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(71) Applicant: **Yanmar Co., Ltd.**
Osaka-shi, Osaka 530-8311 (JP)

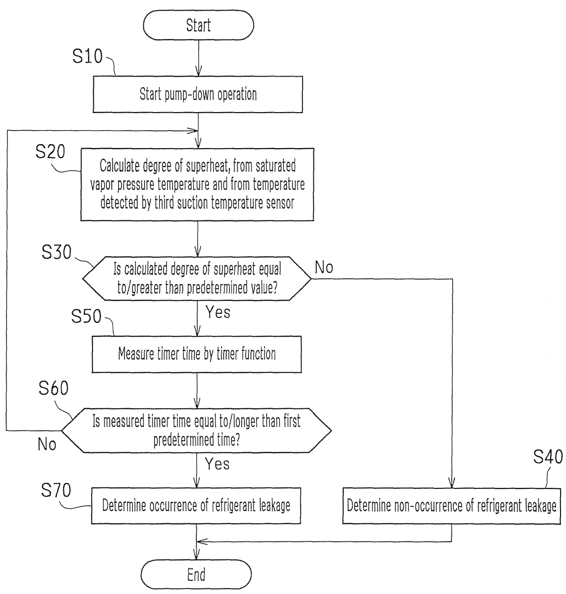
(72) Inventors:
- **OKADA Hideshi**
  Osaka-shi
  Osaka 530-0014 (JP)
- **ASAI Makoto**
  Osaka-shi
  Osaka 530-0014 (JP)

(74) Representative: **Hinkelmann, Klaus**
Patentanwaltskanzlei Hinkelmann
Lyonel-Feininger-Strasse 28
80807 München (DE)

(54) HEAT PUMP

(57) A heat pump has a compressor, a heat source-side heat exchanger, a receiver, at least one expansion valve, and a utilization-side heat exchanger, and is configured to perform a pump-down operation for recovering a liquid refrigerant into the receiver during a predetermined stopping time. The heat pump is configured to determine whether refrigerant leakage has occurred or not, by detecting an amount of the liquid refrigerant in the receiver in the pump-down operation.

Fig.6
(First embodiment)



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Description

[Technical Field]

[0001] The present invention relates to a heat pump, and particularly relates to a heat pump which determines the occurrence or non-occurrence of refrigerant leakage.

[Background Art]

[0002] A heat pump is generally designed to compress a refrigerant by a compressor, to condense the compressed refrigerant and release heat of condensation from the refrigerant through a heat source-side heat exchanger (for example, an outdoor heat exchanger) or a utilization-side heat exchanger (for example, an indoor heat exchanger), to expand the condensed refrigerant under reduced pressure by an expansion valve, to cause the depressurized expanded refrigerant to evaporate and absorb heat of vaporization through the utilization-side heat exchanger or the heat source-side heat exchanger, and to suck the vaporized refrigerant back into the compressor.

[0003] For prevention of global warming or from other like points of view, a recent trend for the heat pump is to use a refrigerant having a relatively low global warming potential (for example, a single component refrigerant such as R32). Further, a shift to non-chlorofluorocarbon refrigerants has been demanded. Additionally, handling of refrigerants requires attention to safety because chlorofluorocarbon refrigerants having lower global warming potentials are more flammable and some non-chlorofluorocarbon refrigerants are also flammable.

[0004] Under such circumstances, measures for monitoring refrigerant leakage from the heat pump have become stricter, and there is a greater request than ever before for timely determination of the occurrence or non-occurrence of refrigerant leakage.

[0005] In this regard, PTL 1 discloses a refrigeration unit management system which performs a refrigerant leakage detection operation based on an input detection schedule. PTL 2 discloses an arrangement for determining the occurrence or non-occurrence of refrigerant leakage, based on changes in the degree of superheat over time.

[Citation List]

[Patent Literature]

[0006]

[PTL 1] JP 2013-250038 A
[PTL 2] JP 06-137725 A

[Summary of Invention]

[Technical Problem]

[0007] However, PTL 1 merely discloses an arrangement for performing a refrigerant leakage detection operation based on the detection schedule relating to the date and time for implementing a refrigerant leakage detection operation mode. PTL 2 does not mention any timing for determining the occurrence or non-occurrence of refrigerant leakage. Namely, PTL 1 and PTL 2 cannot realize timely determination of the occurrence or non-occurrence of refrigerant leakage.

[0008] Therefore, the present invention aims to provide a heat pump which can timely determine the occurrence or non-occurrence of refrigerant leakage.

[Solution to Problem]

[0009] In order to achieve the above object, the present invention provides a heat pump which includes a compressor, a heat source-side heat exchanger, a receiver, at least one expansion valve, and a utilization-side heat exchanger, and which is configured to perform a pump-down operation for recovering a liquid refrigerant into the receiver during a predetermined stopping time. This heat pump is configured to determine whether refrigerant leakage has occurred or not, by detecting an amount of the liquid refrigerant in the receiver in the pump-down operation.

[0010] In an exemplary embodiment of the present invention, at least one refrigerant path may be provided from a predetermined position in the receiver to a suction side of the compressor. The heat pump may be configured to determine that refrigerant leakage has occurred when a degree of superheat of a refrigerant in the refrigerant path is equal to or greater than a predetermined value after a first predetermined time has passed.

[0011] In another exemplary embodiment of the present invention, a supercooling heat exchanger may be provided in the refrigerant path from the predetermined position in the receiver to the suction side of the compressor. The heat pump may be configured to determine whether refrigerant leakage has occurred or not, after a second predetermined time has passed since the pump-down operation started.

[Advantageous Effects of Invention]

[0012] The present invention enables timely determination of the occurrence or non-occurrence of refrigerant leakage.

[Brief Description of Drawings]

[0013]

Fig. 1 is a schematic block diagram of a heat pump regarding embodiments of the present invention.

Fig. 2 is a schematic block diagram of the heat pump, showing a heating operation state during a heating operation.

Fig. 3 is a schematic block diagram of the heat pump, showing a cooling operation state during a cooling operation.

Fig. 4 is a schematic block diagram of the heat pump, showing a pump-down operation state during a pump-down operation.

Fig. 5 is a schematic block diagram of the heat pump, showing a refrigerant charging state utilizing the pump-down operation, when the heat pump in which an inner volume of the refrigerant circuit is unknown in advance is installed.

Fig. 6 is a flowchart describing an example of control actions in the first embodiment by a control device in the heat pump.

Fig. 7 is a flowchart describing an example of control actions in the second embodiment by the control device in the heat pump.

[Description of Embodiments]

[0014] Embodiments of the present invention are hereinafter described with reference to the drawings.

[0015] Fig. 1 is a schematic block diagram of a heat pump 100 regarding embodiments of the present invention.

[0016] The heat pump 100 shown in Fig. 1 is configured to drive a compressor 10 which compresses a refrigerant, and to control the temperature by utilizing heat of condensation or heat of vaporization of the refrigerant. In this context, the term "to control the temperature" or "temperature control" means, for example, controlling the temperature of indoor air or air in a refrigerator or a freezer when the heat pump 100 serves as an air conditioner, and controlling the temperature of a circulating fluid for a chiller when the heat pump 100 serves as a chiller. The circulating fluid may be of any type as far as working as a heating medium. A typical, but not limitative, example of the circulating fluid is water. The circulating fluid may also be, for example, water containing an antifreezing solution.

[0017] The heat pump 100 has a compressor 10 which sucks and discharges a refrigerant, a heat source-side heat exchanger 20 which exchanges heat between the refrigerant and air (specifically, outdoor air), a heat source-side heat exchanger fan 30 for the heat source-side heat exchanger 20, regulating valves 40 which regulate flow rates of the refrigerant, a utilization-side heat exchanger 50 which exchanges heat between the refrigerant and a temperature control target, a drive source (in this example, an engine 60) which drives the compressor 10, a receiver 71 which recovers a liquid refrigerant, a refrigerant circuit 110 which circulates the refrigerant, and a control device 120.

[0018] In this context, the temperature control target means, for example, indoor air or air in a refrigerator or a freezer when the heat pump 100 serves as an air conditioner, and a circulating fluid when the heat pump 100 serves as a chiller. The engine 60 may be, for example, a gas-fueled engine (so-called gas engine) or a liquid-fueled engine. In this example, the engine 60 is a gas engine, and hence the heat pump 100 is a gas heat pump (GHP). Instead of the engine 60, the drive source may be an electric motor, in which case the heat pump 100 is an electric heat pump (EHP).

[0019] The heat pump 100 circulates the refrigerant between the heat source-side heat exchanger 20 and the utilization-side heat exchanger 50 while repeating a cold state where the refrigerant is depressurized and a hot state where the refrigerant is pressurized. Thereby, the heat pump 100 performs a heating operation for heating (for example, heating indoors) a temperature control target (for example, indoor air) and a cooling operation for cooling (for example, cooling indoors) the temperature control target (for example, indoor air) in a utilization-side heat exchange section 101, as described later.

[0020] The compressor 10 may be composed of a plurality of compressors connected in parallel. The heat source-side heat exchanger 20 may be composed of a plurality of heat source-side heat exchangers connected in parallel. The regulating valves 40 serve as expansion valves, and are composed of a closable first regulating valve 41 and a closable second regulating valve 42 in this example. The first regulating valve 41 may be composed of a plurality of regulating valves connected in parallel. A utilization-side heat exchange section 101 is constituted by the second regulating valve 42 and the utilization-side heat exchanger 50. The utilization-side heat exchange section 101 is an indoor unit in this example. A heat source-side heat exchange section 102 is constituted by components of the heat pump 100, excluding the second regulating valve 42, the utilization-side heat exchanger 50, and a pair of communicating pipes 110a, 110b. The heat source-side heat exchange section 102 is an outdoor unit in this example.

[0021] The heat pump 100 is further equipped with an auxiliary refrigerant evaporator 72 (a sub-evaporator) which exchanges heat between the refrigerant and exhaust heat of the engine 60 (in this example, heat of an engine coolant), and a closable regulating valve 73 for the auxiliary refrigerant evaporator.

[0022] The refrigerant circuit 110 is provided with the compressor 10, the heat source-side heat exchanger 20, the regulating valves 40, the utilization-side heat exchanger 50, the receiver 71, the auxiliary refrigerant evaporator 72, and the regulating valve 73 for the auxiliary refrigerant evaporator.

[0023] The refrigerant circuit 110 has a four-way valve 111, a bridge circuit 112, first to tenth refrigerant paths 113a-113j, and a pair of communicating pipes 110a, 110b.

[0024] The four-way valve 111 is configured to switch between a first connection state (as shown in Fig. 1) and a second connection state by a command signal from the control device 120. In the first connection state, connections are established between an inlet port 111a and a first connection port 111c and between a second connection port 111d and an outlet port 111b. In the second connection state, connections are established between the inlet port 111a and the second connection port 111d and between the first connection port 111c and the outlet port 111b. In this manner, the four-way valve 111 can switch directions of the refrigerant flow. Fig. 1 represents a heating operation state during the heating operation.

[0025] The bridge circuit 112 has four check valves (a first check valve 112a, a second check valve 112b, a third check valve 112c, and a fourth check valve 112d). The bridge circuit 112 has a first check valve train 1121 including two of the check valves (the first and second check valves 112a, 112b), and a second check valve train 1122 including the other two check valves (the third and fourth check valves 112c, 112d).

[0026] In the first check valve train 1121, the first check valve 112a and the second check valve 112b are connected in series such that the refrigerant flows in the same direction. In the second check valve train 1122, the third check valve 112c and the fourth check valve 112d are connected in series such that the refrigerant flows in the same direction. The first check valve train 1121 and the second check valve train 1122 are connected in parallel such that the refrigerant flows in the same direction.

[0027] The bridge circuit 112 has four connection points: a first middle connection point P1 between the first check valve 112a and the second check valve 112b, an outflow connection point P2 between the first check valve 112a and the third check valve 112c, a second middle connection point P3 between the third check valve 112c and the fourth check valve 112d, and an inflow connection point P4 between the second check valve 112b and the fourth check valve 112d.

