



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
18.01.2017 Bulletin 2017/03

(51) Int Cl.:
F25B 49/02 (2006.01) **F25B 43/00** (2006.01)
F25B 13/00 (2006.01)

(21) Application number: **16177127.4**

(22) Date of filing: **30.06.2016**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

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(30) Priority: **14.07.2015 US 201514798949**

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(54) **REFRIGERANT CHARGE AND CONTROL METHOD FOR HEAT PUMP SYSTEMS**

(57) A heat pump system (10) comprises a compressor (16), at least one expansion valve (22; 36), an accumulator (18) for storing a volume of liquid refrigerant therein, a liquid refrigerant indicator connected to the accumulator (18) to indicate an appropriate refrigerant charge in cooling and heating modes, and a controller (28). The controller (28) is configured to determine a target compressor discharge pressure based on measured outdoor air temperature and control the compressor dis-

charge pressure by modulating the position of the at least one expansion valve (22; 36), wherein the higher the target discharge pressure target, the less liquid refrigerant is left in the accumulator (18). The accumulator (18) can be sized to always have capacity to hold excess refrigerant during heating operations, and can include a charge level indicator so as to allow proper charge of the system (10) in the field without additional tools.

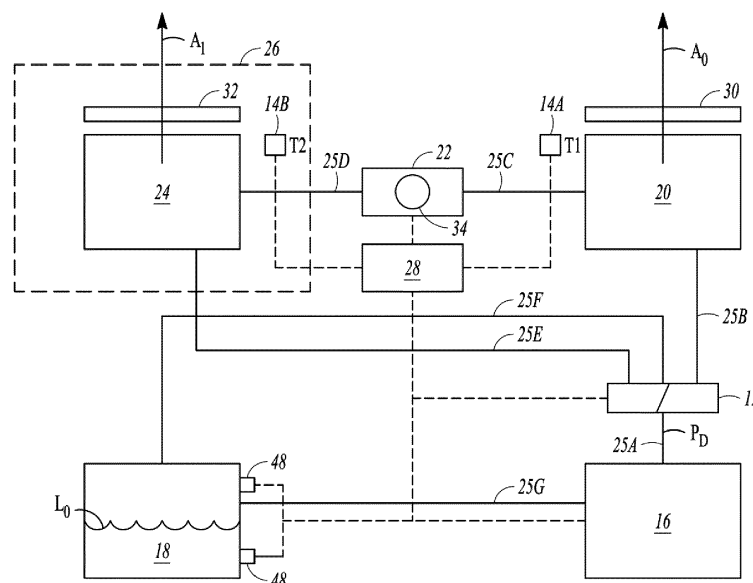


FIG. 1

Description

TECHNICAL FIELD

[0001] This document pertains generally, but not by way of limitation, to heat pump systems utilizing accumulators, and, more particularly, this documents relates to refrigerant charge control in heat pump systems.

BACKGROUND

[0002] Some conventional heat pump systems can perform heating and cooling of an indoor space by utilizing an indoor heat exchanger and an outdoor heat exchanger in conjunction with an accumulator. For example, in order to perform cooling, the indoor heat exchanger operates as an evaporator and the outdoor heat exchanger operates as a condenser. In conjunction with an expansion device, the outdoor condenser is used to lower the temperature of the refrigerant that is subsequently used to cool air of the indoor space. The refrigerant is heated with warm indoor air of the indoor area within the evaporator and then drawn into a compressor for circulating back to the condenser. Placement of the condenser outdoors allows heat from the refrigerant to be discharged to outdoor air. To perform heating, the system operates in reverse.

[0003] Due to thermodynamic differences in performing heating and cooling, different refrigerant charge is required during cooling and heating season for the system to operate at optimum performances. Additional refrigerant charge differentials can arise due to the use of different sized heat exchangers. For example, the indoor heat exchanger is typically smaller in internal volume due to size constraints imposed by the conditioned space. These factors result in the system optimally operating at mainly two different optimum refrigerant charges for heating and cooling. Further, small refrigerant charge differential can arise as indoor and outdoor temperatures change within the cooling or heating season. Thus, for a heat pump to operate at optimum performance, it is desirable to have multiple different refrigerant charges as the conditions change. Refrigerant charge can not only affect the performances such as cooling/heating capacities or energy efficiencies, it can also affect the heat pump operation. For example, if the refrigerant charge is added to the system in the winter, the system may malfunction in the summer.

[0004] Refrigerant charge can be a difficulty for heat pump installers, especially in the residential air source heat pump market. In the summer, one of the conventional methods is to measure the outdoor ambient temperature, and add refrigerant to the system until certain system parameters fall within the required range. This kind of methods requires a field installer to carry sensors and lookup tables. In other systems, additional instrumentation can be built into the system or provided to the installer as a tool that will assist in determining the charge

level. During the winter time, charging refrigerant becomes more difficult. In many cases, the installer has to come back to check the refrigerant charge at the beginning of the cooling season to prevent refrigerant charge related issues.

[0005] Reversible heat pump systems often include an accumulator that is positioned on the low pressure side of the compressor. The accumulator is useful in preventing ingestion of liquid refrigerant into the compressor. Liquid refrigerant can cause damage if drawn into the moving components of the compressor. Accumulators are not typically used on cooling only heat pump systems.

[0006] Additionally, in order to maintain the proper charge level of refrigerant in the system, charge compensators can be used on the high pressure outdoor condenser side. For example, a typical charge compensator can comprise a tube inside of a shield or reservoir. During heating operation, flow of cold refrigerant through the tube causes liquid refrigerant to accumulate in the reservoir. During cooling operation, hot refrigerant in the tube causes liquid refrigerant in the reservoir to boil off into vapor. One such system is described in U.S. Pat. No. 5,136,855 to Lenarduzzi. By adding a charge compensator, the refrigerant charge can be more balanced. However, proper charge of the system in the field is still not resolved. A proper charge in the winter does not guarantee a proper charge in the summer. Other charge control devices are described in U.S. Patent Application Pub. No. 2008/0127667 to Buckley et al., U.S. Pat. No. 8,578,731 to Jin, U.S. Pat. No. 6,227,003 to Smolinsky, and U.S. Pat. No. 5,937,670 to Derryberry.

OVERVIEW

[0007] Systems and methods of the present disclosure address the above-mentioned issues by providing a refrigerant charge method for heat pump systems. The presently disclosed systems and methods also provide a system control method to allow a heat pump system to operate at optimum refrigerant charge as indoor temperature, outdoor temperature, or operating modes change.

[0008] The present inventors have recognized, among other things, that a problem to be solved in heat pump systems can include accommodating excess refrigerant during heating mode operation as compared to cooling mode operation. In an example, the present subject matter can provide a solution to this problem, such as by using an expansion device with a controllable orifice size that can be widened to allow more liquid refrigerant to be stored in an accumulator or that can be narrowed to boil off liquid refrigerant in the accumulator.

[0009] The present inventors have recognized, among other things, that a problem to be solved in heat pump systems can include accommodating differences in refrigerant charge requirement during summer and winter operation. In an example, the present subject matter can provide a solution to this problem, such as by using an accumulator as a refrigerant storage device and charge

level indicator. The accumulator has one or more fill level indicators positioned so as to indicate the proper charge level in the summer as well as in the winter. In another example, the present subject matter provides a control method to optimize the heat pump performance while allowing the excess refrigerant to be stored in the accumulator without overfilling the accumulator, and to prevent the accumulator from running dry during cooling operations.

[0010] A heat pump system comprises a compressor, at least one expansion valve, an accumulator for storing a volume of liquid refrigerant therein, a liquid refrigerant indicator connected to the accumulator to indicate an appropriate refrigerant charge in cooling and heating modes, and a controller. The controller is configured to determine a target compressor discharge pressure based on measured outdoor air temperature and control the compressor discharge pressure by modulating the position of the at least one expansion valve, wherein the higher the target discharge pressure target, the less liquid refrigerant is left in the accumulator. The accumulator can be sized to always have capacity to hold excess refrigerant during heating operations, and can include a charge level indicator so as to allow proper charge of the system in the field without additional tools.

[0011] This overview is intended to provide an overview of subject matter of the present patent application. It is not intended to provide an exclusive or exhaustive explanation of the present subject matter. The detailed description is included to provide further information about the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] In the drawings, which are not necessarily drawn to scale, like numerals may describe similar components in different views. Like numerals having different letter suffixes may represent different instances of similar components. The drawings illustrate generally, by way of example, but not by way of limitation, various embodiments discussed in the present document.

FIG. 1 is a schematic diagram of a heat pump system having a refrigerant expansion device configured to control charge level in an accumulator;

FIG. 2A is a schematic flow chart of the heat pump system of FIG. 1 showing the system operating in a cooling mode with a discharge pressure below a target level;

FIG. 2B is a schematic flow chart of the heat pump system of FIG. 1 showing the system operating in a heating mode with a discharge pressure above a target level;

FIG. 3 is a schematic diagram of a bi-directional electronic expansion valve assembly suitable for use as

the refrigerant expansion device of FIG. 1;

FIG. 4 is a schematic diagram showing an accumulator having a charge level indicator window in an intermediate charge position;

FIG. 5 is a schematic diagram showing an accumulator having charge level indicator windows in summer and winter charge positions;

FIG. 6 is a schematic diagram showing a heat pump system incorporating a heat exchanger for heating water and a level sensor in the accumulator;

FIG. 7 is a flow chart diagramming steps for controlling discharge pressure and refrigerant volume in the heat pump systems of FIGS. 1 - 6;

FIGS. 8A and 8B show the target discharge pressure as a function of outdoor and indoor air temperature in cooling and heating season; and

FIG. 9 shows the target discharge pressure as a function of outdoor air temperature in cooling and heating season.

