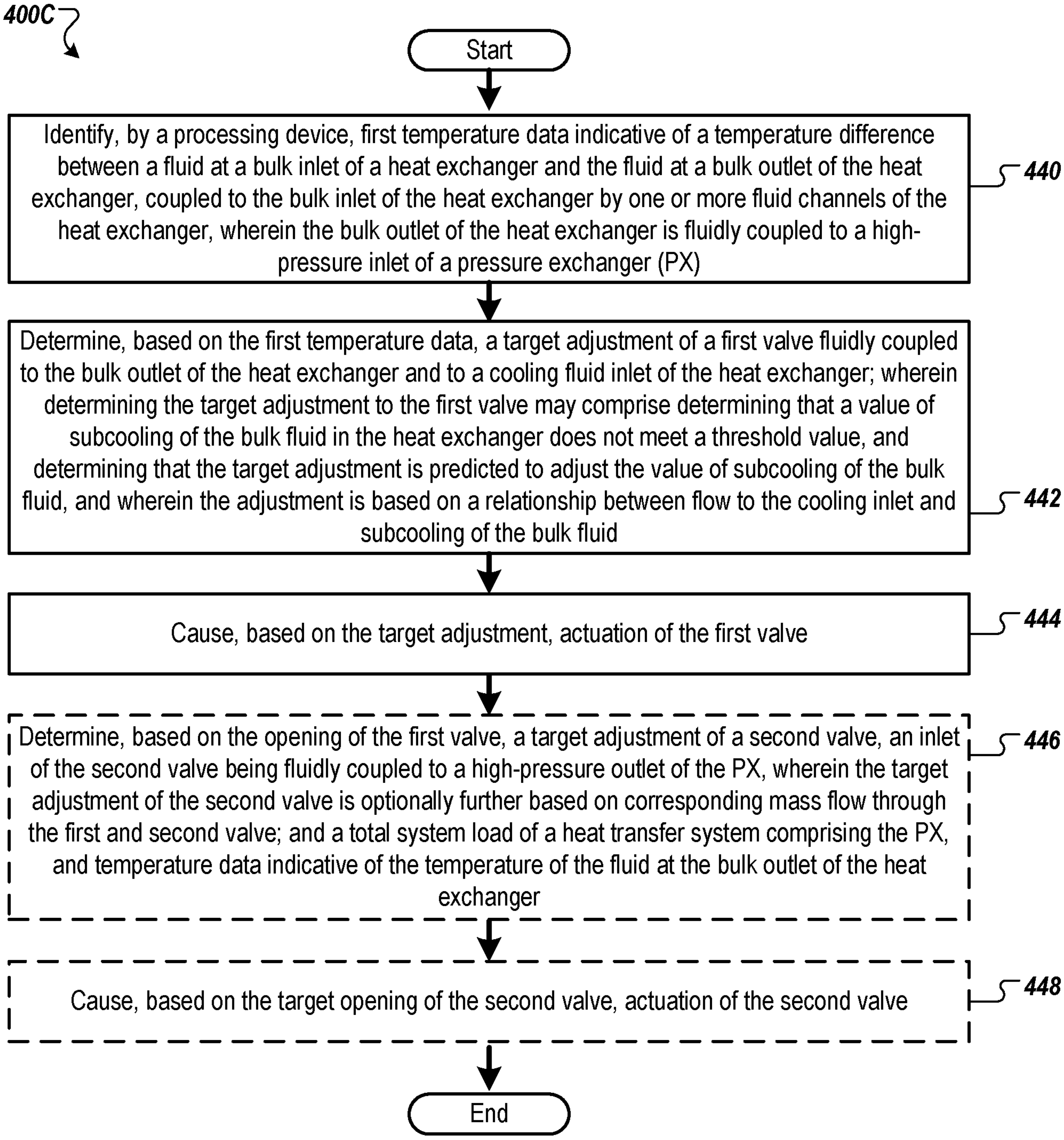

400B
Start
Identify first pressure data associated with a condenser of a heat transfer system
420
Determine a speed of operation of a pressure exchanger (PX) of the heat transfer system based on the first pressure data
422
Obtain, by a processing device, a first indication of the speed of operation of the pressure exchanger (PX) of the heat transfer system
424
Determine, based on the first indication of the speed of operation of the PX, a target speed of operation of a low-pressure booster, wherein an outlet of the low-pressure booster is coupled to provide fluid to a low-pressure inlet of the PX; and wherein the target speed of operation is optionally based on a relationship between low-pressure booster operation speeds and PX operation speeds, and optionally further based on a target low-pressure inlet travel distance, an operating volume of the low-pressure booster, and an operating volume of the PX
426
Cause, based on the target speed of operation of the low-pressure booster, an adjustment to a speed of operation of the low-pressure booster
428
Identify an indication of a temperature of an auxiliary gas cooler of the heat transfer system, wherein an inlet of the auxiliary gas cooler is configured to receive fluid from a high-pressure outlet of the PX
430
Adjust operation of a cooling component of the auxiliary gas cooler based on the second indication
432
End

FIG. 4B



Identify, by a processing device, first temperature data indicative of a temperature difference between a fluid at a bulk inlet of a heat exchanger and the fluid at a bulk outlet of the heat exchanger, coupled to the bulk inlet of the heat exchanger by one or more fluid channels of the heat exchanger, wherein the bulk outlet of the heat exchanger is fluidly coupled to a high-pressure inlet of a pressure exchanger (PX)