[0028] The first refrigerant path 113a connects a discharge port 10a of the compressor 10 and the inlet port 111a of the four-way valve 111. The second refrigerant path 113b connects the outlet port 111b of the four-way valve 111 and a suction port 10b of the compressor 10. The third refrigerant path 113c connects the second connection port 111d of the four-way valve 111 and a first connection port 20a of the heat source-side heat exchanger 20. The fourth refrigerant path 113d connects a second connection port 20b of the heat source-side heat exchanger 20 and the first middle connection point P1 of the bridge circuit 112. The fifth refrigerant path 113e connects the outflow connection point P2 of the bridge circuit 112 and a refrigerant inlet port 71a of the receiver 71. The sixth refrigerant path 113f connects a refrigerant outlet port 71b of the receiver 71 and the inflow connection point P4 of the bridge circuit 112. The seventh refrigerant path 113g connects the second middle connection point P3 of the bridge circuit 112, and the first communicating pipe 110a which is connected to a first refrigerant connection port 50a of the utilization-side heat exchanger 50. The eighth refrigerant path 113h connects the second communicating pipe 110b which is connected to a second refrigerant connection port 50b of the utilization-side heat exchanger 50, and the first connection port 111c of the four-way valve 111. The ninth refrigerant path 113i connects the inflow connection point P4 of the bridge circuit 112 and a refrigerant inlet port 72a of the auxiliary refrigerant evaporator 72. The tenth refrigerant path 113j connects a refrigerant outlet port 72b of the auxiliary refrigerant evaporator 72 and a meeting point P5 in the second refrigerant path 113b. A part of the second refrigerant path 113b downstream (on a compressor 10 side) of the meeting point P5 constitutes a combined path 113b1.

[0029] The receiver 71 temporarily stores a liquid refrigerant flowing from the fifth refrigerant path 113e. The first regulating valve 41 constituting the regulating valves 40 is provided in the fourth refrigerant path 113d. In the heating operation, the valve position of the first regulating valve 41 is adjusted to regulate the flow rate of the refrigerant. The second regulating valve 42 constituting the regulating valves 40 is provided in a refrigerant path 51 in the utilization-side heat exchange section 101, between the first communicating pipe 110a and the first refrigerant connection port 50a of the utilization-side heat exchanger 50. In the cooling operation, the valve position of the second regulating valve 42 is adjusted to regulate the flow rate of the refrigerant. The regulating valve 73 for the auxiliary refrigerant evaporator is provided in the ninth refrigerant path 113i. In the heating operation or the cooling operation, the valve position of the regulating valve 73 for the auxiliary refrigerant evaporator is adjusted to regulate the flow rate of the refrigerant.

[0030] In the present embodiments, the heat pump 100 is further equipped with a first changeover valve 114 and a check valve 115. The refrigerant circuit 110 further includes an eleventh refrigerant path 113k.

[0031] The eleventh refrigerant path 113k connects the refrigerant path on the heat source-side heat exchanger 20 side than the first regulating valve 41 in the fourth refrigerant path 113d and the outflow connection point P2 of the bridge circuit 112. The first changeover valve 114 and the check valve 115 are provided in the eleventh refrigerant path 113k. By opening and closing, the first changeover valve 114 switches between a circulating state for allowing circulation of the refrigerant and a blocking state for blocking circulation of the refrigerant in the eleventh refrigerant path 113k. The check valve 115 allows circulation of the refrigerant from the first changeover valve 114 to the outflow connection point P2 of the bridge circuit 112, and blocks circulation of the refrigerant from the outflow connection point P2 of the bridge circuit 112 to the first changeover valve 114.

[0032] In the present embodiments, the heat pump 100 is further equipped with an oil separator 81 and an accumulator 82.

[0033] The oil separator 81 is provided in the first refrigerant path 113a. The oil separator 81 separates lubrication oil for the compressor 10 from the refrigerant, and returns the separated lubrication oil to the compressor 10 via a valve 81a (specifically, an electromagnetic valve). The accumulator 82 is provided in the combined path 113b1 of the second refrigerant path 113b. The accumulator 82 separates a remaining liquid refrigerant which has not completely evaporated in the heat source-side heat exchanger 20, the utilization-side heat exchanger 50, and the auxiliary refrigerant evaporator 72 each of which works as an evaporator.

[0034] In the present embodiments, the heat pump 100 is further equipped with a second changeover valve 116. The refrigerant circuit 110 further includes a twelfth refrigerant path 113l.

[0035] The twelfth refrigerant path 113l connects a bottom opening 82a of the accumulator 82 and the refrigerant path on the compressor 10 side than the accumulator 82 in the combined path 113b1. The second changeover valve 116 is provided in the twelfth refrigerant path 113l. By opening and closing, the second changeover valve 116 switches between a circulating state for allowing circulation of the refrigerant and a blocking state for blocking circulation of the refrigerant in the twelfth refrigerant path 113l.

[0036] In the present embodiments, the heat pump 100 is further equipped with a supercooling heat exchanger 91 and a closable regulating valve 92 for the supercooling heat exchanger. The refrigerant circuit 110 further includes a thirteenth refrigerant path 113m.

[0037] The thirteenth refrigerant path 113m connects the inflow connection point P4 in the bridge circuit 112 and the refrigerant path of the compressor 10 side than the second changeover valve 116 in the twelfth refrigerant path 113l. In the supercooling heat exchanger 91, an inlet port 91a on the receiver 71 side and an outlet port 91b on the inflow connection point P4 side in the bridge circuit 112 communicate with the sixth refrigerant path 113f, and an inlet port 91c on the side of the regulating valve 92 for the supercooling heat exchanger and an outlet port 91d on the accumulator 82 side communicate with the thirteenth refrigerant path 113m. The regulating valve 92 for the supercooling heat exchanger is provided in the refrigerant path on the inflow connection point P4 side of the bridge circuit 112 than the supercooling heat exchanger 91 in the thirteenth refrigerant path 113m. In the cooling operation, the valve position of the regulating valve 92 is adjusted to regulate the flow rate of the refrigerant. In the cooling operation, the supercooling heat exchanger 91 exchanges heat between the refrigerant flowing in the sixth refrigerant path 113f and the refrigerant flowing to the refrigerant path on the supercooling heat exchanger 91 side than the regulating valve 92 for the supercooling heat exchanger in the thirteenth refrigerant path 113m. In this manner, the refrigerant flowing in the sixth refrigerant path 113f can be cooled with a higher efficiency in the cooling operation.

[0038] In the present embodiments, the heat pump 100 is further equipped with a third changeover valve 117 and a capillary tube 118 (a fine tube). The refrigerant circuit 110 further includes a fourteenth refrigerant path 113n.

[0039] The fourteenth refrigerant path 113n connects a refrigerant-liquid-level outlet port 71c of the receiver 71 and the refrigerant path on the supercooling heat exchanger 91 side than the regulating valve 92 for the supercooling heat exchanger in the thirteenth refrigerant path 113m. The refrigerant-liquid-level outlet port 71c of the receiver 71 is provided at a higher position than the refrigerant outlet port 71b of the receiver 71 by a predetermined distance. The third changeover valve 117 is provided in the fourteenth refrigerant path 113n. By opening and closing, the third changeover valve 117 switches between a circulating state for allowing circulation of the refrigerant and a blocking state for blocking circulation of the refrigerant in the fourteenth refrigerant path 113n. The capillary tube 118 is provided in the refrigerant path on the thirteenth refrigerant path 113m side than the third changeover valve 117 in the fourteenth refrigerant path 113n, and regulates the flow rate of the refrigerant.

[0040] In the present embodiments, the heat pump 100 is further equipped with a closable regulating valve 119 for refrigerant charging. The refrigerant circuit 110 further includes a fifteenth refrigerant path 113o.

[0041] The fifteenth refrigerant path 113o connects a refrigerant charging port 102a for charging the refrigerant and the refrigerant path on the auxiliary refrigerant evaporator 72 side than the regulating valve 73 for the auxiliary refrigerant evaporator in the ninth refrigerant path 113i. The regulating valve 119 for refrigerant charging is provided in the fifteenth refrigerant path 113o, and the valve position of the regulating valve 119 for refrigerant charging is adjusted to regulate the flow rate of the refrigerant.

[0042] The valve positions of the first regulating valve 41, the second regulating valve 42, the regulating valve 73 for the auxiliary refrigerant evaporator, the regulating valve 92 for the supercooling heat exchanger, and the regulating valve 119 for refrigerant charging can be adjusted by command signals from the control device 120. Thereby, the first regulating valve 41, the second regulating valve 42, the regulating valve 73 for the auxiliary refrigerant evaporator, the regulating valve 92 for the supercooling heat exchanger, and the regulating valve 119 for refrigerant charging can regulate the flow of the refrigerant in the refrigerant circuit 110.

[0043] In this example, the first regulating valve 41 is composed of a plurality of closable regulating valves connected in parallel. The first regulating valve 41 can regulate the flow rate of the refrigerant in the refrigerant circuit 110 by combining the parallel-connected, position-adjusted regulating valves.

[0044] The compressor 10 is connected to the engine 60 via a clutch 11. Based on a command signal from the control device 120, the clutch 11 is either in an engaged state for allowing transmission of a driving force from the engine 60 to the compressor 10, or in a disengaged state for blocking transmission of a driving force from the engine 60 to the compressor 10.

[0045] The heat pump 100 is further equipped with a discharge pressure sensor 151, a suction pressure sensor 152, a first suction temperature sensor 161, a second suction temperature sensor 162, a third suction temperature sensor 163, and an engine speed sensor 170.

[0046] The discharge pressure sensor 151 detects the discharge pressure of the refrigerant in the discharge path of the compressor 10. To be specific, the discharge pressure sensor 151 is provided in the first refrigerant path 113a, upstream (on the compressor 10 side) of the oil separator 81. The discharge pressure sensor 151 detects the pressure of the refrigerant in the first refrigerant path 113a, on the upstream side of the oil separator 81.

[0047] The suction pressure sensor 152 detects the suction pressure of the refrigerant in the suction path of the compressor 10. To be specific, the suction pressure sensor 152 is provided in the second refrigerant path 113b, upstream (on the four-way valve 111 side) of the meeting point P5. The suction pressure sensor 152 detects the pressure of the refrigerant in the second refrigerant path 113b, on the upstream side of the meeting point P5.

[0048] Each of the first suction temperature sensor 161, the second suction temperature sensor 162, and the third suction temperature sensor 163 detects the suction temperature of the refrigerant in the suction path of the compressor 10. In this example, these temperature sensors are thermistors.

[0049] To be specific, the first suction temperature sensor 161 is provided in the combined path 113b1 of the second refrigerant path 113b, upstream (on the meeting point P5 side) of the accumulator 82. The first suction temperature sensor 161 detects the temperature of the refrigerant in the combined path 113b1, on the upstream side of the accumulator 82.

[0050] The second suction temperature sensor 162 is provided in the refrigerant path on the downstream side (the compressor 10 side) than the connection point with the twelfth refrigerant path 113l in the combined path 113b1 of the second refrigerant path 113b. The second suction temperature sensor 162 detects the temperature of the refrigerant in the combined path 113b1, on the downstream side of the connection point with the twelfth refrigerant path 113l.

[0051] The third suction temperature sensor 163 is provided in the refrigerant path on the downstream side (the compressor 10 side) than the connection point with the thirteenth refrigerant path 113m in the twelfth refrigerant path 113l. The third suction temperature sensor 163 detects the temperature of the refrigerant in the twelfth refrigerant path 113l, on the downstream side of the connection point with the thirteenth refrigerant path 113m.

[0052] The engine speed sensor 170 is provided at the engine 60, and detects the engine speed which is the number of rotations of the engine 60 (the number of rotations per unit time).

[0053] The control device 120 is configured to control the drive of the refrigerant circuit 110, based on the detection signals from these sensors.

[0054] Specifically, the control device 120 causes the compressor 10 to compress the refrigerant sucked in from the second refrigerant path 113b and to discharge the compressed refrigerant to the first refrigerant path 113a. In the heating operation, the control device 120 allows the four-way valve 111 to be in the first connection state in which communication is provided between the first refrigerant path 113a and the eighth refrigerant path 113h and between the third refrigerant path 113c and the second refrigerant path 113b. In the cooling operation, the control device 120 allows the four-way valve 111 to be in the second connection state in which communication is provided between the first refrigerant path 113a and the third refrigerant path 113c and between the eighth refrigerant path 113h and the second refrigerant path 113b.