DETAILED DESCRIPTION

[0013] FIG. 1 is a schematic of heat pump system 10 having reversing valve 12, first temperature sensor 14A, second temperature sensor 14B, compressor 16, accumulator 18, outdoor heat exchanger 20, expansion device 22 and indoor heat exchanger 24, which are connected in series through refrigerant lines 25A - 25G to form a vapor-compression circuit for conditioning indoor air A_i of space 26.

[0014] System 10 is connected to a digital control system, which includes controller 28, outdoor fan 30 and indoor fan 32. Based upon factors such as outdoor air temperature T_1 and indoor air temperature T_2 sensed by sensors 14A and 14B, respectively, measured discharge pressure P_D and target discharge pressure P_T , which can be determined by temperatures T_1 and T_2 , controller 28 operates fans 30 and 32, compressor 16, valve 12 and expansion device 22 to provide conditioned air to space 26.

[0015] System 10 may also include, although not shown, other valves that can be used for various purposes such as service valves used to control draining of fluid from system 10, check valves configured to prevent back flow of fluid through system 10, or level sensors for determining the amount of fluid in the accumulator 18. System 10 may also include other components, such as a drier that operates to remove moisture from the refrigerant, or a water heater heat exchanger, as is discussed with reference to FIG. 6. Any suitable refrigerant as is known in the industry, such as R-410A refrigerant, may be used with system 10.

[0016] System 10 is configured as a split system in which indoor heat exchanger 24 is positioned within space 26, and outdoor heat exchanger 20, accumulator 18, compressor 16 and expansion device 22 are positioned outside space 26. In some embodiments, compressor 16, accumulator 18 and expansion device 22 can be located within space 26 individually or in combination. In other embodiments, all components of system 10 can be located outside of space 26, such as in rooftop system applications. Space 26 comprises a building, home or any other enclosed space in which conditioned air is desired to be provided. Outdoor heat exchanger 20 and indoor heat exchanger 24 are able to operate as both condensers and evaporators, and system 10 is operable to provide conditioned air to space 26 that is either heated or cooled. As such, valve 12 operates as a reversing valve, as is known in the industry, to allow refrigerant from compressor 16 through the vapor-compression circuit in forward and reverse directions.

[0017] Indoor heat exchanger 24 can be sized to have a smaller refrigerant capacity than outdoor heat exchanger 20, typically due to constraints within space 26. Additionally, because of differing mass flow characteristics in the vapor-compression cycle between heating and cooling, less refrigerant volume may be required during the heating mode as compared to the cooling mode. As such, it can be desirable to store excess refrigerant during heating operations of system 10 for later use during cooling operations. Accumulator 18 stores liquid refrigerant while system 10 operates in a heating mode, thereby preventing liquid refrigerant from reaching compressor 16. Flooding of compressor 16 with liquid refrigerant can be harmful to the operation of compressor 16. The refrigerant can be reintroduced into the vapor-compression cycle during cooling mode operation.

[0018] The common use of an accumulator in a heat pump system is to prevent liquid refrigerant to enter the compressor. During compressor run time, the common practice is to constantly maintain certain level of superheat at the evaporator outlet. This can be accomplished by using a properly sized orifice, using a thermal expansion valve, or using an electric expansion valve as the expansion device. Using these methods result in a dry accumulator (an accumulator without any liquid refrigerant). In view of the foregoing differences between operating in the heating mode, which is typically conducted in the winter, and operating in the cooling mode, which is typically conducted in the summer, difficulties can arise in maintaining system 10 charged with refrigerant at the proper active charge level.

[0019] Here, the active charge is defined as the weight of all refrigerant in the heat pump system except for the liquid refrigerant stored in the accumulator. Additionally, even the slightest leak of, for example, several ounces of refrigerant, can cause system 10 to operate inefficiently. Thus, the refrigerant charge is desired to be checked and adjusted periodically to account for seasonal temperature changes and leaks. Adding a charge compen-

sator may solve the seasonal charge issue by either storing a full tank of liquid refrigerant or no liquid refrigerant at all. However, this will only partially resolve the seasonal refrigerant charge issue. The system 10 disclosed herein, utilizes accumulator 18 that is sized to allow system 10 to operate with a liquid refrigerant charge in heating and cooling modes, in winter and summer, with initial charge level L_A that accommodates all operating modes and conditions so that accumulator 18 will not run dry or overflow.

[0020] Expansion device 22 and accumulator 18 of the present disclosure alleviate differences in operation during summer and winter, i.e. differences in refrigerant charge requirements while operating in cooling and heating modes. In particular, expansion device 22 can be adjusted, e.g. the diameter O_D of orifice 34 can be altered, in order to control the flow rate of liquid refrigerant leaving the condenser. Expansion device 22 can be opened, e.g. orifice 34 can be increased in size, to allow more refrigerant to enter the evaporator and thereby be stored in the accumulator. Alternatively, expansion device 22 can be closed, e.g. orifice 34 can be reduced in size, to allow less refrigerant to pass through the evaporator and enter accumulator 18 to boil off liquid refrigerant stored therein. This process causes the active refrigerant charge in system 10 to change. The more expansion device 22 is closed, the less liquid refrigerant is stored in accumulator 18. The refrigerant that leaves accumulator 18 becomes a part of the active charge in system 10 and causes the discharge pressure to increase. Therefore, controlling discharge pressure P_D by opening or closing expansion device 22 is an effective method to adjust active refrigerant charge in system 10. Further, discharge pressure P_D of system 10 is directly related to condensing temperature of system 10.

[0021] In the case of cooling, outdoor heat exchanger 20 is the condenser. Controlling discharge pressure P_D to maintain an appropriate amount of temperature difference between the condensing temperature and the outdoor air temperature can effectively achieve optimum performance. Here, the optimum performance is defined as an appropriate compromise between cooling or heating capacity and the energy efficiency determined by for a particular system.

[0022] In the case of heating, indoor heat exchanger 24 is the condenser, controlling discharge pressure P_D to maintain an appropriate amount of temperature difference between the condensing temperature and indoor air temperature can effectively achieve optimum performance. However, in case the measured indoor air temperature is not available to controller 28, the outdoor temperature can be used to determine the discharge pressure target P_T .

[0023] FIG. 2A is a schematic flow chart of heat pump system 10 of FIG. 1 showing the system operating in a cooling mode with discharge pressure P_{D-Low} below target pressure P_T . In the depicted embodiment of FIG. 2A, system 10 operates as an air conditioning system to pro-

vide cooled air to space 26 such that the vapor-compression circuit acts as a cooling circuit. The cooling circuit comprises compressor 16, reversing valve 12, outdoor heat exchanger 20 acting as a condenser, expansion device 22, Indoor heat exchanger 24 acting as an evaporator, accumulator 18 and refrigerant lines 25A - 25G. The cooling circuit provides cooling to indoor air A_i of space 26.

[0024] As a result of system 10 operating at P_{D-Low} in the cooling mode, liquid refrigerant level in accumulator 18 is at L_{Pos} , which is above the correct charge level L_A . Such a condition may arise due to ambient air temperature changes, e.g. a sudden temperature spike, or switching from a heating operation mode. To reach target discharge pressure P_T , controller 28 closes expansion device 22. This action causes some liquid refrigerant in the accumulator to boil off and brings the liquid level back to L_A .

[0025] While system 10 is operating in a cooling mode to provide cooled indoor air A_i to space 26, compressor 16 compresses a refrigerant to a high pressure and to a high temperature above that of ambient outdoor air A_o such that the refrigerant is comprised substantially of superheated vapor.

[0026] The refrigerant is discharged from compressor 16 into line 25A where valve 12 operates to supply the refrigerant to outdoor heat exchanger 20 through line 25B while controller 28 activates fan 30 to blow relatively cooler outdoor air A_o across outdoor heat exchanger 20. The refrigerant dumps heat to outdoor air A_o within outdoor heat exchanger 20 as outdoor air A_o passes over heat exchange circuits of outdoor heat exchanger 20. The refrigerant cools and condenses to a subcooled liquid having a lower temperature than before while still at a high pressure.

[0027] From outdoor heat exchanger 20, the refrigerant is passed through line 25C and expansion device 22, which rapidly lowers the pressure and rapidly lowers the temperature of the refrigerant to below that of indoor air A_i such that the refrigerant converts to a two-phase state of liquid and vapor in an expansion process. Under pressure from compressor 16, the cold refrigerant continues to flow into indoor heat exchanger 24 through line 25D where controller 28 activates fan 32 to blow relatively warmer indoor air A_i across indoor heat exchanger (evaporator) 24. Indoor air A_i dumps heat to the refrigerant within indoor heat exchanger 24 as indoor air A_i passes over heat exchange circuits of indoor heat exchanger 24, thereby cooling space 26. The refrigerant evaporates and absorbs heat from the relatively warmer indoor air A_i such that the refrigerant is vaporized to a primary saturated vapor. The warm vapor is then drawn into accumulator 18 through line 25E, valve 12 and line 25F. The common practice is to allow slightly superheated refrigerant to enter the accumulator. For example, the superheat at the inlet of accumulator 18 can be about 3 °F to about 15 °F (~16.1 °C - -9.4 °C). In order to realize the above mentioned benefits, the proposed control method will under

certain conditions allow some liquid refrigerant to enter accumulator 18. One function of accumulator 18 is to only allow refrigerant vapor to enter compressor 16 as long as accumulator 18 is itself not full of liquid refrigerant.

[0028] Finally, the vaporized refrigerant is drawn into compressor 16 through line 25G where it is compressed and heated into a high temperature, high pressure vapor such that the cycle can be repeated. Controller 28 monitors the temperature inputs utilizing temperature sensors 14A (outdoor air temperature) to maintain discharge pressure P_D at target pressure P_T .

