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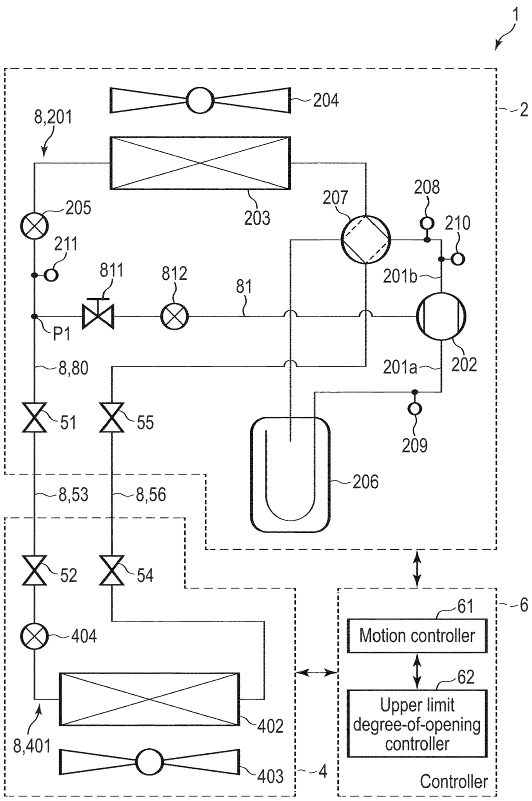
(54) **REFRIGERATION CYCLE DEVICE**

(57) According to one embodiment, a refrigeration cycle device (1, 11) includes a compressor (202), a condenser (203, 402), an evaporator (203, 402), a main flow path (8), a first branch path (81), a first expansion valve (812), a discharge temperature detector (208), a suction pressure detector (209), a discharge pressure detector (210), and a controller (6). The first branch path (81) diverts part of the refrigerant flowing from the condenser (203, 402) to the evaporator (203, 402) from the main flow path (8) at a position downstream from the condenser (203, 402) and guides the diverted refrigerant to the compressor (202). The first expansion valve (812) is controlled a degree of opening between a lower limit degree of opening and an upper limit degree of opening, and regulates a flow rate of the refrigerant flowing through the first branch path (81) according to the degree of opening. The controller (6) sets the upper limit degree of opening of the first expansion valve on the basis of at least one of a suction pressure detected by the suction pressure detector (209) and a discharge pressure detected by the discharge pressure detector (210) and a rotational speed of the compressor (202). The controller (6) corrects the set upper limit degree of opening of the first expansion valve on the basis of the discharge temperature detected by the discharge temperature detector (208).



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Description

FIELD

[0001] Embodiments described herein relate generally to a refrigeration cycle device.

BACKGROUND

[0002] A refrigeration cycle capable of liquid injection is widely used in, for example, refrigerating devices to be firstly named, water heaters, air-conditioning devices of cold-districts specifications and the like in which R32 is used as the refrigerant. In a refrigeration cycle such as a variable refrigerant flow (VRF) or the like, the load variation is great, refrigerant is retained inside the indoor unit, accumulator and the like, and operation characteristics, particularly, liquid pipe pressure (pressure of the refrigerant flowing through the liquid pipe) largely varies. When a refrigerant R32 is used in such a refrigeration cycle described above, the liquid pipe pressure largely varies due to operations and shutdowns of a plurality of indoor units, and hence excessive injection or insufficient injection into the compressor is liable to occur.

[0003] When the injection is insufficient, by lowering the compression ratio by means of, for example, frequency constraint or the like of the compressor, it is possible to lower the discharge temperature of the refrigerant, stabilize the refrigeration cycle, and make the compressor continue to appropriately operate. Conversely, when the injection is excessively carried out, depending on the degree of the excessive injection, there is a possibility of dilution of the refrigeration machine oil, stoppage of the compressor and liquid compression or the like both resulting from an abrupt load change being caused.

[0004] The present invention has been contrived on the basis of the aforementioned circumstances and an object thereof is to provide a refrigeration cycle device capable of appropriately stabilizing a refrigeration cycle in which liquid injection is executed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005]

FIG. 1 is a circuit diagram schematically showing a refrigeration cycle of a refrigeration cycle device (air-conditioning device) according to a first embodiment.