[0055] The heat source-side heat exchanger 20 serves, in the heating operation, as an evaporator in which the refrigerant absorbs heat and evaporates, and serves, in the cooling operation, as a condenser in which the refrigerant releases heat and liquefies. The utilization-side heat exchanger 50 serves, in the heating operation, as a heater in which the refrigerant releases heat and thereby heats the temperature control target (for example, indoor air), and serves, in the cooling operation, as a cooler in which the refrigerant absorbs heat and thereby cools the temperature control target (for example, indoor air). The auxiliary refrigerant evaporator 72 and the supercooling heat exchanger 91 serve as evaporators in which the refrigerant absorbs heat and evaporates.

[0056] The control device 120 has a processor unit 121 composed of a microcomputer such as a CPU (Central Processing Unit), and a memory unit 122 including a non-volatile memory such as a ROM (Read Only Memory) and a volatile memory such as a RAM (Random Access Memory). The control device 120 has a timer function.

[0057] The control device 120 controls operations of the various components by allowing the processor unit 121 to load and run a control program that is prestored in the ROM in the memory unit 122, on the RAM in the memory unit 122.

[0058] By sending a command order to the first regulating valve 41, the control device 120 regulates the flow rate of the refrigerant, from the bridge circuit 112 to the heat source-side heat exchanger 20 in the heating operation, and from the heat source-side heat exchanger 20 to the bridge circuit 112 in the cooling operation. Specifically, in the heating operation, the control device 120 allows the first regulating valve 41 to serve as an expansion valve for regulating the flow rate of the refrigerant, depending on the degree of superheat (a difference between the saturated vapor pressure temperature and the detected temperature) which is calculated, in this case, from the saturated vapor pressure temperature based on the pressure detected by the suction pressure sensor 152 and from the temperature detected by the first suction temperature sensor 161. In the cooling operation, the control device 120 can open the first regulating valve 41 fully. The saturated vapor pressure temperature can be converted from the suction pressure of the compressor 10 detected by the suction pressure sensor 152, by means of a predetermined conversion formula or conversion table.

[0059] By sending a command order to the second regulating valve 42, the control device 120 regulates the flow rate of the refrigerant, from the utilization-side heat exchanger 50 to the bridge circuit 112 in the heating operation, and from the bridge circuit 112 to the utilization-side heat exchanger 50 in the cooling operation. Specifically, in the heating operation, the control device 120 can open the second regulating valve 42 fully. In the cooling operation, the control device 120 allows the second regulating valve 42 to serve as an expansion valve for regulating the flow rate of the refrigerant, depending on the degree of superheat which is calculated, in this case, from the saturated vapor pressure temperature based on the pressure detected by the suction pressure sensor 152 and from the temperature detected by the first suction temperature sensor 161.

[0060] By sending a command order to the regulating valve 73 for the auxiliary refrigerant evaporator, the control device 120 regulates the flow rate of the refrigerant from the bridge circuit 112 to the auxiliary refrigerant evaporator 72 in the heating operation or the cooling operation.

[0061] By sending a command order to the first changeover valve 114, the control device 120 keeps the first changeover valve 114 closed in the heating operation, and blocks circulation of the refrigerant from the heat source-side heat exchanger 20 to the receiver 71. In the cooling operation, the control device 120 keeps the first changeover valve 114 open, and allows circulation of the refrigerant from the heat source-side heat exchanger 20 to the receiver 71. In the case where the control device 120 keeps the first changeover valve 114 open in the cooling operation, the first regulating valve 41 may be fully closed.

[0062] By sending a command order to the second changeover valve 116, the control device 120 keeps the second changeover valve 116 open in the heating operation or the cooling operation, and allows circulation of the refrigerant from the bottom opening 82a of the accumulator 82 to the compressor 10, or the control device 120 keeps the second changeover valve 116 closed in the heating operation or the cooling operation, and blocks circulation of the refrigerant from the bottom opening 82a of the accumulator 82 to the compressor 10. Specifically, in the heating operation or the cooling operation, the control device 120 keeps the second changeover valve 116 open if the degree of superheat is equal to or greater than a predetermined value (a first predetermined value), and keeps the second changeover valve 116 closed if the degree of superheat is less than the predetermined value (the first predetermined value). In this case, the degree of superheat is calculated from the saturated vapor pressure temperature based on the pressure detected by the suction pressure sensor 152 and from the temperature detected by the second suction temperature sensor 162.

[0063] By sending a command order to the third changeover valve 117, the control device 120 keeps the third changeover valve 117 closed in the heating operation or the cooling operation, and blocks circulation of the refrigerant from the refrigerant-liquid-level outlet port 71c of the receiver 71 to the supercooling heat exchanger 91. By sending a command order to the regulating valve 119 for refrigerant charging, the control device 120 fully closes the regulating valve 119 for refrigerant charging in the heating operation or the cooling operation, and blocks circulation of the refrigerant from outside. The third changeover valve 117 and the regulating valve 119 for refrigerant charging are employed in the pump-down operation to be described later.

[0064] Next, operational actions by the heat pump 100 in the heating operation and the cooling operation are described with reference to Figs. 2 and 3.

(Actions in the heating operation)

[0065] Fig. 2 is a schematic block diagram of the heat pump 100, showing a heating operation state during the heating operation. In Fig. 2 and Figs. 3-5 to be described later, bold lines (including bold broken lines in Figs. 4 and 5) indicate the flow of the refrigerant.

[0066] In an example of the heating operation shown in Fig. 2, the control device 120 adjusts the valve positions of the first regulating valve 41 and the regulating valve 73 for the auxiliary refrigerant evaporator, fully opens the second regulating valve 42, fully closes the regulating valve 92 for the supercooling heat exchanger and the regulating valve 119 for refrigerant charging, keeps the first changeover valve 114 and the third changeover valve 117 closed, and keeps the second changeover valve 116 open.

[0067] For the heating operation by the heat pump 100, the control device 120 switches the four-way valve 111 into the first connection state in which communication is provided between the first refrigerant path 113a and the eighth refrigerant path 113h and between the third refrigerant path 113c and the second refrigerant path 113b. Accordingly, the refrigerant in a high-pressure gaseous state (hereinafter called a high-pressure gas refrigerant) discharged from the compressor 10 passes the oil separator 81 in the first refrigerant path 113a, and flows through the four-way valve 111, the eighth refrigerant path 113h, and the second communicating pipe 110b, to the utilization-side heat exchanger 50.

[0068] The temperature of the high-pressure gas refrigerant flowing into the refrigerant circuit 110 of the utilization-side heat exchanger 50 is higher than that of the temperature control target of the utilization-side heat exchanger 50 (in this example, indoor air). Hence, heat is transferred from the high-pressure gas refrigerant to the temperature control target (in this example, indoor air). As a result, the high-pressure gas refrigerant releases heat of condensation and liquefies into a refrigerant in a high-pressure liquid state (hereinafter called a high-pressure liquid refrigerant). On the other hand, the temperature control target (in this example, indoor air) is heated by the heat release effect of the refrigerant. Namely, in the heating operation, the utilization-side heat exchanger 50 serves as a heater in which heat is released from the high-pressure gas refrigerant, for heating the temperature control target (in this example, indoor air).

[0069] The high-pressure liquid refrigerant flows from the utilization-side heat exchanger 50, through the second regulating valve 42, the first communicating pipe 110a, and the seventh refrigerant path 113g, to the second middle connection point P3 of the bridge circuit 112. Since the second middle connection point P3 is provided between an inlet port of the third check valve 112c and an outlet port of the fourth check valve 112d, the high-pressure liquid refrigerant does not flow toward the first check valve 112a and the fourth check valve 112d, but flows from the second middle connection point P3, through the third check valve 112c and the outflow connection point P2, then through the fifth refrigerant path 113e, the receiver 71, and the supercooling heat exchanger 91 in the sixth refrigerant path 113f, to the inflow connection point P4 of the bridge circuit 112. While the high-pressure liquid refrigerant is flowing through the inflow connection point P4 which is provided on an inlet port side of the second check valve 112b and the fourth check valve 112d, the high-pressure liquid refrigerant is also flowing through the second middle connection point P3 and the outflow connection point P2 as mentioned above. Due to the pressure difference between the high-pressure liquid refrigerant flowing through the inflow connection point P4 and the high-pressure liquid refrigerant flowing through the second middle connection point P3 and the outflow connection point P2, the high-pressure liquid refrigerant flowing through the inflow connection point P4 does not flow into the first check valve 112a and the fourth check valve 112d, but flows through the second check valve 112b and the first middle connection point P1 and passes the first regulating valve 41.

[0070] At the first regulating valve 41, the high-pressure liquid refrigerant expands to be a refrigerant in a low-pressure gas-liquid two-phase state (hereinafter called a low-pressure gas-liquid two-phase refrigerant). This low-pressure gas-liquid two-phase refrigerant flows into the heat source-side heat exchanger 20 through the fourth refrigerant path 113d.

[0071] The temperature of the low-pressure gas-liquid two-phase refrigerant flowing into the heat source-side heat exchanger 20 is lower than that of air circulating in the heat source-side heat exchanger 20 (specifically, outdoor air). Hence, heat is transferred from the air (specifically, outdoor air) to the low-pressure gas-liquid two-phase refrigerant. As a result, the low-pressure gas-liquid two-phase refrigerant gains heat of vaporization and evaporates into a refrigerant in a low-pressure gas state (hereinafter called a low-pressure gas refrigerant). Namely, in the heating operation, the heat source-side heat exchanger 20 serves as a refrigerant evaporator in which heat is absorbed by the low-pressure gas-liquid two-phase refrigerant.

[0072] Thereafter, the low-pressure gas refrigerant flows from the heat source-side heat exchanger 20 to the third refrigerant path 113c. At this time, the control device 120 allows the four-way valve 111 to provide communication between the third refrigerant path 113c and the second refrigerant path 113b, so that the low-pressure gas refrigerant passes the accumulator 82 in the second refrigerant path 113b and the second changeover valve 116 and is sucked into the compressor 10.

[0073] The high-pressure liquid refrigerant which flows from the sixth refrigerant path 113f to the ninth refrigerant path 113i passes the regulating valve 73 for the auxiliary refrigerant evaporator.

[0074] At the regulating valve 73 for the auxiliary refrigerant evaporator, the high-pressure liquid refrigerant expands to be a low-pressure gas-liquid two-phase refrigerant. This low-pressure gas-liquid two-phase refrigerant flows into the auxiliary refrigerant evaporator 72.

[0075] The temperature of the low-pressure gas-liquid two-phase refrigerant flowing in the refrigerant circuit 110 side in the auxiliary refrigerant evaporator 72 is lower than the temperature of an engine coolant flowing in an engine coolant circuit (not shown) side in the auxiliary refrigerant evaporator 72. Hence, heat is transferred from the engine coolant to the low-pressure gas-liquid two-phase refrigerant. As a result, the low-pressure gas-liquid two-phase refrigerant gains heat of vaporization and evaporates into a low-pressure gas refrigerant, which is then sent into the tenth refrigerant path 113j. On the other hand, the engine coolant is cooled by the heat absorption effect of the refrigerant.

[0076] From here on, the heat pump 100 repeats a series of above-described actions for the heating operation in a similar manner.

[0077] As described above, the heat pump 100 can suitably heat the temperature control target (in this example, indoor air) by means of the utilization-side heat exchange section 101 (in this example, the indoor unit), by properly performing the heating operation.

(Actions in the cooling operation)

[0078] Fig. 3 is a schematic block diagram of the heat pump 100, showing a cooling operation state during the cooling operation.

[0079] In an example of the cooling operation shown in Fig. 3, the control device 120 fully closes the regulating valve 119 for refrigerant charging, adjusts the valve positions of the first regulating valve 41, the second regulating valve 42, the regulating valve 73 for the auxiliary refrigerant evaporator, and the regulating valve 92 for the supercooling heat exchanger, keeps the first changeover valve 114 and the second changeover valve 116 open, and keeps the third changeover valve 117 closed.