[0029] As mentioned, system 10 may be operating with too little active charge such that too much liquid refrigerant is stored in accumulator 18, indicated by charge level L_{Pos} . In order to bring the liquid refrigerant level down to level L_A , orifice 34 of expansion device 22 can be reduced in size by controller 28. The reduction of the diameter O_D of orifice 34 allows less hot liquid refrigerant to be fed to expansion device 22 by outdoor heat exchanger 20 (acting as a condenser). In indoor heat exchanger 24 (acting as an evaporator) all of the liquid refrigerant is evaporated. In accumulator 18, some of the stored liquid refrigerant is also evaporated. Thus the active charge increases causing the discharge P_D increase. Controller 28 continues this process by determining P_D and comparing it to P_T until discharge pressure P_D reaches target pressure P_T , as described below with reference to FIG. 7.

[0030] Controller 28 actively controls operation of the cooling circuit and the operation of expansion device 22 to control the discharge pressure P_D by controlling valve 12 and orifice 34 using feedback from temperature sensors 14A and 14B. In particular, controller 28 can operate control algorithms (e.g. the method of FIG. 7) based on a comparison of measured discharge pressure P_D and target pressure P_T (calculated based on sensed temperatures T_1 or T_2), the ΔP . Target pressure P_T can be determined based on experimentation, testing or calculation given a particular configuration of system 10. For example, a series of tests with different discharge pressure under the same outdoor air temperature can be done in cooling mode to find out at which discharge pressure P_D the performance of system 10 is optimized. Then, use that discharge pressure P_D as the target discharge pressure P_T under the tested outdoor air temperature. Further, a series of such tests can be done with different outdoor air temperatures. This ensures that system 10 performs at optimum performances under any summer outdoor air temperatures. The same series of tests can be done in heating mode operation except that the indoor air temperature is preferred to replace outdoor air temperature. As mentioned early in this document, the outdoor air temperature can also be used in heating mode if the indoor air temperature is absent. FIGS. 8A, 8B and 9 Show the relationships between the target discharge pressure and the outdoor and indoor air temperatures. In one embodiment, system 10 is provided with only outdoor air temperature sensor 14A, from which target discharge pressure P_T can be determined using tempera-

ture T_1 . In another embodiment, system 10 is provided with both outdoor air temperature sensor 14A and indoor air temperature sensor 14B, in which case target discharge pressure P_T can be determined using indoor temperature sensor 14B or temperature T_2 , which provides a more accurate indication of target discharge pressure P_T in the heating mode. In both embodiments, system 10 is provided with a pressure sensor in line 25A to directly sense discharge pressure P_D .

[0031] Controller 28 may also operate system 10 in a heating mode (or simply may operate to increase the amount of liquid stored in accumulator 18 regardless of heating or cooling), as is discussed with reference to FIG. 2B.

[0032] FIG. 2B is a schematic flow chart of the heat pump system of FIG. 1 showing system 10 operating in a heating mode with discharge pressure P_{D-High} above target pressure P_T . In the depicted embodiment of FIG. 2B, system 10 operates as a heat pump system to provide heated air to space 26 such that the vapor-compression circuit acts as a heating circuit. The heating circuit comprises compressor 16, reversing valve 12, outdoor heat exchanger 20 acting as an evaporator, expansion device 22, indoor heat exchanger 24 acting as a condenser, accumulator 18 and refrigerant lines 25A - 25G. The heating circuit provides heating to indoor air A_i of space 26.

[0033] As a result of system 10 operating at P_{D-High} in the heating mode, liquid refrigerant level in accumulator 18 is at L_{Neg} , which is below correct charge level L_B . Such a condition may arise due to ambient air temperature changes, e.g. a sudden temperature drop, or switching from a cooling operation mode. To reach the target discharge pressure P_T , controller 28 opens expansion device 22. This action results in additional liquid refrigerant to remain in the accumulator and brings the liquid level back to level L_B .

[0034] While system 10 is operating in a heating mode to provide heated indoor air A_i to space 26, compressor 16 compresses a refrigerant to a high pressure and to a high temperature above that of ambient indoor air A_i such that the refrigerant is comprised substantially of superheated vapor.

[0035] The superheated refrigerant is discharged from compressor 16 into line 25A where reversing valve 12 operates to supply the refrigerant to indoor heat exchanger 24 through line 25E while controller 28 activates fan 32 to blow relatively cooler indoor air A_i across indoor heat exchanger 24. Indoor air A_i draws heat from the refrigerant within indoor heat exchanger 24 as indoor air A_i passes over heat exchange circuits of indoor heat exchanger 24, thereby heating space 26. The refrigerant cools and condenses to a subcooled liquid having a lower temperature than before while still at a high pressure.

[0036] From indoor heat exchanger 24, the refrigerant is passed through line 25D and expansion device 22, which lowers the pressure and the temperature of the refrigerant to below that of outdoor air A_o such that the

refrigerant converts to a two-phase state of liquid and vapor in an expansion process. Under pressure from compressor 16, the cold refrigerant continues to flow into outdoor heat exchanger 20 through line 25C where controller 28 activates fan 30 to blow relatively warmer outdoor air A_o across outdoor heat exchanger (evaporator) 20. The refrigerant draws heat from outdoor air A_o within outdoor heat exchanger 20 as outdoor air A_o passes over heat exchange circuits of outdoor heat exchanger 20. The refrigerant evaporates and absorbs heat from the relatively warmer outdoor air A_o such that the refrigerant is vaporized to a saturated vapor. The vapor is then drawn into accumulator 18 through line 25B, valve 12 and line 25F. The common practice is to allow slightly superheated refrigerant to enter the accumulator. For example, the superheat at the inlet of accumulator 18 can be about 3 °F to about 15 °F (~16.1 °C -- 9.4 °C). In order to realize the above mentioned benefits, the proposed control method will under certain conditions allow some liquid refrigerant to enter accumulator 18.

[0037] Finally, the vaporized refrigerant is drawn into compressor 16 through line 25G where it is compressed and heated into a high temperature, high pressure vapor such that the cycle can be repeated. Controller 28 monitors the temperature inputs utilizing temperature sensors 14A (outdoor air temperature) or 14B (indoor air temperature) to maintain the discharge temperature P_D at target pressure P_T .

[0038] As mentioned, system 10 may be operating with too much active charge such that too little liquid refrigerant is stored in accumulator 18, indicated by P_D being high than P_T . In order to bring P_D down to match P_T , orifice 34 of expansion device 22 can be enlarged by controller 28. Enlargement of the diameter O_D of orifice 34 allows some additional liquid refrigerant to enter accumulator 18 to increase liquid refrigerant level to L_B . Controller 28 continues this process by determining P_D and comparing it to P_T until the discharge pressure reaches target pressure P_T , as described below with reference to FIG. 7.

[0039] The liquid refrigerant levels such as L_A and L_B in the accumulator 18 are artificial levels. In fact, after the initial refrigerant charge, the liquid level in accumulator varies between summer and winter. It even varies when outdoor or indoor air temperature changes in the same cooling or heating operation. This is because, as the indoor, outdoor, or operating mode changes, the optimum active charge for system 10 changes. The proposed control method allows system 10 to have optimum performance at all conditions by controlling the discharge pressure to test verified target pressure.

[0040] In view of the foregoing, system 10, using expansion device 22, can convert between operating in heating and cooling modes and controller 28 will automatically control expansion device 22 to maintain discharge pressure P_D at target pressure P_T or within an acceptable range, so that heating and cooling may occur at optimal levels, which may be determined on an indi-

vidual basis for the particular arrangement of system 10. As a result, the active charge level of the liquid refrigerant increases or decreases causing the weight of liquid refrigerant within accumulator 18 to increase or decrease.

[0041] Expansion device 22 can comprise a single integrated electronic unit wherein the size (e.g. diameter O_D) of orifice 34 (FIG. 1) is actively controlled, as shown in FIGS. 2A and 2B, and flow is reversible through the device. However, expansion device 22 may also comprise an assembly of several components, as shown in FIG. 3.

[0042] FIG. 3 is a schematic diagram of bi-directional electronic expansion valve (BEEV) 36 suitable for use as expansion device 22 in system 10 of FIGS. 1 - 2B. Device 36 can also be any kind of expansion valve with a variable orifice. BEEV 36 comprises first expansion device 38A, first check valve 40A, second expansion device 38B and second check valve 40B. Expansion devices 38A and 38B may not be reversible and have orifices 41A and 41B, respectively, which can restrict flow through the respective valve. Likewise, check valves 40A and 40B comprise valves that permit flow in only one direction without much restriction. Expansion devices 38A and 38B and check valves 40A and 40B are arranged to have opposite flow directions.

[0043] First expansion device 38A and first check valve 40A can be placed in space 26 proximate indoor heat exchanger 24 (e.g. in line 25D), while second expansion device 38B and second check valve 40B can be placed outdoors proximate outdoor heat exchanger 20 (e.g. in line 25C). Thus, in a cooling mode, refrigerant flow F_C passes through second check valve 40B and first expansion device 38A, and in a heating mode, refrigerant flow F_H passes through first check valve 40A and second expansion device 38B.

[0044] Orifices 41A and 41B have variable diameters that can be actively controlled similarly as is described with reference to orifice 34 in FIGS. 2A and 2B, above.

[0045] FIG. 4 is a schematic diagram showing accumulator 18 having charge level indicator window 42A in an intermediate charge position 3 on housing 44. Housing 44 is connected to refrigerant lines 25F and 25G, as described with reference to FIGS. 1 - 2B. Housing 44 comprises any suitable accumulator design for storing pressurized refrigerant that may be in liquid and vapor form and allowing only vapor refrigerant to exit. Indicator window 42A comprises any suitable material that is sufficiently transparent to view liquid refrigerant. The indicator window can also be a liquid refrigerant level detector capable of provide an electronic signal such as voltage or current when the refrigerant liquid-vapor interface is near level 3 in FIG. 4.