FIG. 2 is a view showing an effect of cooling control of a compressor based on injection in the refrigeration cycle device (air-conditioning device) according to the first embodiment by means of an example of time transition of the refrigerant discharge temperature and degree of opening of an expansion valve.

FIG. 3 is a view showing an example of time transition of the refrigerant discharge temperature and degree of opening of an expansion valve in a case where the liquid pipe pressure lowers in a comparative example in which upper limit degree-of-opening control of the expansion valve is not executed.

FIG. 4 is a view showing an example of time transition of the refrigerant discharge temperature and degree of opening of an expansion valve in a case where the liquid pipe pressure lowers in the first embodiment in which upper limit degree-of-opening control of the expansion valve is executed.

FIG. 5 is a circuit diagram schematically showing a refrigeration cycle of a refrigeration cycle device (air-conditioning device) according to a second embodiment.

DETAILED DESCRIPTION

[0006] In general, a refrigeration cycle device comprises a compressor, a condenser, an evaporator, a main flow path, a first branch path, a first expansion valve, a discharge temperature detector, a suction pressure detector, a discharge pressure detector, and a controller. The compressor sucks a refrigerant from a suction pipe, compresses the sucked refrigerant, and discharges the compressed refrigerant into a discharge pipe. The condenser condenses the refrigerant. The evaporator evaporates the refrigerant. The main flow path includes the suction pipe and the discharge pipe, and through which the refrigerant circulates by way of the compressor, the condenser, and the evaporator. The first branch path diverts part of the refrigerant flowing from the condenser to the evaporator from the main flow path at a position downstream from the condenser and guides the diverted refrigerant to the compressor. The first expansion valve is controlled a degree of opening between a lower limit degree of opening and an upper limit degree of opening, regulates a flow rate of the refrigerant flowing through the first branch path according to the degree of opening. The discharge temperature detector detects a discharge temperature of the refrigerant discharged from the compressor into the discharge pipe. The suction pressure detector detects a suction pressure of the refrigerant sucked from the suction pipe into the compressor. The discharge pressure detector detects a discharge pressure of the refrigerant discharged from the compressor into the discharge pipe. The controller controls operations of the compressor, the first expansion valve, the discharge temperature detector, the suction pressure detector, and the discharge pressure detector. The controller sets the upper limit degree of opening of the first expansion valve on the basis of at least one of the suction pressure detected by the suction pressure detector and the discharge pressure detected by the discharge pressure detector and a rotational speed of the compressor. The controller corrects the set upper limit degree of opening of the first expansion valve on the basis of the discharge temperature detected by the discharge temperature detector.

[0007] Embodiments of the present invention will be described hereinafter with reference to the accompanying drawings.

(First Embodiment)

[0008] FIG. 1 is a circuit diagram schematically showing a refrigeration cycle of a refrigeration cycle device 1 according to this embodiment. The refrigeration cycle device 1 is capable of operating in each of a cooling mode, heating mode or in both the modes and is applicable to various purposes. In FIG. 1, a circuit diagram of an air-conditioning device (hereinafter referred to as the air-conditioning device 1) is shown as an example of the refrigeration cycle device 1. Besides, the refrigeration cycle device 1 is applicable as, for example, a water-cooled heat source device, air-cooled heat-pump chilling unit, condensing unit, and the like.

[0009] As shown in FIG. 1, the air-conditioning device 1 includes an outdoor unit 2 and indoor unit 4 connected to each other by a flow path (hereinafter referred to as a main flow path) 8 through which a refrigerant circulates, and controller 6 configured to control the operations of the outdoor unit 2 and indoor unit 4. In FIG. 1, a configuration example including one outdoor unit 2 and one indoor unit 4 is shown. Irrespective of the example shown in FIG. 1, the air-conditioning device 1 may include a plurality of indoor units 4. The main flow path 8 is configured by connecting a plurality of piping members to each other. These piping members include piping (hereinafter referred to as the outdoor side piping) 201 constituting the flow path on the outdoor unit 2 side and piping (hereinafter referred to as the indoor side piping) 401 constituting the flow path of the indoor unit 4. The outdoor side piping 201 and indoor side piping 401 are coupled to each other by means of a connection liquid pipe 53 through couplings 51 and 52 and, at the same time, are coupled to each other by means of a connection gas pipe 56 through couplings 54 and 55. The couplings 51, 52, 54, and 55 are, for example, packed valves. Each of the connection liquid pipe 53 and connection gas pipe 56 constitutes a part of the main flow path 8.