[0080] For the cooling operation by the heat pump 100, the control device 120 switches the four-way valve 111 into the second connection state in which communication is provided between the first refrigerant path 113a and the third refrigerant path 113c and between the eighth refrigerant path 113h and the second refrigerant path 113b. Accordingly, the high-pressure gas refrigerant discharged from the compressor 10 passes the oil separator 81 in the first refrigerant path 113a, and flows through the four-way valve 111 and the third refrigerant path 113c, to the heat source-side heat exchanger 20.

[0081] The temperature of the high-pressure gas refrigerant flowing into the heat source-side heat exchanger 20 is higher than that of the air (specifically, outdoor air) circulating in the heat source-side heat exchanger 20. Hence, heat is transferred from the high-pressure gas refrigerant to the air (specifically, outdoor air). As a result, the high-pressure gas refrigerant releases heat of condensation and liquefies into a high-pressure liquid refrigerant. Namely, in the cooling operation, the heat source-side heat exchanger 20 serves as a refrigerant condenser in which heat is released from the high-pressure gas refrigerant.

[0082] The high-pressure liquid refrigerant flows from the heat source-side heat exchanger 20, on the one hand, via the fourth refrigerant path 113d, the first changeover valve 114 and the check valve 115 in the eleventh refrigerant path 113k, and, at the same time, via the first regulating valve 41 in the fourth refrigerant path 113d, the first middle connection point P1, the first check valve 112a, and the outflow connection point P2 of the bridge circuit 112, then through the fifth refrigerant path 113e, the receiver 71, the supercooling heat exchanger 91 in the sixth refrigerant path 113f, to the inflow connection point P4 of the bridge circuit 112. While the high-pressure liquid refrigerant is flowing through the inflow connection point P4 which is provided on the inlet port side of the second check valve 112b and the fourth check valve 112d, the high-pressure liquid refrigerant is also flowing through the first middle connection point P1 and the outflow connection point P2 as mentioned above. Due to the pressure difference between the high-pressure liquid refrigerant flowing through the inflow connection point P4 and the high-pressure liquid refrigerant flowing through the first middle connection point P1 and the outflow connection point P2, the high-pressure liquid refrigerant flowing through the inflow connection point P4 does not flow into the second check valve 112b and the third check valve 112c, but flows through the fourth check valve 112d and the second middle connection point P3, into the seventh refrigerant path 113g and the first communicating pipe 110a, and passes the second regulating valve 42.

[0083] At the second regulating valve 42, the high-pressure liquid refrigerant expands to be a low-pressure gas-liquid two-phase refrigerant. This low-pressure gas-liquid two-phase refrigerant flows into the utilization-side heat exchanger 50.

[0084] The temperature of the low-pressure gas-liquid two-phase refrigerant flowing into the utilization-side heat exchanger 50 from the refrigerant circuit 110 is lower than that of the temperature control target (in this example, indoor air) in the utilization-side heat exchanger 50. Hence, heat is transferred from the temperature control target (in this example, indoor air) to the low-pressure gas-liquid two-phase refrigerant. As a result, the low-pressure gas-liquid two-phase refrigerant gains heat of vaporization and evaporates into a low-pressure gas refrigerant. On the other hand, the temperature control target (in this example, indoor air) is cooled by the heat absorption effect of the refrigerant. Namely, in the cooling operation, the second regulating valve 42 serves as an expansion valve in which the high-pressure liquid refrigerant expands to be a low-pressure gas-liquid two-phase refrigerant, and the utilization-side heat exchanger 50 serves as a cooler in which heat is absorbed by the low-pressure gas-liquid two-phase refrigerant, for cooling the temperature control target (in this example, indoor air).

[0085] Thereafter, the low-pressure gas refrigerant flows from the utilization-side heat exchanger 50 through the second communicating pipe 110b to the eighth refrigerant path 113h. At this time, the control device 120 allows the four-way valve 111 to provide communication between the eighth refrigerant path 113h and the second refrigerant path 113b, so that the low-pressure gas refrigerant passes through the accumulator 82 in the second refrigerant path 113b and the second changeover valve 116 and is sucked into the compressor 10.

[0086] The high-pressure liquid refrigerant which flows from the sixth refrigerant path 113f to the ninth refrigerant path 113i passes the regulating valve 73 for the auxiliary refrigerant evaporator.

[0087] At the regulating valve 73 for the auxiliary refrigerant evaporator, the high-pressure liquid refrigerant expands to be a low-pressure gas-liquid two-phase refrigerant. This low-pressure gas-liquid two-phase refrigerant flows into the auxiliary refrigerant evaporator 72.

[0088] The temperature of the low-pressure gas-liquid two-phase refrigerant flowing in the refrigerant circuit 110 in the auxiliary refrigerant evaporator 72 is lower than the temperature of an engine coolant flowing in the engine coolant circuit (not shown) in the auxiliary refrigerant evaporator 72. Hence, heat is transferred from the engine coolant to the low-pressure gas-liquid two-phase refrigerant. As a result, the low-pressure gas-liquid two-phase refrigerant gains heat of vaporization and evaporates into a low-pressure gas refrigerant, which is then sent into the tenth refrigerant path 113j. On the other hand, the engine coolant is cooled by the heat absorption effect of the refrigerant.

[0089] The high-pressure liquid refrigerant which flows from the sixth refrigerant path 113f to the thirteenth refrigerant path 113m passes the regulating valve 92 for the supercooling heat exchanger.

[0090] At the regulating valve 92 for the supercooling heat exchanger, the high-pressure liquid refrigerant expands to be a low-pressure gas-liquid two-phase refrigerant. This low-pressure gas-liquid two-phase refrigerant flows into the supercooling heat exchanger 91.

[0091] The temperature of the low-pressure gas-liquid two-phase refrigerant flowing in the thirteenth refrigerant path 113m in the supercooling heat exchanger 91 is lower than the temperature of the high-pressure liquid refrigerant flowing in the sixth refrigerant path 113f in the supercooling heat exchanger 91. Hence, heat is transferred from the high-pressure liquid refrigerant to the low-pressure gas-liquid two-phase refrigerant. As a result, the low-pressure gas-liquid two-phase refrigerant gains heat of vaporization and evaporates into a low-pressure gas refrigerant, which is then sent into the twelfth refrigerant path 113l at a point downstream (on the compressor 10 side) of the second changeover valve 116. On the other hand, the high-pressure liquid refrigerant is cooled by the heat absorption effect of the refrigerant.

[0092] From here on, the heat pump 100 repeats a series of above-described actions for the cooling operation in a similar manner.

[0093] As described above, the heat pump 100 can suitably cool the temperature control target (in this example, indoor air) by means of the utilization-side heat exchange section 101 (in this example, the indoor unit), by properly performing the cooling operation.

[Pump-down operation]

[0094] The heat pump 100 is configured to perform a pump-down operation for recovering the liquid refrigerant into the receiver 71 in a predetermined stopping time. In this context, the pump-down operation to be performed in the predetermined stopping time may be performed every time the heat pump 100 is stopped (for example, every time just before the clutch 11 is disengaged while the engine 60 is kept driving) and also when the operation of the heat pump 100 is terminated (for example, just before the engine 60 is stopped).

[0095] The pump-down operation is based on the cooling operation. In the pump-down operation, the control device 120 keeps the first changeover valve 114 open, and fully opens the first regulating valve 41. If the degree of superheat is equal to or greater than a predetermined value (a second predetermined value), the control device 120 causes the third changeover valve 117 to open and allows circulation of the refrigerant from the refrigerant-liquid-level outlet port 71c of the receiver 71 to the supercooling heat exchanger 91. If the degree of superheat is less than the predetermined value (the second predetermined value), the control device 120 causes the third changeover valve 117 to close. In this case, the degree of superheat is calculated from the saturated vapor pressure temperature based on the pressure detected by the suction pressure sensor 152 and from the temperature detected by the third suction temperature sensor 163. Further, for charging of the refrigerant in the pump-down operation, the control device 120 regulates the flow rate of the refrigerant charged (specifically, replenished) from outside by sending a command order to the regulating valve 119 for refrigerant charging. Specifically, in the pump-down operation, if the degree of superheat is equal to or greater than the predetermined value (the second predetermined value), the control device 120 regulates the flow rate of the refrigerant from the refrigerant charging port 102a to the auxiliary refrigerant evaporator 72. If the degree of superheat is less than the predetermined value (the second predetermined value), the control device 120 fully closes the regulating valve 119 for refrigerant charging. Also in this case, the degree of superheat is calculated from the saturated vapor pressure temperature based on the pressure detected by the suction pressure sensor 152 and from the temperature detected by the third suction temperature sensor 163.

(Actions in the pump-down operation)

[0096] Next, operational actions by the heat pump 100 in the pump-down operation are described with reference to Fig. 4.

[0097] Fig. 4 is a schematic block diagram of the heat pump 100, showing a pump-down operation state during the pump-down operation.

[0098] The pump-down operation is based on the cooling operation. In the pump-down operation shown in Fig. 4, the control device 120 fully opens the first regulating valve 41, fully closes the second regulating valve 42, the regulating valve 73 for the auxiliary refrigerant evaporator, the regulating valve 92 for the supercooling heat exchanger, and the regulating valve 119 for refrigerant charging, keeps the first changeover valve 114 and the third changeover valve 117 open, and keeps the second changeover valve 116 closed. In this example, a fan (not shown) provided in the utilization-side heat exchange section 101 for ventilation of the utilization-side heat exchanger 50 is stopped.

[0099] For the pump-down operation by the heat pump 100, the control device 120 switches the four-way valve 111 into the second connection state in which communication is provided between the first refrigerant path 113a and the third refrigerant path 113c and between the eighth refrigerant path 113h and the second refrigerant path 113b. Accordingly, the high-pressure gas refrigerant discharged from the compressor 10 passes the oil separator 81 in the first refrigerant path 113a, and flows through the four-way valve 111 and the third refrigerant path 113c, to the heat source-side heat exchanger 20.

[0100] As in the cooling operation, the high-pressure gas refrigerant flowing into the heat source-side heat exchanger 20 releases heat of condensation and liquefies into a high-pressure liquid refrigerant.

[0101] The high-pressure liquid refrigerant flows from the heat source-side heat exchanger 20, on the one hand, via the fourth refrigerant path 113d, the first changeover valve 114 and the check valve 115 in the eleventh refrigerant path 113k, and, at the same time, via the first regulating valve 41 in the fourth refrigerant path 113d, the first middle connection point P1, the first check valve 112a, and the outflow connection point P2 of the bridge circuit 112, then through the fifth refrigerant path 113e, to the receiver 71. Since the second regulating valve 42, the regulating valve 73 for the auxiliary refrigerant evaporator, and the regulating valve 92 for the supercooling heat exchanger in the exit path from the receiver 71 are closed, the high-pressure liquid refrigerant accumulates in the receiver 71 after the refrigerant flowing through the sixth refrigerant path 113f, the inflow connection point P4, the fourth check valve 112d, the second middle connection point P3, and the seventh refrigerant path 113g has completely flown out to the communicating pipe 110a.

[0102] From here on, the heat pump 100 repeats a series of above-described actions for the pump-down operation in a similar manner, causing a rise in the liquid refrigerant level Ra of the liquid refrigerant R accumulating in the receiver 71. When the liquid refrigerant level Ra of the liquid refrigerant R accumulating in the receiver 71 reaches the refrigerant-liquid-level outlet port 71c of the receiver 71, the liquid refrigerant R flows out of the refrigerant-liquid-level outlet port 71c, passes the third changeover valve 117 and the capillary tube 118 in the fourteenth refrigerant path 113n (see the bold broken line), then passes the inlet port 91c and the outlet port 91d of the supercooling heat exchanger 91, and flows to the downstream of the outlet port 91d in the thirteenth refrigerant path 113m (see the bold broken line). If the degree of superheat is less than the predetermined value (the second predetermined value), the control device 120 recognizes that the amount of liquid refrigerant R in the receiver 71 has reached a predetermined amount (specifically, recognizes that the liquid refrigerant level Ra of the liquid refrigerant R is at the refrigerant-liquid-level outlet port 71c of the receiver 71), closes the third changeover valve 117, and ends the pump-down operation. In this case, the degree of superheat is calculated from the saturated vapor pressure temperature based on the pressure detected by the suction pressure sensor 152 and from the temperature detected by the third suction temperature sensor 163. The upper limit of the pump-down operation time is set in advance.