[0046] Indicator window 42A is positioned at level 3 shown in FIG. 4. Refrigerant can be added to system 10 in summer or winter so that liquid refrigerant is at the level of window 42A at position 3. In summer during cooling, if system 10 is charged to level 3, liquid refrigerant will rise to level 4 in winter during heating. Thus, extra

volume V_2 will be provided between level 4 and level 5 to provide a buffer so that compressor 16 is not fed liquid refrigerant. In winter during heating, if system 10 is charged to level 3, liquid refrigerant will fall to level 2 in the summer during cooling. Thus, extra volume V_2 will be provided between level 2 and level 1 to prevent accumulator 18 from running dry. As such, volume V_1 comprises the range of liquid refrigerant in which system 10 is configured to operate between winter and summer (heating and cooling) operations. Accumulator 18 permits volume V_1 to reside in two different bandwidths opposite level 3, depending on when the refrigerant level was topped off, with two different reserve volumes V_2 residing at opposite ends of the two volumes V_2 within accumulator 18.

[0047] FIG. 5 is a schematic diagram showing accumulator 18 having charge level indicator windows 42B and 42C in summer and winter charge positions 4 and 2 on housing 44. Accumulator 18 of FIG. 5 operates in the same way as described with respect to FIG. 4, except indicator windows 42B and 42C are located at levels 2 and 4. Indicator windows 42B and 42C can also be a liquid refrigerant detector capable of provide an electronic signal such as voltage or current when the refrigerant liquid-vapor interface is near level 2 or 4 in FIG. 5.

[0048] The above mentioned accumulator design can be used to help heat pump installer to determine appropriate refrigerant charge after the system is newly installed, during maintenance or system repair. As has been discussed, normally, cooling mode operation requires more active charge than heating mode operation. During cooling operation in the summer, refrigerant can be filled to level 2 so that in the winter refrigerant level will not rise above level 4. During heating operation in the winter, refrigerant can be filled to level 4 so that in the summer refrigerant will not drop below level 2.

[0049] Heating mode operation requires more active charge than the cooling mode. During cooling operation in the summer, refrigerant can be filled to level 4 so that in the winter refrigerant level will not drop below level 2. During heating operation in the winter, refrigerant can be filled to level 2 so that in the summer refrigerant will not rise above level 4.

[0050] In another embodiment, charge level indicator windows 42B and 42C can be replaced with a single, oblong window spanning the length of the accumulator from window 42B to 42C, for example. The ends of the window are positioned at or near levels 2 and 4 to allow for charge readings at the desired levels. In other embodiments, charge level indicator windows 42A - 42C can be replaced with other elements that provide an indication of the liquid level, such as a float or hash marks and the like. In yet another embodiment, the two indicators 42B and 42C can be replaced by a refrigerant lever detector with continuous liquid level detection capability and with an electric signal output to indicate the liquid level in accumulator 18.

[0051] As another example of applying the current in-

vention, FIG. 6 is a schematic diagram showing a heat pump system 10A incorporating heat exchanger 46 for heating water. Water heat exchanger 46 comprises a means for heating water stored at a location separate from system 10A.

[0052] Water heat exchanger 46 is positioned in series with outdoor heat exchanger 20 and a three way valve 47 on the high pressure side of compressor 16. Water heat exchanger 46 can, therefore, act as a desuperheater or a condenser. Operation of water heat exchanger 46 is discussed below in brief and is discussed in greater detail in U.S. Patent Application Pub. No. 2014/0245770 to Chen et al., which is hereby incorporated by reference in its entirety for all purposes.

[0053] System 10A has three major heat exchangers indoor, outdoor, and water heat exchangers. By changing the position of the reversing valve 12 and the three way valve 47, different combination of the heat exchanges can be used. In certain cases, all three heat exchanger can be used. In other cases, only two heat exchangers are used. When there is an unused heat exchanger, the amount of refrigerant in a particular heat exchanger is not certain without a proper refrigerant management. The above mentioned patent provided a method to drive the refrigerant out of the unused heat exchanger before the system starts a new mode of operation. During the new mode of operation, certain valves such as 34A, 34B, or SV can be opened or closed to manage the amount of refrigerant in the unused heat exchange. As an example application of the current invention, system 10A can still use the same method mentioned in the above patent to drive the refrigerant out of the unused heat exchange before a new mode operation starts. However, to manage the refrigerant in the active system during new mode of operation, the method proposed in the current invention can be used. The target discharge pressure P_T can be used to control the discharge pressure P_D . Accumulator 18 can be used to store liquid refrigerant allowing the active refrigerant change to be optimized. In the case of using the water heat exchanger as a condenser, the target discharge pressure can be determined based on water heat exchanger water inlet temperature. As described earlier in this document, the condensing temperature of the water heat exchanger can be optimized based on a series of tests. When the water heat exchanger is used as a desuperheater, the outdoor or indoor air temperature can be used to determine the target discharge pressure P_T in cooling or heating mode operation.

[0054] FIG. 7 is a flow chart diagramming the steps for controlling discharge pressure and active refrigerant charge in heat pump system 10 of FIGS. 1 - 6. During operation to cool or heat space 26, heat pump system 10 controls diameter O_D of orifice 34 of expansion device 22 based on whether compressor discharge pressure P_D satisfies the predetermined target discharge pressure P_T .

[0055] At step 100, discharge pressure P_D , outdoor temperature T_1 and/or indoor temperature T_2 are meas-

ured such as by using temperature sensor 14A and/or 14B. According to other examples, temperature T_1 and/or T_2 can be calculated by measuring other physical properties such as electric resistance or electric current which are indirectly related to the temperature. At 102, the target discharge pressure P_T is determined based on T_1 or T_2 as shown in FIGS. 8A and 8B or FIG 9. At 104, ΔP , the difference between P_D and P_T , is computed. If the ΔP is greater than a constant ΔP_1 , step 106A is executed to increase the O_D of orifice 34 of expansion device 22. Here ΔP_1 can be a constant value which specifies the tolerance of the discharge pressure controller. If the ΔP is less than a constant minus ΔP_1 , step 106B is executed to decrease the O_D of orifice 34 of expansion device 22. Otherwise, O_D is unchanged. The process repeats itself after a time delay as shown in step 108. FIG. 7 is one of the method which can be used to control the discharge pressure P_D based on a predetermine target discharge pressure P_T . Other methods such as PID control can also be used to control the discharge pressure.

[0056] In cooling mode, discharge pressure P_D is determined using outdoor temperature T_1 . As outdoor temperature T_1 increases, the target discharge temperature (as used in determining target pressure P_T) increases (within a predetermined range).

[0057] In heating mode, there are two options for determining discharge pressure P_D . In Option 1, discharge pressure P_D is determined using indoor temperature sensor 14B and temperature T_2 . As indoor temperature T_2 increases, the target discharge temperature (as used in determining target pressure P_T) increases (within a predetermined range). In Option 2, discharge pressure P_D is determined using outdoor temperature sensor 14A and temperature T_1 . As outdoor temperature T_1 increases, the target discharge temperature (as used in determining target pressure P_T) increases (within a predetermined range). The advantage of Option 1 is better energy efficiency optimization over the indoor temperature range. The advantage of Option 2 is using fewer sensors, as indoor temperature sensors are typically optional features in heat pump systems, depending on the intended use.

[0058] Controller 28 can be configured to execute the method of FIG. 7 and actively control discharge pressure P_D . Controller 28 can include circuitry, memory and user input devices. Controller 28 can be connected in electronic communication with temperature sensors 14A and 14B, valve 12, expansion device 22, and compressor 16. Controller can also be connected to liquid refrigerant level sensor(s) to determine whether the heat pump system 10 is properly charged with refrigerant. Controller 28 can also include other components commonly found in electronic controllers, such as analog-to-digital converters that may convert analog input from the sensors to digital signals useable by circuitry, clocks, signal conditioners, signal filters, voltage regulators, current controls, modulating circuitry, input ports, output ports and the like. Con-

troller 28 can also include appropriate input ports for receiving sensor inputs and user inputs. For example, a user of system 10 (FIG. 1) may input desired target pressure P_T , and an acceptable range encompassing target pressure P_T , into the memory of controller 28. The memory may comprise non-volatile random access memory (NVRM), read only memory, physical memory, optical memory or the like. Controller 28 may comprise any suitable computing device such as an analog circuit, or a digital circuit, such as a microprocessor, a microcontroller, an application-specific integrated circuit (ASIC) or a digital signal processor (DSP).

[0059] As another example of applying the current invention, the system 10 may include a feature to provide a refrigerant charge level indication. In this case, the accumulator 18 is equipped with an electronic refrigerant level indicator 48, as indicated schematically in FIG. 1. Indicator 48 is able to detect two liquid refrigerant levels. These two levels are at the maximum and minimum required charge level. When the controller 28 senses the liquid refrigerant at the maximum level, it may increase the target discharge pressure normally calculated using FIGS. 8A and 8B or FIG. 9.

[0060] As a results, the active refrigerant charge increases preventing the liquid refrigerant from entering the compressor. The controller 28 may also send an electric signal indicating that the system 10 is over charged. In case the target discharge pressure reaches an unacceptable level, the controller may shut down the system 10 which may include compressor, fan, blower, and other components. When the controller 28 senses the liquid refrigerant at the minimum level it may send an electric signal indicating that the system 10 is under charged.

[0061] System 10 includes several benefits over conventional systems, some of which are discussed below.