[0010] The outdoor unit 2 includes, as main constituents, a compressor 202, outdoor heat exchanger 203, outdoor air blower 204, outdoor expansion valve 205, accumulator 206, four-way valve 207, discharge temperature detector 208, suction pressure detector 209, discharge pressure detector 210, refrigerant pressure detector 211, and the like. In addition to these, the outdoor unit 2 may include, for example, an oil separator and the like.

[0011] The compressor 202 sucks the refrigerant from a suction pipe 201a, compresses the sucked refrigerant, and discharges the compressed refrigerant into a discharge pipe 201b. The compressor 202 is configured to include, for example, a compression mechanism, housing (well-closed container) accommodating therein the aforementioned compression mechanism and retaining therein a refrigeration machine oil configured to lubricate the compression mechanism, rotating shaft, motor-driven mechanism, and the like. The compressor 202 provides a value of the rotational speed at the time of an operation thereof to the controller 6 by wire or wirelessly. Each of the suction pipe 201a and discharge pipe 201b is included in the main flow path 8 and constitutes a part of the outdoor side piping 201. The suction pipe 201a is connected to the accumulator 206 at one end thereof and is connected to a suction port of the compressor 202 at the other end thereof. The discharge pipe 201b is connected to a discharge port of the compressor 202 at one end thereof and is connected to the four-way valve 207 at the other end thereof. The four-way valve 207 guides the refrigerant discharged from the compressor 202 to a condenser and guides the refrigerant evaporated by an evaporator to the accumulator 206.

[0012] The outdoor heat exchanger 203 carries out heat exchange between the outdoor air and refrigerant. The outdoor heat exchanger 203 functions as a condenser configured to condense the refrigerant when the air-conditioning device 1 carries out a cooling operation, and functions as an evaporator configured to evaporate the refrigerant when the air-conditioning device 1 carries out a heating operation. At the time of, for example, a cooling operation, the refrigerant flows through the compressor 202, four-way valve 207, outdoor heat exchanger 203, outdoor expansion valve 205, and indoor unit 4 in the order mentioned, whereby the space of the air-conditioning object is cooled. On the other hand, at the time of a heating operation, the refrigerant flows through compressor 202, four-way valve 207, indoor unit 4, outdoor expansion valve 205, and outdoor heat exchanger 203 in the order mentioned, whereby the space of the air-conditioning object is heated. In the four-way valve 207, port switching is appropriately carried out in such a manner that the refrigerant flows through the main flow path 8 (outdoor side piping 201, indoor side piping 401, connection liquid pipe 53, and connection gas pipe 56) as described above at the time of a cooling operation and at the time of a heating operation. It should be noted that the outdoor heat exchanger 203 may have, for example, a block construction divided into a plurality of blocks so that the flow of the refrigerant may include a plurality of lines. In that case, it is also possible to appropriately add and arrange four-way valves.

[0013] The outdoor air blower 204 is arranged in the vicinity of the outdoor heat exchanger 203, sucks the air on the outside of the room (hereinafter referred to as the outdoor air), and blows the air subjected to heat exchange in the outdoor heat exchanger 203 out of the room. The outdoor air sucked in by the outdoor air blower 204 is blown onto the outdoor heat exchanger 203. Thereby, heat exchange is carried out between the aforementioned outdoor air and refrigerant flowing through the outdoor heat exchanger 203 and the refrigerant is condensed or is evaporated.

[0014] The outdoor expansion valve 205 decompresses the refrigerant (high-pressure liquid-phase refrigerant) flowing out of, for example, the outdoor heat exchanger 203 according to the degree of opening thereof to thereby change the refrigerant into a low-pressure gas-liquid two-phase refrigerant or liquid-phase refrigerant. The outdoor expansion valve 205 has a valve structure in which a narrowing-down amount of the refrigerant is adjusted by controlling the degree of opening of the valve between, for example, the lower limit degree of opening and upper limit degree of opening and is configured as a pulse motor valve (PMV) in which the degree of opening is continuously changed according to the number of supplied drive pulses. The outdoor expansion valve 205 is subjected to degree-of-opening adjustment by the controller 6 and provides a value of the current degree of opening (actual degree of opening) to the controller 6 by wire or wirelessly.