[0103] As described above, the heat pump 100 can recover the liquid refrigerant R into the receiver 71 during the predetermined stopping time, by performing the pump-down operation during the predetermined stopping time.

[Refrigerant charging operation for installation of the heat pump]

[0104] For the heat pump 100, a preset required amount of refrigerant is charged in the refrigerant circuit 110. The required amount of refrigerant to be charged in the refrigerant circuit 110 may vary with the inner volume of the refrigerant circuit 110 (for example, the length and diameter of the pair of communicating pipes 110a, 110b) which depends on the installation site of the heat pump 100. In other words, for each of the refrigerant circuit 110 in the utilization-side heat exchange section 101 side and the refrigerant circuit 110 in the heat source-side heat exchange section 102 side, the rated amount of refrigerant charging is set in advance. Hence, if the inner volume (in this example, the length and diameter of the pair of communicating pipes 110a, 110b) of the other refrigerant circuit whose inner volume is indefinite is known, it is possible to charge the refrigerant without problem.

[0105] Specifically, as in the case where the heat pump 100 is newly installed, in the case where a refrigerant circuit (for example, the pair of communicating pipes 110a, 110b) whose inner volume is indefinite is also installed in addition to the utilization-side heat exchange section 101 and the heat source-side heat exchange section 102, since the inner volume (for example, the length and diameter of the pair of communicating pipes 110a, 110b) of the refrigerant circuit whose inner volume is indefinite is usually known in advance, the inner volume of the refrigerant circuit whose inner volume is indefinite (for example, the inner volume based on the length and diameter of the pair of communicating pipes 110a, 110b) can be obtained by calculation. In this manner, a required amount of refrigerant can be charged in the refrigerant circuit 110 without fail.

[0106] In contrast, when the heat pump 100 is installed while exchanging the utilization-side heat exchange section 101 and the heat source-side heat exchange section 102 while leaving the refrigerant circuit (for example, the pair of communicating pipes 110a, 110b) whose inner volume is indefinite, the inner volume (for example, the inner volume based on the length and diameter of the pair of communicating pipes 110a, 110b) of the refrigerant circuit whose inner volume is indefinite is not known in advance in many cases.

[0107] Hence, in the heat pump 100 according to the present embodiment when the inner volume (in this example, the inner volume based on the length and diameter of the pair of communicating pipes 110a, 110b) of the refrigerant circuit whose inner volume is indefinite is not known in advance, the operation of charging the refrigerant at the time of installing the heat pump 100 utilizes the pump-down operation for recovering the liquid refrigerant to the receiver 71 at the predetermined stop.

[0108] Fig. 5 is a schematic block diagram of the heat pump 100, showing a refrigerant charging state utilizing the pump-down operation, when the heat pump 100 in which the inner volume of the refrigerant circuit is unknown in advance (for example, in the case where existing pipes are used as the communicating pipes 110a, 110b) is installed.

[0109] As shown in Fig. 5, while the control device 120 adjusts the valve position of the regulating valve 119 for refrigerant charging, the refrigerant is charged from the refrigerant charging port 102a in the fifteenth refrigerant path 113o via the regulating valve 119 for refrigerant charging, at the auxiliary refrigerant evaporator 72 side than the regulating valve 73 for the auxiliary refrigerant evaporator in the ninth refrigerant path 113i (see the bold chained line). Then, if the degree of superheat is less than the predetermined value (the second predetermined value), the control device 120 recognizes that the amount of liquid refrigerant R in the receiver 71 has reached a required amount. In this case, the degree of superheat is calculated from the saturated vapor pressure temperature based on the pressure detected by the suction pressure sensor 152 and from the temperature detected by the third suction temperature sensor 163. In this heat pump 100, the required amount of refrigerant to be charged in the refrigerant circuit 110 is an amount of refrigerant when the control device 120 recognizes that the amount of liquid refrigerant R in the receiver 71 has reached the required amount. On recognizing that the amount of liquid refrigerant R in the receiver 71 has reached the required amount, the control device 120 fully closes the regulating valve 119 for refrigerant charging, and/or, closes the third changeover valve 117.

<Detection of refrigerant leakage>

[0110] As mentioned earlier, measures for monitoring refrigerant leakage from the heat pump have become stricter, and there is a greater request than ever before for timely determination of the occurrence or non-occurrence of refrigerant leakage.

[0111] From this point of view, the heat pump 100 according to the present embodiments is configured such that the control device 120 detects the amount of liquid refrigerant R in the receiver 71 in the pump-down operation (in this example, every time the pump-down operation is performed) and thereby determines the occurrence or non-occurrence of refrigerant leakage. Specific embodiments for determining the occurrence or non-occurrence of refrigerant leakage are described by way of the first embodiment and the second embodiment given below.

(First embodiment)

[0112] The heat pump 100 may be provided with an additional detection member such as a liquid level sensor for detecting the liquid refrigerant level Ra of the liquid refrigerant R in the receiver 71. Instead, the first embodiment utilizes the refrigerant paths from a predetermined position in the receiver 71 (in this example, the refrigerant-liquid-level outlet port 71c) to the suction side of the compressor 10 (in this example, the refrigerant paths including the fourteenth refrigerant path 113n, the refrigerant passage on the supercooling heat exchanger 91 side than the connection point with the fourteenth refrigerant path 113n in the thirteenth refrigerant path 113m, and the refrigerant passage on the compressor 10 side than the connection point with the thirteenth refrigerant path 113m in the combined path 113b1). If the degree of superheat of the refrigerant in these refrigerant paths (in this example, the degree of superheat is calculated from the saturated vapor pressure temperature based on the pressure detected by the suction pressure sensor 152 and from the temperature detected by the third suction temperature sensor 163) remains to be equal to or greater than the predetermined value (the second predetermined value) after a first predetermined time, the control device 120 determines that refrigerant leakage has occurred (namely, determines that the amount of refrigerant is less than the required charging amount).

[0113] To be more specific, in this pump-down operation, if the degree of superheat which was previously equal to or greater than the predetermined value (the second predetermined value) has become less than the predetermined value (the second predetermined value) within the first predetermined time, the control device 120 recognizes that the amount of liquid refrigerant R in the receiver 71 is sufficient and determines that refrigerant leakage has not occurred. In this case, the degree of superheat is calculated from the saturated vapor pressure temperature based on the pressure detected by the suction pressure sensor 152 and from the temperature detected by the third suction temperature sensor 163. On the other hand, if the degree of superheat remains to be equal to or greater than the predetermined value (the second predetermined value) for the first predetermined time or longer, the control device 120 recognizes that the amount of liquid refrigerant R in the receiver 71 is insufficient, and determines that refrigerant leakage has occurred. The occurrence or non-occurrence of refrigerant leakage is determined within a predetermined detection time which is shorter than the pump-down operation time.

(Control actions in the first embodiment)

[0114] Regarding the first embodiment, an example of control actions by the control device 120 in the heat pump 100 is now described with reference to Fig. 6.

[0115] Fig. 6 is a flowchart describing an example of control actions in the first embodiment by the control device 120 in the heat pump 100.

[0116] In a series of processing actions shown in Fig. 6, the control device 120 starts the pump-down operation (Step S10), and calculates the degree of superheat from the saturated vapor pressure temperature based on the pressure detected by the suction pressure sensor 152 and from the temperature detected by the third suction temperature sensor 163 (Step S20).

[0117] Next, the control device 120 judges whether the calculated degree of superheat is equal to or greater than the predetermined value, or not (Step S30). If the degree of superheat is less than the predetermined value (No in Step S30), the control device 120 determines that refrigerant leakage has not occurred (Step S40), and ends the process. If the degree of superheat is equal to or greater than the predetermined value (Yes in Step S30), the control device 120 measures a timer time by a timer function (Step S50), and the process goes to Step S60.

[0118] Then, the control device 120 judges whether the measured timer time is equal to or longer than the first predetermined time (Step S60). If the measured timer time is shorter than the first predetermined time (No in Step S60), the process goes to Step S20. If the measured timer time is equal to or longer than the first predetermined time (Yes in Step S60), the control device 120 determines that refrigerant leakage has occurred (Step S70), and ends the process.

(Second embodiment)

[0119] In the first embodiment, the supercooling heat exchanger 91 is provided in the refrigerant paths (in this example, in the thirteenth refrigerant path 113m) from the predetermined position in the receiver 71 (in this example, the refrigerant-liquid-level outlet port 71c) to the suction side of the compressor 10. In this arrangement, prior to the pump-down operation, a refrigerant whose degree of superheat is less than the predetermined value (the second predetermined value) (for example, the liquid refrigerant or the gas-liquid two-phase refrigerant) may remain in the supercooling heat exchanger 91 and also in the refrigerant paths on the compressor 10 side than the supercooling heat exchanger 91 (in this example, in the refrigerant path on the twelfth refrigerant path 113l side than the supercooling heat exchanger 91 in the thirteenth refrigerant path 113m). Since the degree of superheat of the refrigerant remaining in the refrigerant paths is less than the predetermined value (the second predetermined value), if the occurrence or non-occurrence of refrigerant leakage is determined immediately after the start of the pump-down operation, the control device 120 may misjudge that refrigerant leakage has not occurred, against the fact that refrigerant leakage has occurred.

[0120] Therefore, in the case where the supercooling heat exchanger 91 is provided in the refrigerant paths from the predetermined position in the receiver 71 to the suction side of the compressor 10, as in the first embodiment, the control device 120 in the second embodiment is configured to determine the occurrence or non-occurrence of refrigerant leakage after a second predetermined time has passed since the pump-down operation started. In other words, in the second embodiment, the control device 120 determines the occurrence of refrigerant leakage, if the degree of superheat of the refrigerant in the refrigerant paths from the predetermined position in the receiver 71 to the suction side of the compressor 10, detected after the second predetermined time has passed since the start of the pump-down operation, is equal to or greater than the predetermined value (the second predetermined value). In this embodiment, the second predetermined time can be set to be equal to or longer than a period of time during which it is assumed that all of the refrigerant (for example, the liquid refrigerant or the gas-liquid two-phase refrigerant) staying in the refrigerant path, the degree of superheat of which is smaller than the predetermined value (the second predetermined value) flows.

(Control actions in the second embodiment)

[0121] Regarding the second embodiment, an example of control actions by the control device 120 in the heat pump 100 is now described with reference to Fig. 7.

[0122] Fig. 7 is a flowchart describing an example of control actions in the second embodiment by the control device 120 in the heat pump 100. The exemplary control actions shown in Fig. 7 are similar to those in Fig. 6, except for additional Steps S11, S12 between Step S10 and Step S20.

[0123] In Fig. 7, the same processing actions as those mentioned in the flowchart of Fig. 6 for the first embodiment are mentioned by the same signs, and the following description is focused on the difference from the first embodiment.

[0124] After the start of the pump-down operation (Step S10), the control device 120 measures the timer time by the timer function (Step S11), and the process goes to Step S12.

[0125] Next, the control device 120 judges whether the measured timer time has reached the second predetermined time (Step S12). If the measured timer time has not reached the second predetermined time (No in Step S12), the process goes back to Step S11, and the control device 120 waits until the second predetermined time has passed. If the measured timer time has reached the second predetermined time (Yes in Step S12), the process goes to Step S20.

(The present embodiments)

[0126] As described above, the present embodiments detect the amount of liquid refrigerant R in the receiver 71 in the pump-down operation in which the liquid refrigerant R is recovered into the receiver 71 during the predetermined stopping time (in this example, every time the pump-down operation is performed), and thereby determine the occurrence or non-occurrence of refrigerant leakage. Therefore, it is possible to determine the occurrence or non-occurrence of refrigerant timely.