[0062] The correct refrigerant charge of system 10 can be simply determined using windows 42A -42C. No tools are required.

[0063] Since conventional systems can only have one active charge, the performance can only be optimized at one outdoor temperature. System 10 can adjust active charge at various indoor and outdoor temperatures, the system performance can be optimized at various conditions.

[0064] The performance of system 10 is less sensitive to small refrigerant leaks than conventional systems since the refrigerant in accumulator 18 will make up the lost refrigerant in the active system.

[0065] System 10 does not require refrigerant checks in the opposite season in which it is installed.

[0066] System 10 will have less likelihood of shutting down due to high discharge pressure issues over conventional systems because of the self-correcting advantages of accumulator 18 and expansion device 22 when controlled by controller 28.

Various Notes & Examples

[0067] In Example 1, a heat pump system comprises: a compressor, at least one expansion valve, an accumulator continuously storing a volume of liquid refrigerant therein, a liquid refrigerant indicator connected to the accumulator to indicate an appropriate refrigerant charge in cooling and heating modes, and a controller configured to determine a target compressor discharge pressure based on outdoor air temperature and control the compressor discharge pressure by modulating the position of the at least one expansion valve, wherein the higher the target discharge pressure target, the less liquid refrigerant is left in the accumulator.

[0068] Example 2 can include, or can optionally be combined with the subject matter of one or any combination of Example 1, to optionally include an indoor heat exchanger, and an outdoor heat exchanger in fluid communication with indoor heat exchanger, wherein the at least one expansion valve is arranged between and modulates the flow of the refrigerant between the indoor heat exchanger and the outdoor heat exchanger.

[0069] Example 3 can include, or can optionally be combined with the subject matter of one or any combination of Examples 1 and 2, to optionally include modulating a position of the at least one expansion valve comprises opening and/or closing the at least one expansion valve causing an orifice size of the valve to increase or decrease.

[0070] Example 4 can include, or can optionally be combined with the subject matter of one or any combination of Examples 1 - 3, to optionally include an accumulator having an element that is configured to indicate a desired amount for the volume of liquid refrigerant within the accumulator.

[0071] Example 5 can include, or can optionally be combined with the subject matter of one or any combination of Examples 1 - 4, to optionally include an element that is positioned such the volume of the liquid refrigerant when filled to the desired amount comprises at least a charge difference volume between a cooling mode of system operation and a heating mode of system operation and a reserve volume to prevent the accumulator from being dry or over flow.

[0072] Example 6 can include, or can optionally be combined with the subject matter of one or any combination of Examples 1 - 5, to optionally include an element that is positioned to indicate the volume of the liquid refrigerant that is appropriate regardless of a current mode of system operation and regardless of a season in which refrigerant is contemplated to be added to the system.

[0073] Example 7 can include, or can optionally be combined with the subject matter of one or any combination of Examples 1 - 6, to optionally include an element comprising two elements spaced from one another, each of the two elements indicating the volume of liquid refrigerant in the accumulator that is appropriate based upon both a current mode of system operation and one season

in which refrigerant is contemplated to be added to the system.

[0074] Example 8 can include, or can optionally be combined with the subject matter of one or any combination of Examples 1 - 7, to optionally include a volume of liquid refrigerant in the accumulator that comprises at least twice as much refrigerant as a volume difference in refrigerant utilized by the system between a cooling mode of system operation and a heating mode of system operation.

[0075] Example 9 can include, or can optionally be combined with the subject matter of one or any combination of Examples 1 - 8, to optionally include a controller that is further configured to determine an indoor air temperature and the compressor discharge pressure is derived from the indoor air temperature.

[0076] Example 10 can include, or can optionally be combined with the subject matter of one or any combination of Examples 1 - 9, to optionally include a heating mode of system operation, an indoor air temperature is utilized in controlling the compressor discharge pressure, and wherein in a cooling mode of system operation, the outdoor air temperature is utilized in controlling the compressor discharge pressure.

[0077] Example 11 can include, or can optionally be combined with the subject matter of one or any combination of Examples 1 - 10, to optionally include a controller that is further configured to determine a potential for an overflowed accumulator and increase a compressor discharge pressure target which modulates the position of the at least one expansion valve to a more closed position when the overflowed accumulator is detected.

[0078] Example 12 can include, or can optionally be combined with the subject matter of one or any combination of Examples 1 - 11, to optionally include at least one expansion valve comprising an assembly of two or more expansion valves, each of the two or more expansion valves having an associated check valve.

[0079] In Example 13, a method comprises: storing a volume of liquid refrigerant continuously within an accumulator during operation of the heat pump, the volume of liquid refrigerant comprising an appropriate amount for both a heating mode and a cooling mode of operation of a heat pump; determining an outdoor air temperature and a compressor discharge pressure; and controlling the compressor discharge pressure based upon the determined outdoor air temperature; wherein the volume of the liquid refrigerant within the accumulator changes based upon the discharge pressure.

[0080] Example 14 can include, or can optionally be combined with the subject matter of one or any combination of Example 13, to optionally include increasing a compressor discharge pressure target to modulate the position of the at least one expansion valve to prevent a overflowed accumulator; and issuing one of a warning or turning off the heat pump system if the target discharge pressure reaches a predetermined high limit to prevent compressor damage.

[0081] Example 15 can include, or can optionally be combined with the subject matter of one or any combination of Examples 13 and 14, to optionally include indicating a desired amount for the volume of liquid refrigerant within the accumulator.

[0082] Example 16 can include, or can optionally be combined with the subject matter of one or any combination of Examples 13 - 15, to optionally include indicating that is independent of a current mode of heat pump operation and a season in which refrigerant is contemplated to be added to the heat pump.

[0083] Example 17 can include, or can optionally be combined with the subject matter of one or any combination of Examples 13 - 16, to optionally include indicating that is dependent upon both a current mode of heat pump operation and a season in which refrigerant is contemplated to be added to the heat pump.

[0084] Example 18 can include, or can optionally be combined with the subject matter of one or any combination of Examples 13 - 17, to optionally include determining an indoor air temperature and deriving the compressor discharge pressure from the indoor air temperature.

[0085] Example 19 can include, or can optionally be combined with the subject matter of one or any combination of Examples 13 - 18, to optionally include controlling the compressor discharge pressure based upon an indoor air temperature in a heating mode of heat pump operation; and controlling the compressor discharge pressure based upon the determined outdoor air temperature in a cooling mode of heat pump operation.

[0086] In Example 20, an accumulator comprises: a housing configured to house a continuous volume of liquid refrigerant during both a heating mode and a cooling mode of operation of a heat pump; and an element that is configured to indicate a desired amount for the volume of the liquid refrigerant within the accumulator.

[0087] Example 21 can include, or can optionally be combined with the subject matter of one or any combination of Example 20, to optionally include an element that is positioned such the volume of the liquid refrigerant when filled to the desired amount comprises at least a liquid refrigerant charge difference volume between a cooling mode of heat pump operation and a heating mode of heat pump operation and a reserve volume to prevent the accumulator from being dry or overflow.

[0088] Example 22 can include, or can optionally be combined with the subject matter of one or any combination of Examples 20 and 21, to optionally include and element that is positioned to indicate the volume of the liquid refrigerant that is appropriate regardless of a current mode of system operation and regardless of a season in which refrigerant is contemplated to be added to the system.

[0089] Example 23 can include, or can optionally be combined with the subject matter of one or any combination of Examples 20 - 22, to optionally include an element that comprises two elements spaced from one another.

other, each of the two elements indicating the volume of liquid refrigerant in the accumulator that is appropriate based upon both a current mode of system operation and one season in which refrigerant is contemplated to be added to the system.

[0090] Each of these non-limiting examples can stand on its own, or can be combined in any permutation or combination with any one or more of the other examples.

[0091] The above detailed description includes references to the accompanying drawings, which form a part of the detailed description. The drawings show, by way of illustration, specific embodiments in which the present subject matter can be practiced. These embodiments are also referred to herein as "examples." Such examples can include elements in addition to those shown or described. However, the present inventors also contemplate examples in which only those elements shown or described are provided. Moreover, the present inventors also contemplate examples using any combination or permutation of those elements shown or described (or one or more aspects thereof), either with respect to a particular example (or one or more aspects thereof), or with respect to other examples (or one or more aspects thereof) shown or described herein.

[0092] In the event of inconsistent usages between this document and any documents so incorporated by reference, the usage in this document controls.

[0093] In this document, the terms "a" or "an" are used, as is common in patent documents, to include one or more than one, independent of any other instances or usages of "at least one" or "one or more." In this document, the term "or" is used to refer to a nonexclusive or, such that "A or B" includes "A but not B," "B but not A," and "A and B," unless otherwise indicated. In this document, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Also, in the following claims, the terms "including" and "comprising" are open-ended, that is, a system, device, article, composition, formulation, or process that includes elements in addition to those listed after such a term in a claim are still deemed to fall within the scope of that claim. Moreover, in the following claims, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects.

[0094] Method examples described herein can be machine or computer-implemented at least in part. Some examples can include a computer-readable medium or machine-readable medium encoded with instructions operable to configure an electronic device to perform methods as described in the above examples. An implementation of such methods can include code, such as microcode, assembly language code, a higher-level language code, or the like. Such code can include computer readable instructions for performing various methods. The code may form portions of computer program products. Further, in an example, the code can be tangibly stored on one or more volatile, non-transitory, or non-

volatile tangible computer-readable media, such as during execution or at other times. Examples of these tangible computer-readable media can include, but are not limited to, hard disks, removable magnetic disks, removable optical disks (e.g., compact disks and digital video disks), magnetic cassettes, memory cards or sticks, random access memories (RAMs), read only memories (ROMs), and the like.