Determine, based on the first temperature data, a target adjustment of a first valve fluidly coupled to the bulk outlet of the heat exchanger and to a cooling fluid inlet of the heat exchanger; wherein determining the target adjustment to the first valve may comprise determining that a value of subcooling of the bulk fluid in the heat exchanger does not meet a threshold value, and determining that the target adjustment is predicted to adjust the value of subcooling of the bulk fluid, and wherein the adjustment is based on a relationship between flow to the cooling inlet and subcooling of the bulk fluid

Cause, based on the target adjustment, actuation of the first valve

Determine, based on the opening of the first valve, a target adjustment of a second valve, an inlet of the second valve being fluidly coupled to a high-pressure outlet of the PX, wherein the target adjustment of the second valve is optionally further based on corresponding mass flow through the first and second valve; and a total system load of a heat transfer system comprising the PX, and temperature data indicative of the temperature of the fluid at the bulk outlet of the heat exchanger

Cause, based on the target opening of the second valve, actuation of the second valve

FIG. 4C

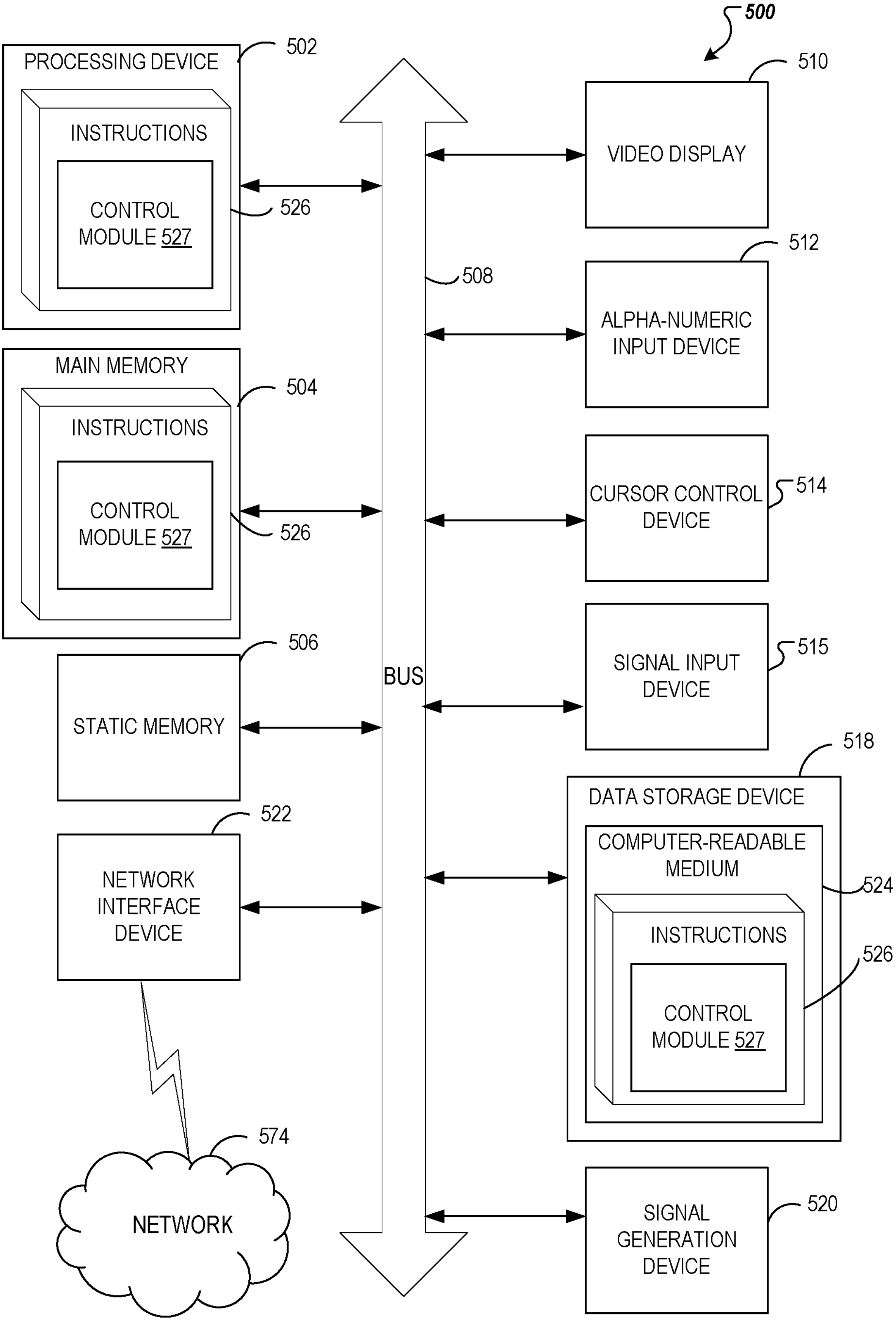

500
PROCESSING DEVICE
502
INSTRUCTIONS
CONTROL MODULE 527
526
MAIN MEMORY
504
INSTRUCTIONS
CONTROL MODULE 527
526
STATIC MEMORY
506
NETWORK INTERFACE DEVICE
522
NETWORK
574
BUS
508
VIDEO DISPLAY
510
ALPHA-NUMERIC INPUT DEVICE
512
CURSOR CONTROL DEVICE
514
SIGNAL INPUT DEVICE
515
DATA STORAGE DEVICE
518
COMPUTER-READABLE MEDIUM
524
INSTRUCTIONS
526
CONTROL MODULE 527
SIGNAL GENERATION DEVICE
520

FIG. 5