[0127] The first embodiment determines that refrigerant leakage has occurred if the degree of superheat of the refrigerant in the refrigerant paths from the predetermined position in the receiver 71 to the suction side of the compressor 10 (in this example, the degree of superheat is calculated from the saturated vapor pressure temperature based on the pressure detected by the suction pressure sensor 152 and from the temperature detected by the third suction temperature sensor 163 provided in the refrigerant path on the compressor 10 side than the connection point with the thirteenth refrigerant path 113m in the combined path 113b1) remains to be equal to or greater than the predetermined value (the second predetermined value) after the first predetermined time has passed. Accordingly, the first embodiment can determine the occurrence or non-occurrence of refrigerant leakage by judging whether the amount of liquid refrigerant R in the receiver 71, as initially charged, is maintained in the required amount. This can also improve the precision in determining the occurrence or non-occurrence of refrigerant leakage. Besides, this embodiment can reduce the cost by utilizing the existing pressure sensor and the existing temperature sensor, without requiring an additional detection member such as a liquid level sensor.

[0128] In the case where the supercooling heat exchanger 91 is provided in the refrigerant paths from the predetermined position in the receiver 71 to the suction side of the compressor 10, as in the first embodiment, the second embodiment determines the occurrence or non-occurrence of refrigerant leakage after the second predetermined time has passed since the pump-down operation started. Even if the refrigerant whose degree of superheat is less than the predetermined value (the second predetermined value) (for example, the liquid refrigerant or the gas-liquid two-phase refrigerant) remains in the supercooling heat exchanger 91 and also in the refrigerant paths on the compressor 10 side than the supercooling heat exchanger 91, the second embodiment can wait until the remaining refrigerant (for example, the liquid refrigerant or the gas-liquid two-phase refrigerant) flows out completely, and can determine the occurrence or non-occurrence of refrigerant leakage thereafter. This can improve the precision in determining the occurrence or non-occurrence of refrigerant leakage.

[0129] The present invention can be embodied and practiced in other different forms without being limited to the above-described embodiments. Therefore, such embodiments are considered in all respects as illustrative and not restrictive. The scope of the invention is indicated by the appended claims rather than by the foregoing description. All variations and modifications falling within the equivalency range of the appended claims are intended to be embraced therein.

[0130] The present application claims priority to Japanese Patent Application No. 2015-014140, filed January 28, 2015. The contents of this application are incorporated herein by reference in its entirety.

[Industrial Applicability]

[0131] The present invention relates to a heat pump, and is particularly applicable to use for timely determination of the occurrence or non-occurrence of refrigerant leakage.

[Reference Signs List]

[0132]

10	compressor
11	clutch
20	heat source-side heat exchanger
30	heat source-side heat exchanger fan
40	regulating valves (an example of expansion valves)
41	first regulating valve
42	second regulating valve
50	utilization-side heat exchanger
51	refrigerant path
60	engine
71	receiver
71a	refrigerant inlet port
71b	refrigerant outlet port
71c	refrigerant-liquid-level outlet port
72	auxiliary refrigerant evaporator
73	regulating valve for the auxiliary refrigerant evaporator
81	oil separator
82	accumulator
91	supercooling heat exchanger
92	regulating valve for the supercooling heat exchanger
100	heat pump
101	utilization-side heat exchange section
102	heat source-side heat exchange section
102a	refrigerant charging port
110	refrigerant circuit
110a	first communicating pipe
110b	second communicating pipe
111	four-way valve
112	bridge circuit
113a	first refrigerant path
113b	second refrigerant path
113b1	combined path
113c	third refrigerant path
113d	fourth refrigerant path
113e	fifth refrigerant path
113f	sixth refrigerant path
113g	seventh refrigerant path
113h	eighth refrigerant path
113i	ninth refrigerant path
113j	tenth refrigerant path
113k	eleventh refrigerant path
113l	twelfth refrigerant path
113m	thirteenth refrigerant path
113n	fourteenth refrigerant path
113o	fifteenth refrigerant path
114	first changeover valve
115	check valve
116	second changeover valve
117	third changeover valve
118	capillary tube
119	regulating valve for refrigerant charging
120	control device
121	processor unit
122	memory unit
151	discharge pressure sensor

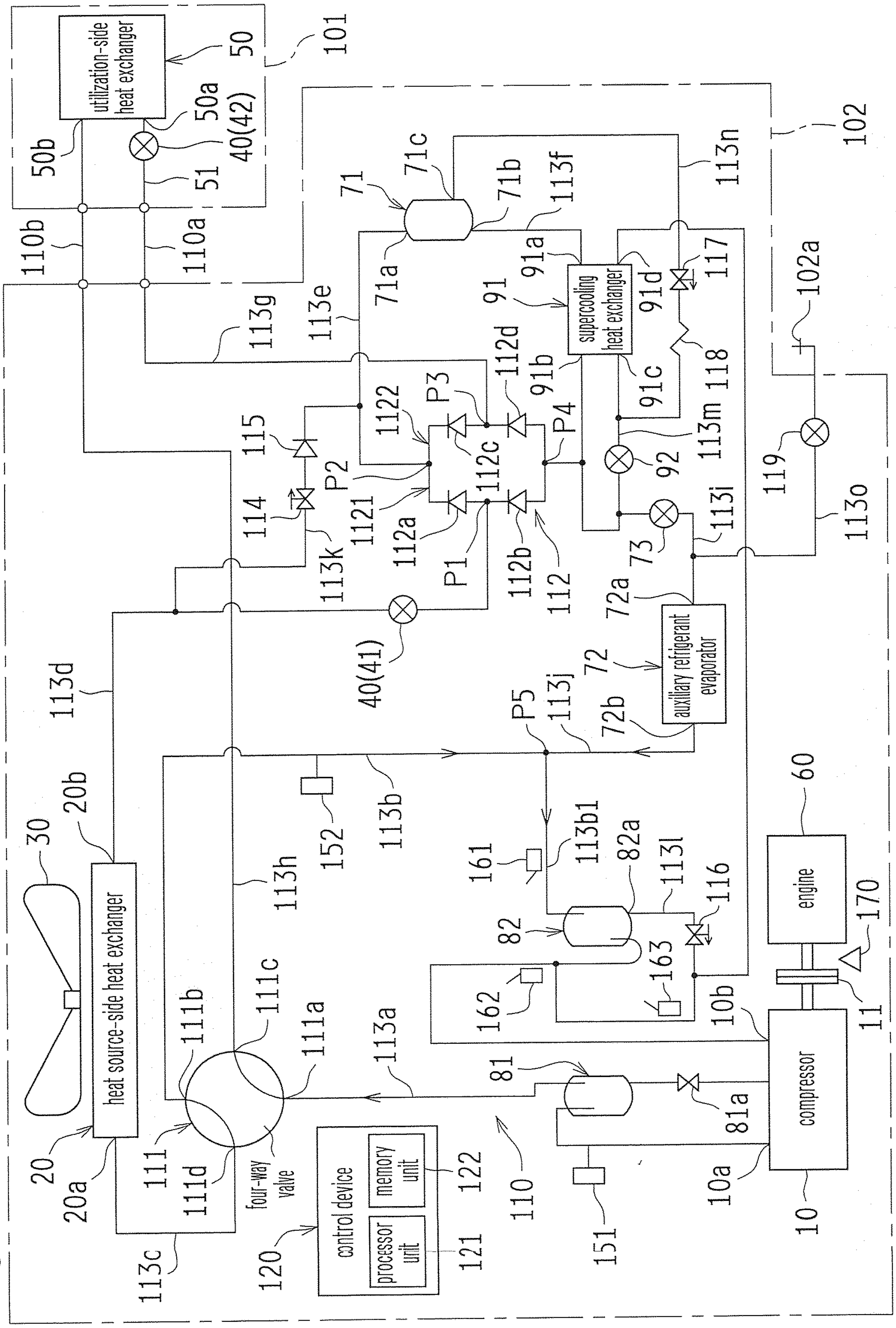
152	suction pressure sensor
161	first suction temperature sensor
162	second suction temperature sensor
163	third suction temperature sensor
170	engine speed sensor
R	liquid refrigerant
Ra	liquid refrigerant level

Claims

1. A heat pump comprising a compressor, a heat source-side heat exchanger, a receiver, at least one expansion valve, and a utilization-side heat exchanger, and being configured to perform a pump-down operation for recovering a liquid refrigerant into the receiver during a predetermined stopping time, wherein the heat pump is configured to determine whether refrigerant leakage has occurred or not, by detecting an amount of the liquid refrigerant in the receiver in the pump-down operation.

2. A heat pump according to claim 1,
wherein at least one refrigerant path is provided from a predetermined position in the receiver to a suction side of the compressor, and
the heat pump is configured to determine that refrigerant leakage has occurred when a degree of superheat of a refrigerant in the refrigerant path is equal to or greater than a predetermined value after a first predetermined time has passed.

3. A heat pump according to claim 2,
wherein a supercooling heat exchanger is provided in the refrigerant path from the predetermined position in the receiver to a suction side of the compressor, and
the heat pump is configured to determine whether refrigerant leakage has occurred or not, after a second predetermined time has passed since the pump-down operation started.


100
101
102
102a
utilization-side heat exchanger
50
50a
50b
40(42)
51
110a
110b
113g
113e
71
71a
71b
71c
113f
113n
91
91a
91b
91c
91d
supercooling heat exchanger
117
118
113m
92
112
112a
112b
112c
112d
1121
1122
P1
P2
P3
P4
P5
115
114
113k
73
113i
119
113o
72
72a
72b
auxiliary refrigerant evaporator
113j
40(41)
113d
113b
113b1
152
161
82
82a
113l
116
162
163
60
engine
170
11
10b
30
20
20a
20b
heat source-side heat exchanger
113h
111
111a
111b
111c
111d
four-way valve
113a
81
81a
compressor
10
10a
151
110
control device
processor unit
memory unit
120
121
122
113c
Fig.1

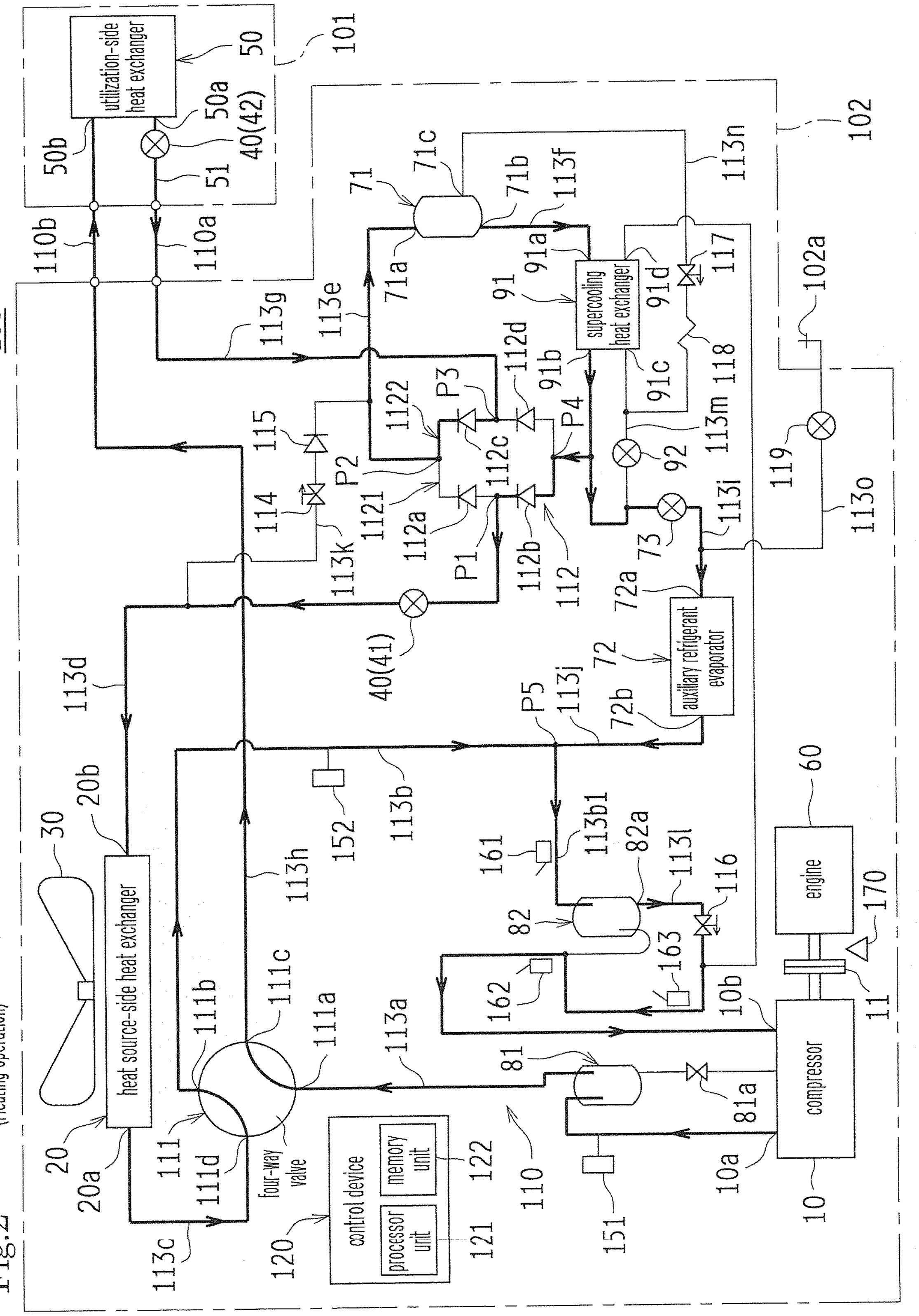

(Heating operation)
heat source-side heat exchanger
four-way valve
control device
processor unit
memory unit
utilization-side heat exchanger
supercooling heat exchanger
auxiliary refrigerant evaporator
compressor
engine