[0095] The above description is intended to be illustrative, and not restrictive. For example, the above-described examples (or one or more aspects thereof) may be used in combination with each other. Other embodiments can be used, such as by one of ordinary skill in the art upon reviewing the above description. The Abstract is provided to comply with 37 C.F.R. §1.72(b), to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. Also, in the above Detailed Description, various features may be grouped together to streamline the disclosure. This should not be interpreted as intending that an unclaimed disclosed feature is essential to any claim. Rather, inventive subject matter may lie in less than all features of a particular disclosed embodiment. Thus, the following claims are hereby incorporated into the Detailed Description as examples or embodiments, with each claim standing on its own as a separate embodiment, and it is contemplated that such embodiments can be combined with each other in various combinations or permutations. The scope of the present subject matter should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

Claims

1. A heat pump system comprising:

a compressor;
at least one expansion valve;
a liquid refrigerant indicator connected to the accumulator to indicate an appropriate refrigerant charge in cooling and heating modes;
an accumulator continuously storing a volume of liquid refrigerant therein; and
a controller configured to determine a target compressor discharge pressure based on outdoor air temperature and control the compressor discharge pressure by modulating the position of the at least one expansion valve, wherein the higher the target discharge pressure target, the less liquid refrigerant is left in the accumulator.

2. The heat pump system of claim 1, further comprising:

an indoor heat exchanger; and
an outdoor heat exchanger in fluid communica-

- tion with indoor heat exchanger;
- wherein the at least one expansion valve is arranged between and modulates the flow of the refrigerant between the indoor heat exchanger and the outdoor heat exchanger.
3. The heat pump system of claim 1 or claim 2, wherein modulating a position of the at least one expansion valve comprises opening and/or closing the at least one expansion valve causing an orifice size of the valve to increase or decrease.
 4. A method comprising:
 - storing a volume of liquid refrigerant continuously within an accumulator during operation of the heat pump, the volume of liquid refrigerant comprising an appropriate amount for both a heating mode and a cooling mode of operation of a heat pump;
 - determining an outdoor air temperature and a compressor discharge pressure; and
 - controlling the compressor discharge pressure based upon the determined outdoor air temperature; wherein the volume of the liquid refrigerant within the accumulator changes based upon the discharge pressure.
 5. An accumulator comprising:
 - a housing configured to house a continuous volume of liquid refrigerant during both a heating mode and a cooling mode of operation of a heat pump; and
 - an element that is configured to indicate a desired amount for the volume of the liquid refrigerant within the accumulator.
 6. The heat pump system of claim 1 or of claim 2 or of claim 3, wherein the accumulator has an element that is configured to indicate a desired amount for the volume of liquid refrigerant within the accumulator; or the method of claim 4, further comprising indicating a desired amount for the volume of liquid refrigerant within the accumulator.
 7. The heat pump system of claim 6, wherein the element is positioned such the volume of the liquid refrigerant when filled to the desired amount comprises at least a charge difference volume between a cooling mode of system operation and a heating mode of system operation and a reserve volume to prevent the accumulator from being dry or over flow; or the accumulator of claim 5, wherein the element is positioned such the volume of the liquid refrigerant when filled to the desired amount comprises at least
 - a liquid refrigerant charge difference volume between a cooling mode of heat pump operation and a heating mode of heat pump operation and a reserve volume to prevent the accumulator from being dry or overflow.
 8. The heat pump system of claim 7, or the accumulator of claim 7, wherein the element is positioned to indicate the volume of the liquid refrigerant that is appropriate regardless of a current mode of system operation and regardless of a season in which refrigerant is contemplated to be added to the system; or the method of claim 6, wherein the indicating is independent of a current mode of heat pump operation and a season in which refrigerant is contemplated to be added to the heat pump.
 9. The heat pump system of claim 6 or claim 7 or claim 8, or the accumulator of claim 5 or claim 7 or claim 8, wherein the element comprises two elements spaced from one another, each of the two elements indicating the volume of liquid refrigerant in the accumulator that is appropriate based upon both a current mode of system operation and one season in which refrigerant is contemplated to be added to the system; or the method of claim 6 or of claim 8, wherein the indicating is dependent upon both a current mode of heat pump operation and a season in which refrigerant is contemplated to be added to the heat pump.
 10. The heat pump system of claim 1 or any preceding heat pump claim, wherein the volume of liquid refrigerant in the accumulator comprises at least twice as much refrigerant as a volume difference in refrigerant utilized by the system between a cooling mode of system operation and a heating mode of system operation.
 11. The heat pump system of claim 1 or any preceding heat pump claim, wherein the controller is further configured to determine an indoor air temperature and the compressor discharge pressure is derived from the indoor air temperature; or the method of claim 4 or of any preceding method claim, further comprising determining an indoor air temperature and deriving the compressor discharge pressure from the indoor air temperature.
 12. The heat pump system of claim 1 or any preceding heat pump claim, wherein in a heating mode of system operation, an indoor air temperature is utilized in controlling the compressor discharge pressure, and wherein in a cooling mode of system operation, the outdoor air temperature is utilized in controlling the compressor discharge pressure; or the method of claim 4 or of any preceding method claim further comprising:

controlling the compressor discharge pressure
based upon an indoor air temperature in a heat-
ing mode of heat pump operation; and
controlling the compressor discharge pressure
based upon the determined outdoor air temper-
ature in a cooling mode of heat pump operation.

13. The heat pump system of claim 1 or any preceding
heat pump claim, wherein the controller is further
configured to determine a potential for an overflowed
accumulator and increase a compressor discharge
pressure target which modulates the position of the
at least one expansion valve to a more closed posi-
tion when the overflowed accumulator is detected.
14. The heat pump system of claim 1 or any preceding
heat pump claim, wherein the at least one expansion
valve comprises an assembly of two or more expan-
sion valves, each of the two or more expansion
valves having an associated check valve.

15. The method of claim 4, further comprising:

increasing a compressor discharge pressure
target to modulate the position of the at least
one expansion valve to prevent a overflowed ac-
cumulator; and
issuing one of a warning or turning off the heat
pump system if the target discharge pressure
reaches a predetermined high limit to prevent
compressor damage.

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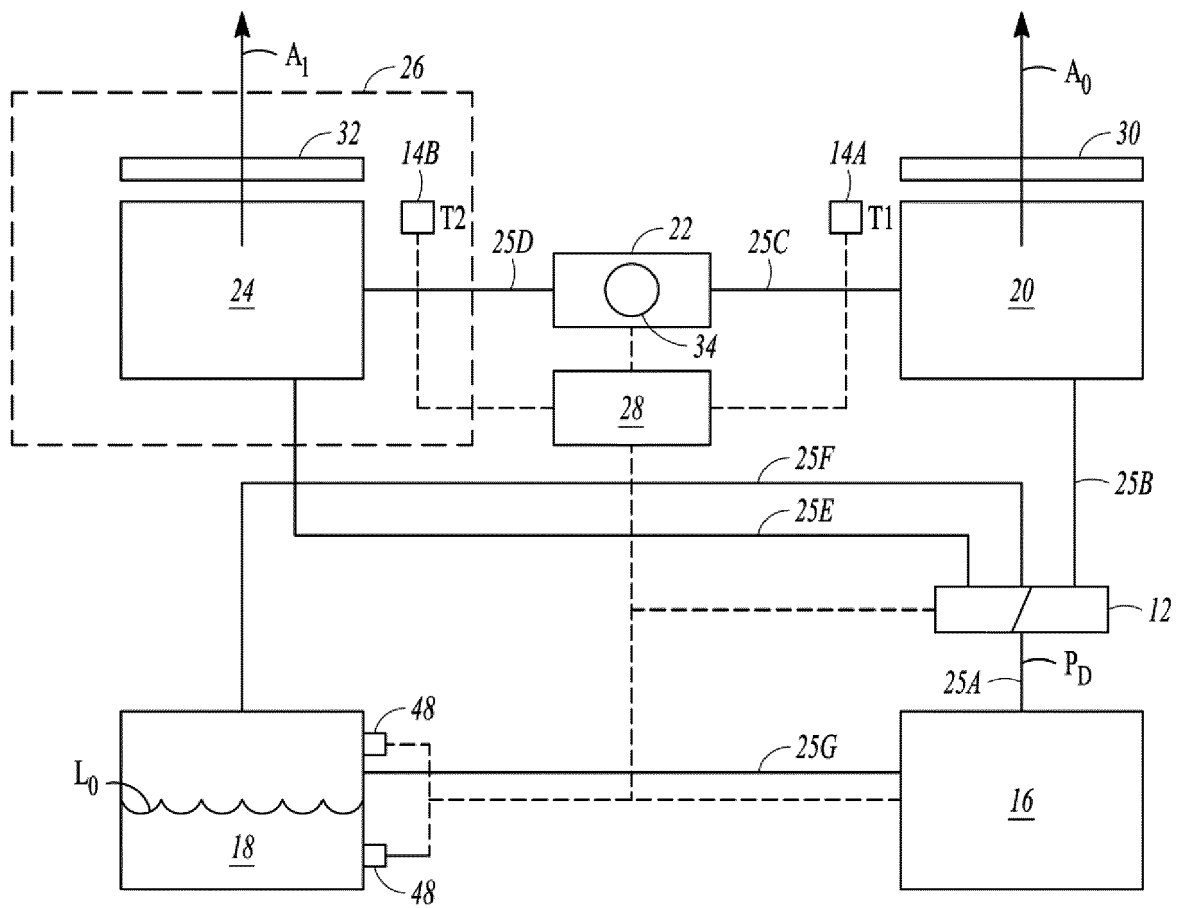