[0015] The accumulator 206 subjects the refrigerant evaporated by the evaporator to gas-liquid separation. The refrigerant which has been subjected to gas-liquid separation by the accumulator 206 is supplied to the compressor 202. Thereby, the compressor 202 is restrained from compressing a liquid-phase refrigerant. The evaporator is the outdoor heat exchanger 203 at the time of the heating operation and is the indoor heat exchanger 402 to be described later at the time of the cooling operation.

[0016] The discharge temperature detector 208 detects the temperature (hereinafter referred to as the discharge temperature) of the refrigerant discharged from the compressor 202, i.e., the discharge temperature of the high-temperature/high-pressure gas-phase refrigerant flowing through the discharge pipe 201b. The discharge temperature detector 208 is, for example, a temperature sensor (thermistor) or the like a temperature-sensitive element of which is arranged inside the housing (well-closed container) or inside the piping or the like of the discharge pipe 201b and which is configured to detect the discharge temperature. The discharge temperature detector 208 provides a value of the detected discharge temperature to the controller 6 by wire or wirelessly.

[0017] The suction pressure detector 209 detects the pressure (hereinafter referred to as the suction pressure) of the refrigerant to be sucked into the compressor 202, i.e., the pressure (suction pressure) of the low-temperature/low-pressure gas-phase refrigerant subjected to gas-liquid separation by the accumulator 206 and flowing through the suction pipe 201a. The suction pressure detector 209 is, for example, a pressure sensor or the like a pressure-sensitive element of which is arranged inside the piping of the suction pipe 201a and which is configured to detect the suction pressure. The suction pressure detector 209 provides a value of the detected suction pressure to the controller 6 by wire or wirelessly.

[0018] The discharge pressure detector 210 detects the pressure (hereinafter referred to as the discharge pressure) of the refrigerant discharged from the compressor 202, i.e., the pressure (discharge pressure) of the high-temperature/high-pressure gas-phase refrigerant flowing through the discharge pipe 201b. The discharge pressure detector 210 is, for example, a pressure sensor or the like a pressure-sensitive element of which is arranged inside the piping of the discharge pipe 201b and which is configured to detect the discharge pressure. The discharge pressure detector 210 provides a value of the detected discharge pressure to the controller 6 by wire or wirelessly.

[0019] The refrigerant pressure detector 211 detects the pressure of the refrigerant flowing from the condenser into the evaporator. For example, the refrigerant pressure detector 211 detects the pressure of the refrigerant flowing out of the outdoor heat exchanger 203 at the time of a cooling operation of the air-conditioning device 1, and detects the pressure of the refrigerant flowing out of the indoor heat exchanger 402 at the time of a heating operation. The refrigerant pressure detector 211 is, for example, a pressure sensor or the like a pressure-sensitive element of which is arranged inside the piping and which is configured to detect the pressure of the refrigerant flowing through the aforementioned piping.

[0020] In the example shown in FIG. 1, regarding the refrigerant pressure detector 211, the pressure-sensitive element thereof is arranged inside the piping (hereinafter referred to as a liquid pipe) 80 serving as a part of the main flow path 8 between the outdoor expansion valve 205 and indoor expansion valve 404. More specifically, the refrigerant pressure detector 211 is arranged at a position closer to the outdoor expansion valve 205 than a bifurcation point P1 at which the first branch path 81 branches off from the liquid pipe 80 serving as a part of the main flow path 8. The refrigerant pressure detector 211 detects the pressure (hereinafter referred to as the liquid-pipe pressure) of the low-pressure gas-liquid two-phase refrigerant decompressed in the outdoor expansion valve 205 or liquid-phase refrigerant at the time of, for example, a cooling operation of the air-conditioning device 1, and detects the liquid pipe pressure of the low-pressure gas-liquid two-phase refrigerant decompressed in the indoor expansion valve 404 or liquid-phase refrigerant at the time of a heating operation. The refrigerant pressure detector 211 provides a value of the detected liquid pipe pressure to the controller 6 by wire or wirelessly.

[0021] Next, the configuration of the indoor unit 4 will be described below. The indoor unit 4 includes, as main constituents, the indoor heat exchanger 402, indoor air blower 403, indoor expansion valve 404, and the like.