Fig.2

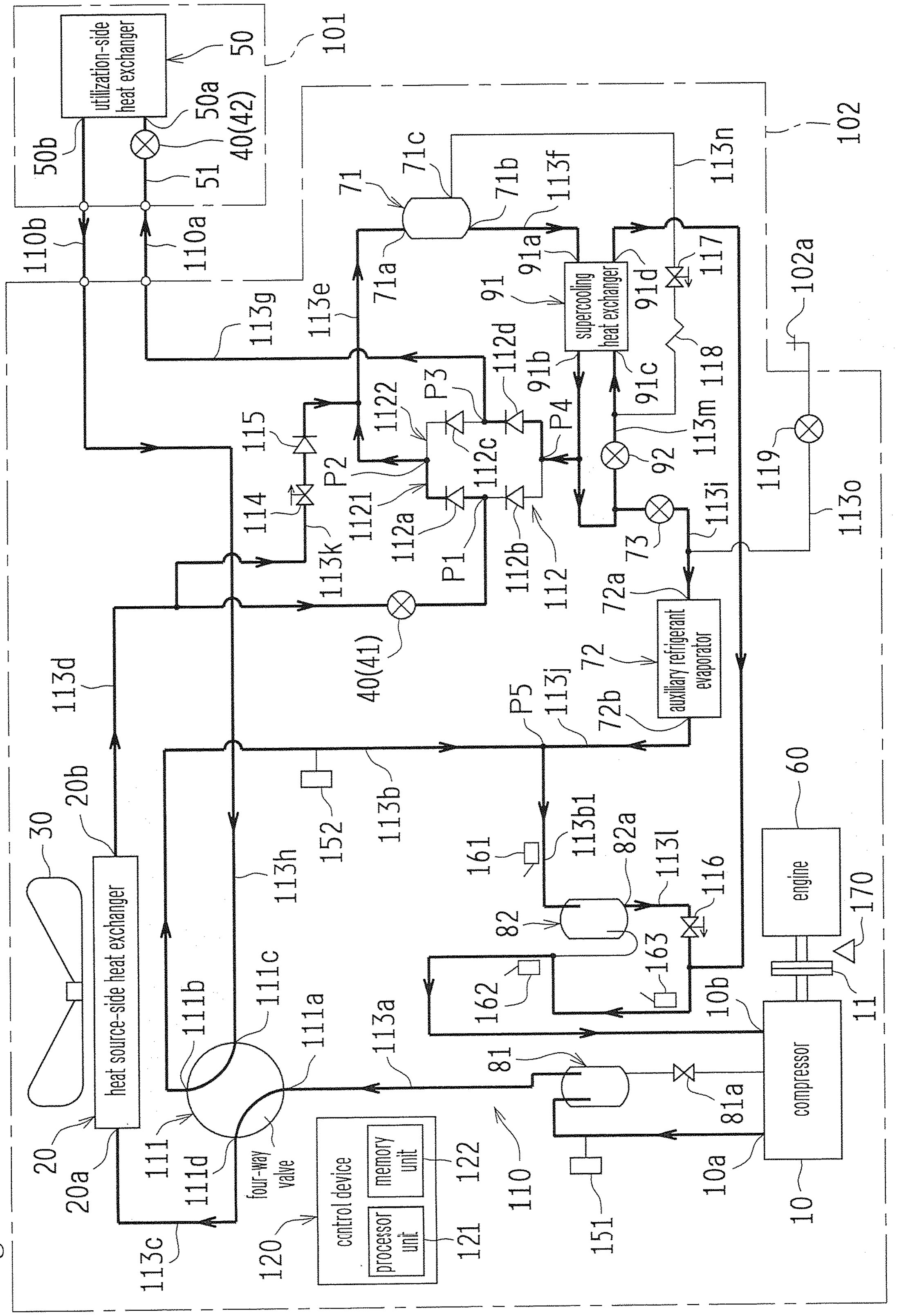

(Cooling operation)
utilization-side heat exchanger
heat source-side heat exchanger
supercooling heat exchanger
auxiliary refrigerant evaporator
four-way valve
control device
processor unit
memory unit
compressor
engine
100
101
102
102a
50
50a
50b
51
40(42)
40(41)
110
110a
110b
111
111a
111b
111c
111d
112
112a
112b
112c
112d
1121
1122
113a
113b
113b1
113c
113d
113e
113f
113g
113h
113i
113j
113k
113l
113m
113n
113o
114
115
116
117
118
119
120
121
122
151
152
161
162
163
170
10
10a
10b
11
20
20a
20b
30
60
71
71a
71b
71c
72
72a
72b
73
81
81a
82
82a
91
91a
91b
91c
91d
92
P1
P2
P3
P4
P5

Fig.3

Fig.4

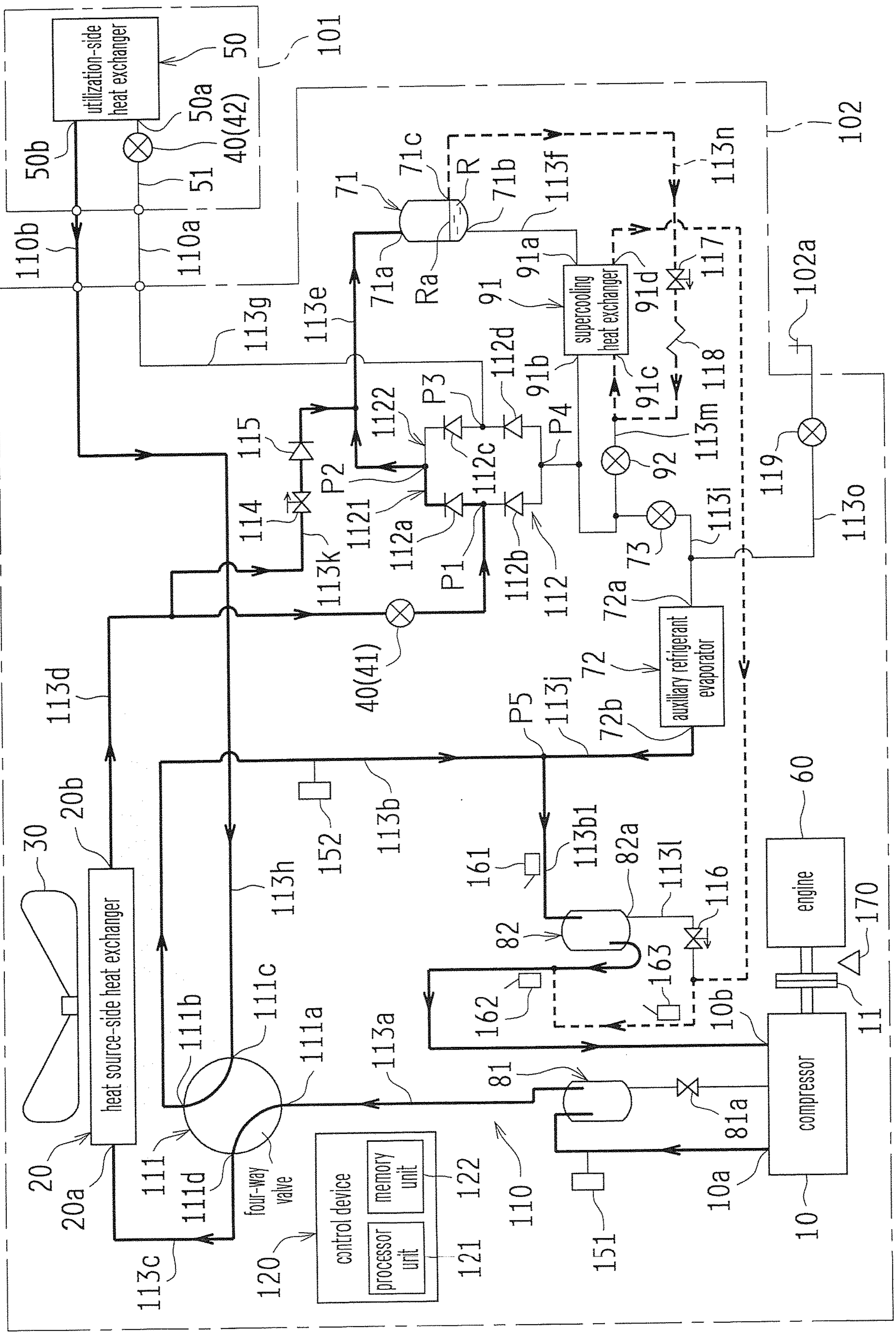

(Pump-down operation)
heat source-side heat exchanger
utilization-side heat exchanger
supercooling heat exchanger
auxiliary refrigerant evaporator
four-way valve
control device
processor unit
memory unit
compressor
engine
100
101
102
102a
110
110a
110b
111
111a
111b
111c
111d
112
112a
112b
112c
112d
1121
1122
113a
113b
113b1
113c
113d
113e
113f
113g
113h
113i
113j
113k
113l
113m
113n
113o
114
115
116
117
118
119
120
121
122
10
10a
10b
11
20
20a
20b
30
40(41)
40(42)
50
50a
50b
51
60
71
71a
71b
71c
72
72a
72b
73
81
81a
82
82a
91
91a
91b
91c
91d
92
151
152
161
162
163
170
P1
P2
P3
P4
P5
R
Ra

Fig.5

(Pump-down operation: for refrigerant charging)