FIG. 1

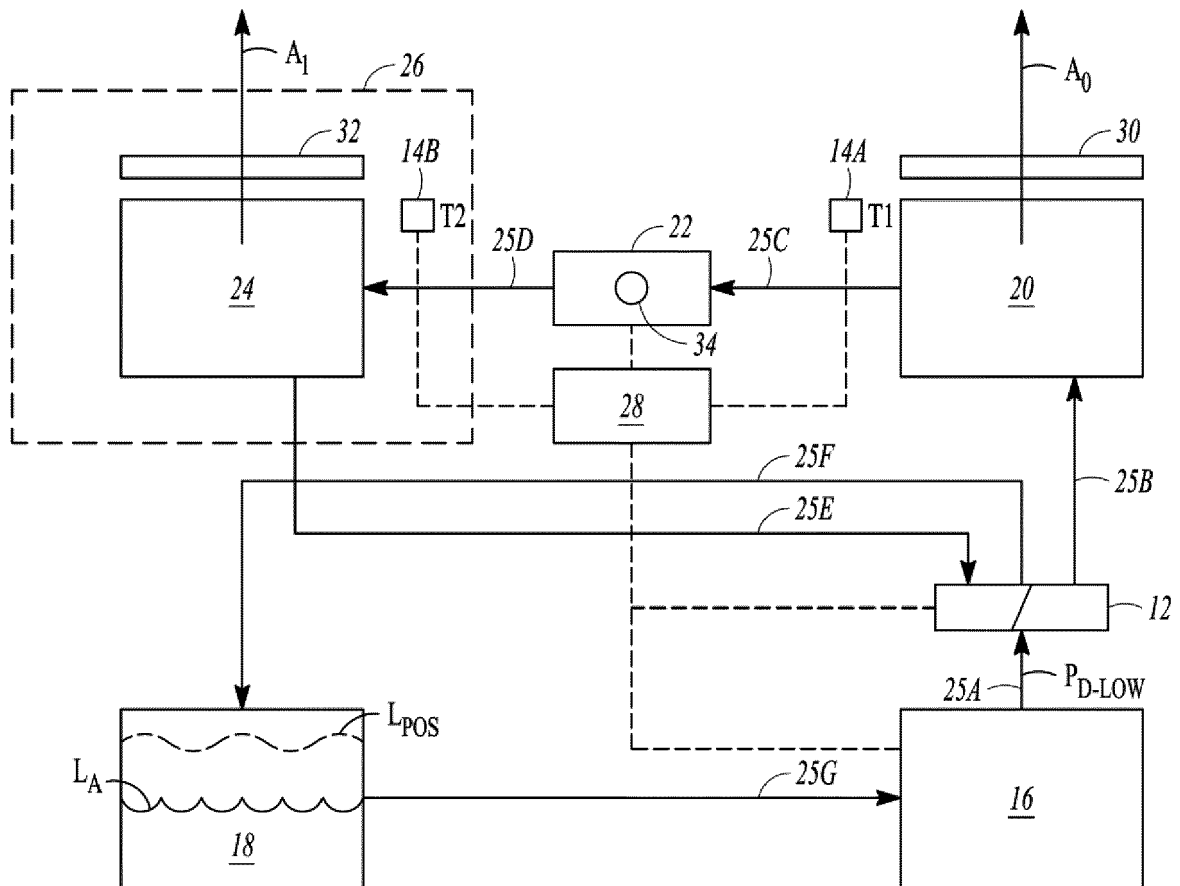


FIG. 2A

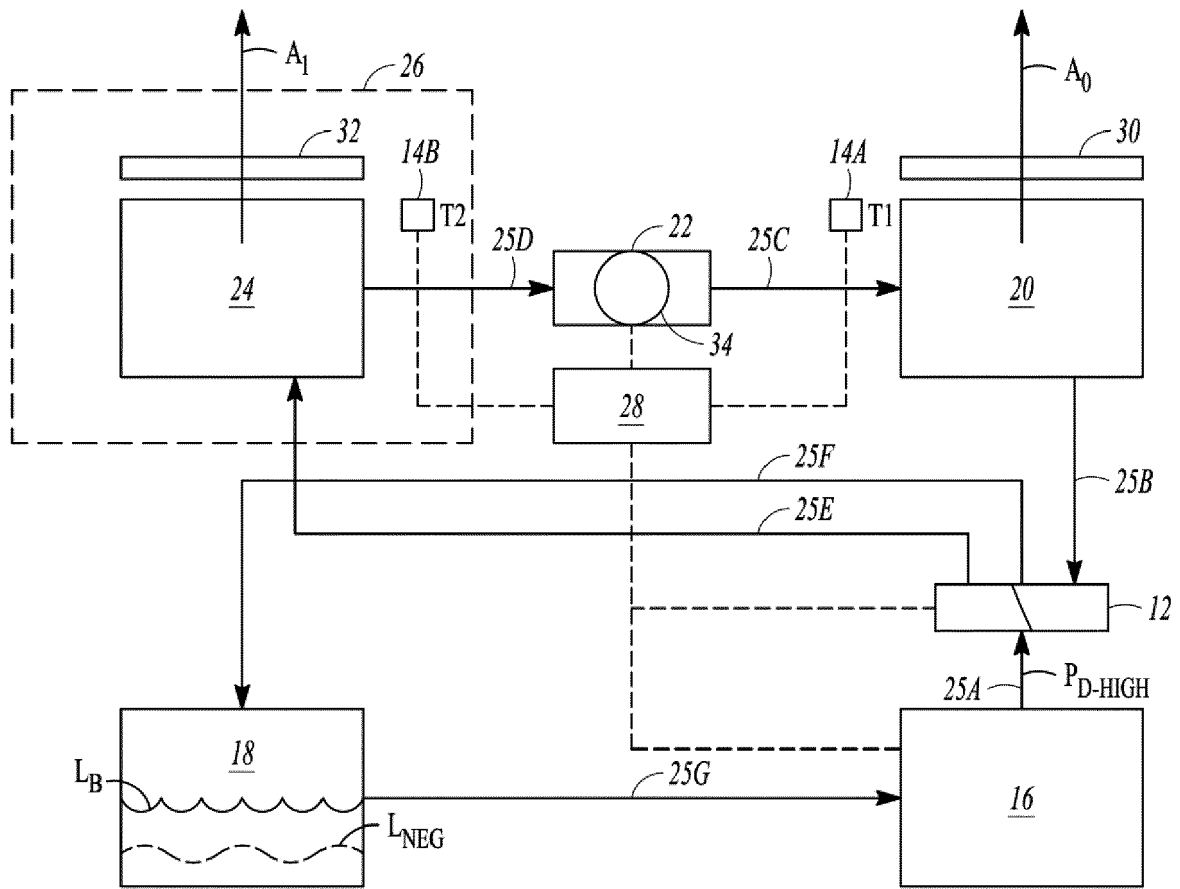


FIG. 2B

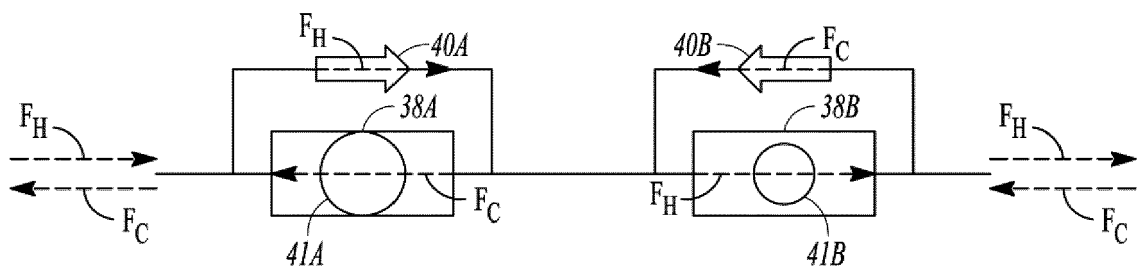


FIG. 3

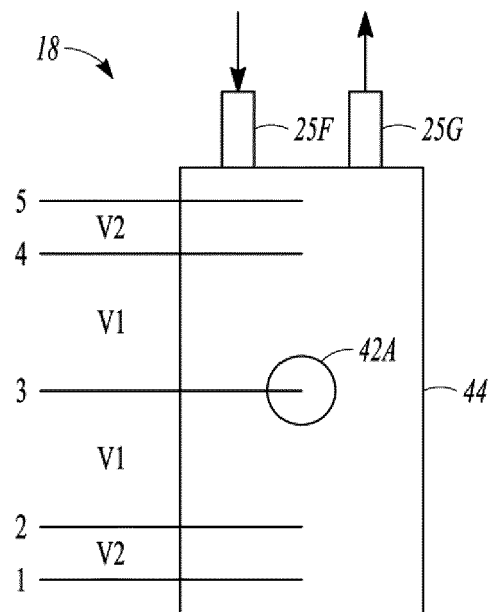


FIG. 4

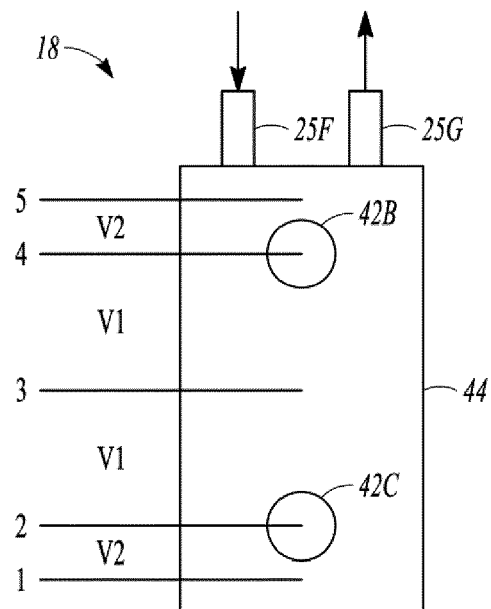


FIG. 5

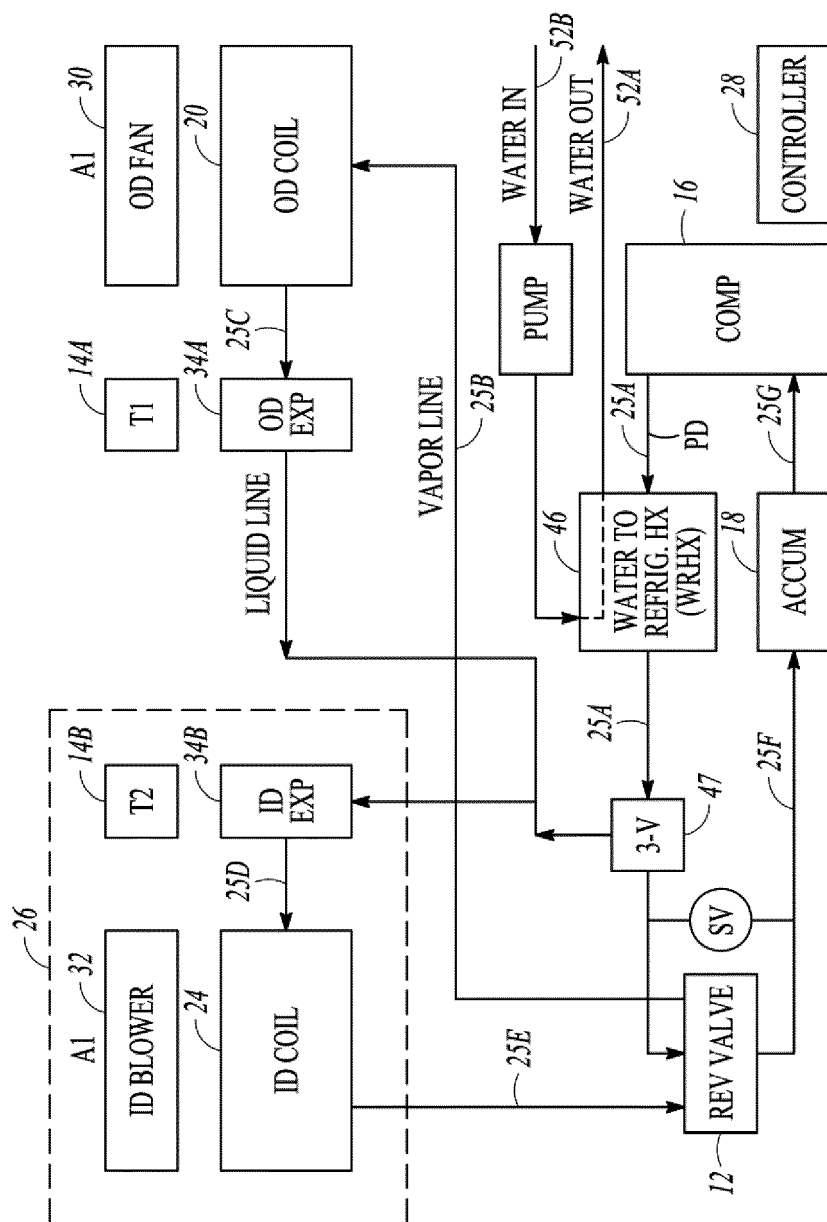
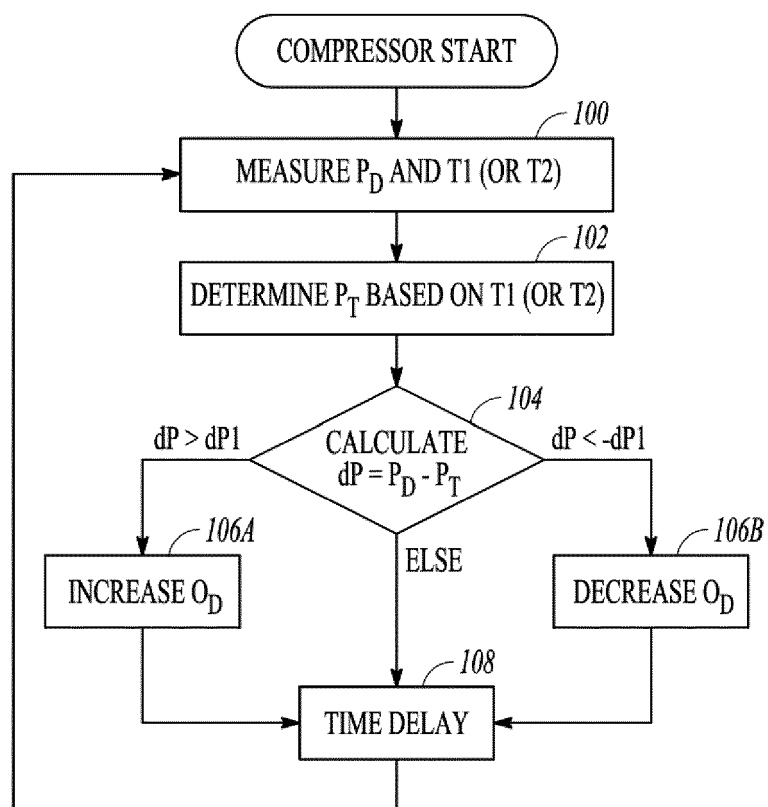


FIG. 6

*FIG. 7*

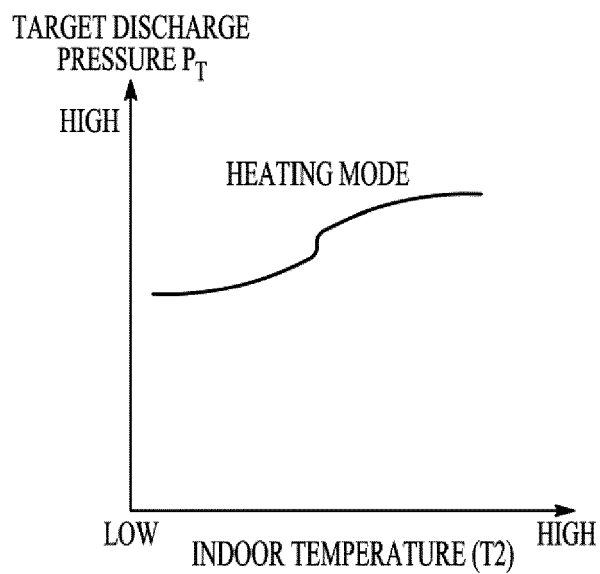