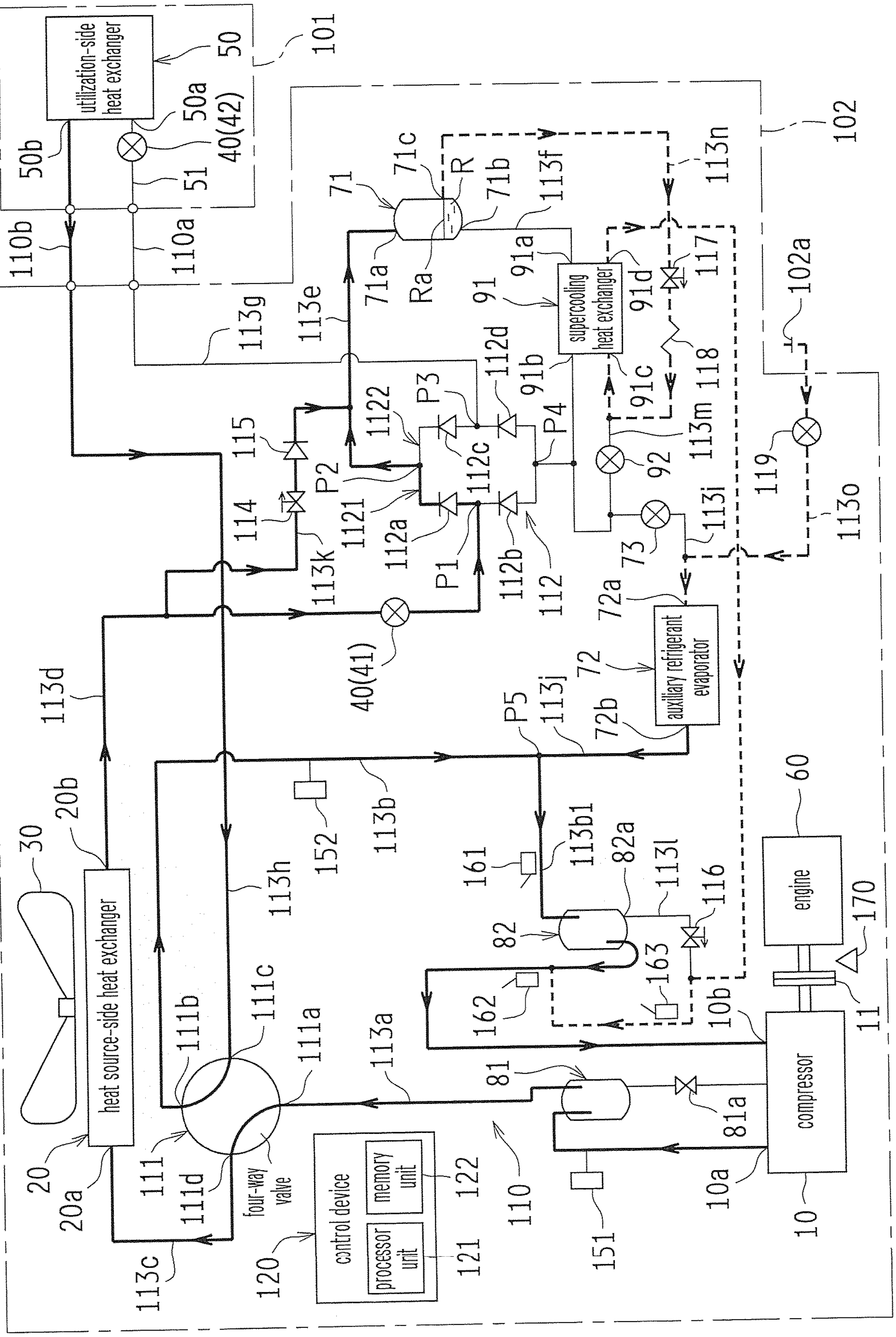


Fig.6

(First embodiment)

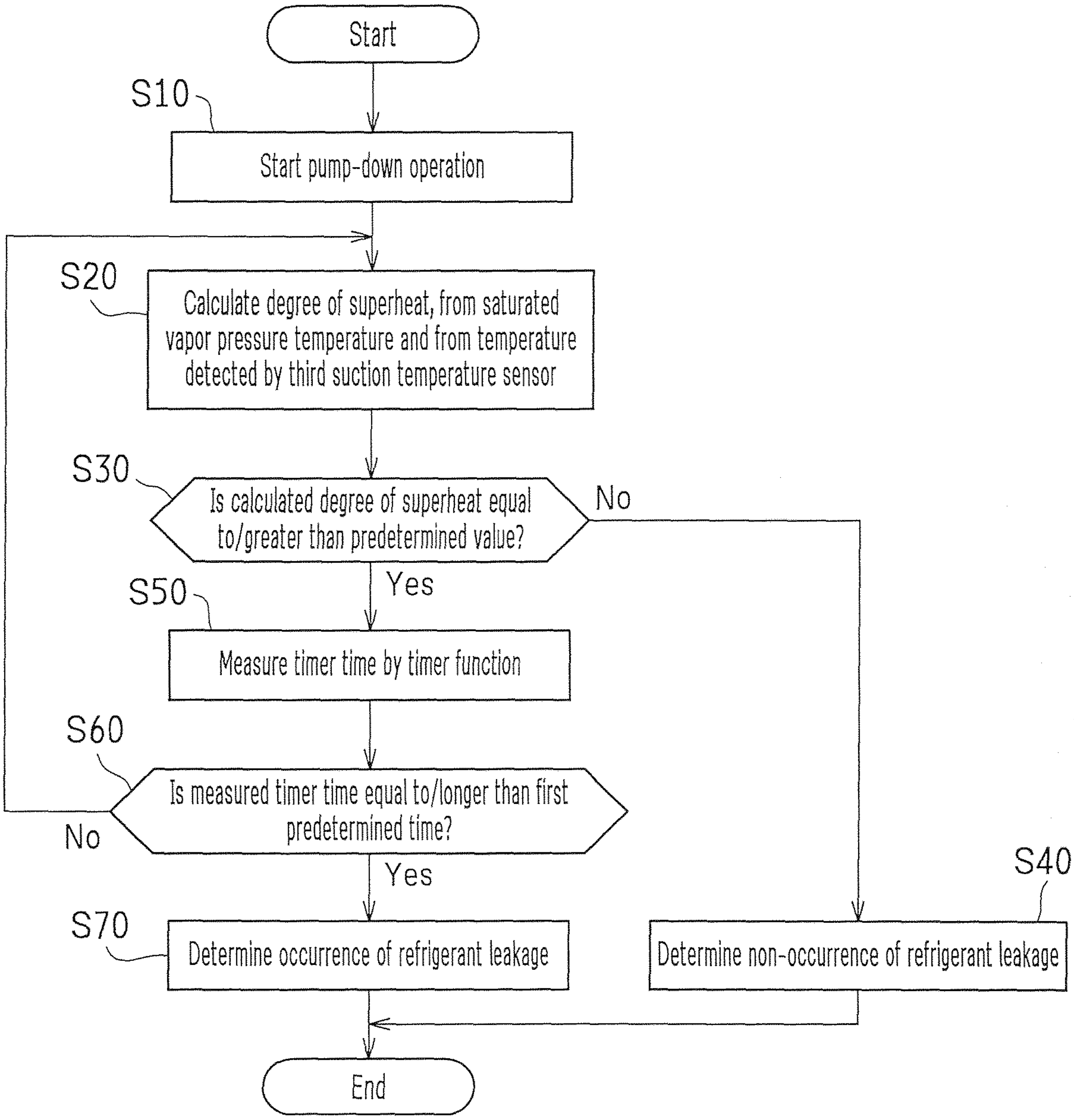
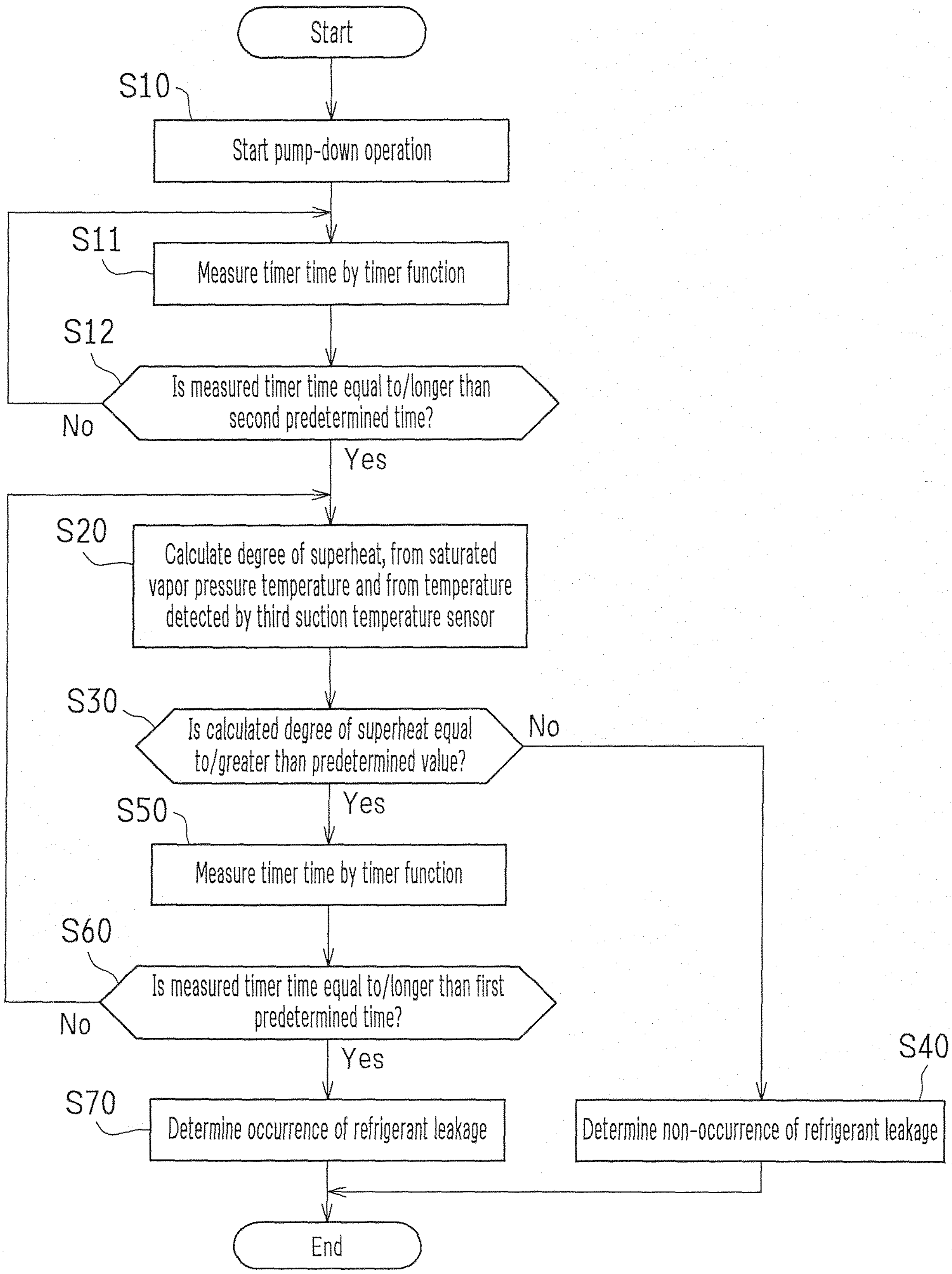


Fig.7

(Second embodiment)



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2016/052069

A. CLASSIFICATION OF SUBJECT MATTER
F25B49/02(2006.01)i, *F25B1/00*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F25B49/02, F25B1/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2014-95514 A (Panasonic Corp.), 22 May 2014 (22.05.2014), paragraphs [0024] to [0029], [0041] to [0057]; fig. 1 (Family: none)	1 2-3
Y	JP 2004-218865 A (Daikin Industries, Ltd.), 05 August 2004 (05.08.2004), paragraphs [0029] to [0030], [0035] to [0042]; fig. 1 to 4 & US 2005/0252221 A1 & US 2008/0134700 A1 paragraphs [0054] to [0056], [0065] to [0076]; fig. 1 to 4 & WO 2004/063644 A1 & EP 1582827 A1 & DE 60322589 D & CN 1692263 A & KR 10-0591419 B1 & AT 403124 T & ES 2311746 T & AU 2003289499 A	2-3

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Date of the actual completion of the international search
05 April 2016 (05.04.16)

Date of mailing of the international search report
19 April 2016 (19.04.16)

Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2002-286333 A (Mitsubishi Electric Corp.), 03 October 2002 (03.10.2002), paragraphs [0016] to [0024]; fig. 1 to 4 (Family: none)	1-2 3
A	JP 2012-117735 A (Sanyo Electric Co., Ltd.), 21 June 2012 (21.06.2012), paragraphs [0053] to [0057], [0069] to [0120]; fig. 1 (Family: none)	1-3
A	JP 2010-190545 A (Sanyo Electric Co., Ltd.), 02 September 2010 (02.09.2010), paragraphs [0034] to [0035]; fig. 2 to 3 (Family: none)	1-3
A	JP 2005-282885 A (Mitsubishi Heavy Industries, Ltd.), 13 October 2005 (13.10.2005), paragraphs [0094] to [0108]; fig. 4 (Family: none)	2-3
A	JP 2007-93141 A (Sanyo Electric Co., Ltd.), 12 April 2007 (12.04.2007), paragraphs [0017] to [0034]; fig. 1, 3 (Family: none)	2-3

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Patent documents cited in the description

- JP 2013250038 A **[0006]**
- JP 6137725 A **[0006]**
- JP 2015014140 A **[0130]**