FIG. 8A

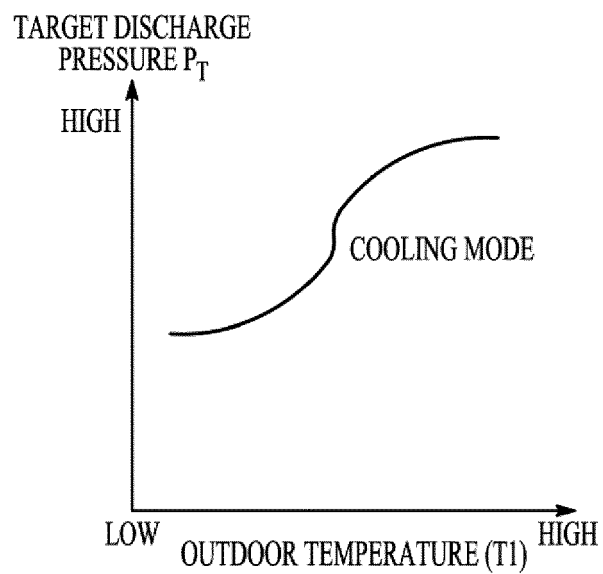


FIG. 8B

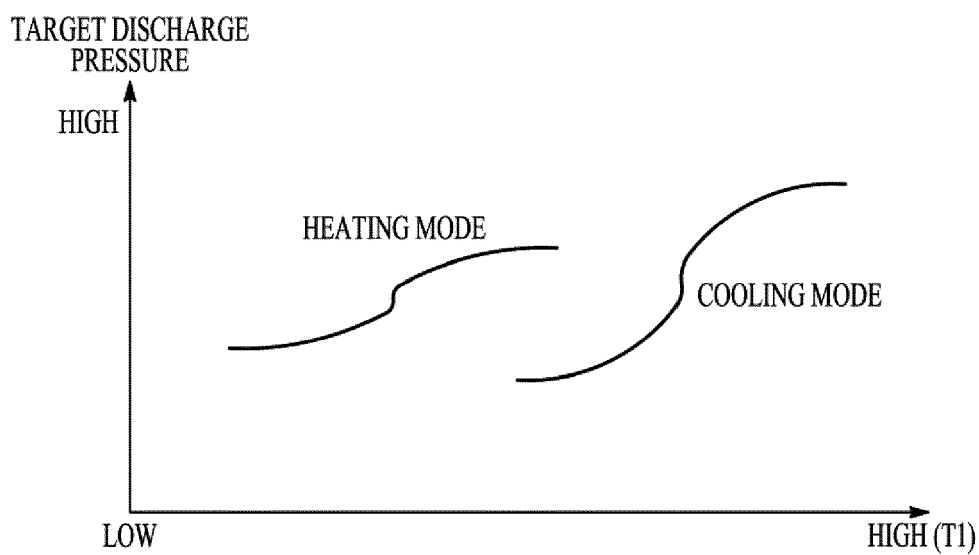


FIG. 9



EUROPEAN SEARCH REPORT

Application Number
EP 16 17 7127

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 11 November 2016	Examiner Szilagyi, Barnabas
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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