[0022] The indoor heat exchanger 402 carries out heat exchange between the indoor air and refrigerant, functions as an evaporator configured to evaporate the refrigerant when the air-conditioning device 1 carries out a cooling operation and functions as a condenser configured to condense the refrigerant when the air-conditioning device 1 carries out a heating operation. For example, at the time of a cooling operation, the refrigerant flows through the compressor 202, four-way valve 207, outdoor heat exchanger 203, outdoor expansion valve 205, indoor expansion valve 404, and indoor heat exchanger 402 in the order mentioned, whereby the space of the air-conditioning object is cooled. On the other hand, at the time of a heating operation, the refrigerant flows through the compressor 202, four-way valve 207, indoor heat exchanger 402, indoor expansion valve 404, outdoor expansion valve 205, and outdoor heat exchanger 203 in the order mentioned, whereby the space of the air-conditioning object is heated.

[0023] The indoor air blower 403 is arranged in the vicinity of the indoor heat exchanger 402, sucks therein the air (hereinafter referred to as the inner air) in the room of the air-conditioning object and blows the air subjected to heat exchange by the indoor heat exchanger 402 into the room. The inner air sucked in by the indoor air blower 403 is blown onto the indoor heat exchanger 402. Thereby, heat exchange is carried out between the aforementioned inner air and refrigerant flowing through the indoor heat exchanger 402.

[0024] The indoor expansion valve 404 is a regulating valve capable of regulating the flow rate of the refrigerant according to the degree of opening thereof. For example, the indoor expansion valve 404 regulates the flow rate of the refrigerant flowing into the indoor heat exchanger 402 at the time of a cooling operation of the air-conditioning device 1 and regulates the flow rate of the refrigerant flowing out of the indoor heat exchanger 402 at the time of a heating operation. That is, the indoor expansion valve 404 regulates the flow rate of the liquid-phase refrigerant condensed by the condenser and guided to the evaporator. The indoor expansion valve 404 has a valve structure in which a narrowing-down amount of the refrigerant is adjusted by controlling the degree of opening of the valve between, for example, the lower limit degree of opening and upper limit degree of opening and is configured as a pulse motor valve (PMV) in which the degree of opening is continuously changed according to the number of supplied drive pulses. The indoor expansion valve 404 is subjected to degree-of-opening adjustment by the controller 6 and provides a value of the current degree of opening (actual degree of opening) to the controller 6 by wire or wirelessly.

[0025] As shown in FIG. 1, the main flow path 8 is bifurcated by the branch path (hereinafter referred to as the first branch path) 81 configured to divert part of the refrigerant flowing from the condenser into the evaporator at a position downstream from the condenser and the first branch path 81 is made a bypass leading to the compressor 202. Accordingly, when the air-conditioning device 1 carries out a cooling operation, part of the liquid-phase refrigerant or gas-liquid two-phase refrigerant condensed by the outdoor heat exchanger 203 is diverted from the main flow path 8 by the first branch path 81 and is injected into the compressor 202. Further, when the air-conditioning device 1 carries out a heating operation, part of the liquid-phase refrigerant or gas-liquid two-phase refrigerant condensed by the indoor heat exchanger 402 is diverted from the main flow path 8 by the first branch path 81 and is injected into the compressor 202. Thereby, the compressor 202 is cooled and discharge temperature of the refrigerant discharged from the compressor 202 is lowered. That is, the first branch path 81 functions as an injection flow path. In the example shown in FIG. 1, the first branch path 81 is configured as the piping branching off from the outdoor side piping 201 and leading to the compressor 202.

[0026] Along the first branch path 81, an on-off valve 811 and expansion valve (hereinafter referred to as a first expansion valve) 812 are arranged.

[0027] The on-off valve 811 blocks or releases the flow of the refrigerant in the first branch path 81. Accordingly, when the on-off valve 811 is in the opened state, the refrigerant diverted from the main flow path 8 flows through the first branch path 81. On the other hand, when the on-off valve 811 is in the closed state, the refrigerant is not diverted from the main flow path 8 and the flow of the refrigerant in the first branch path 81 is brought to a standstill. It should be noted that a configuration in which the on-off valve 811 is omitted and only the first expansion valve 812 is arranged on the first branch path 81 may also be employed.

[0028] The first expansion valve 812 is a regulating valve capable of regulating the flow rate of the refrigerant according to the degree of opening thereof. Accordingly, the first expansion valve 812 regulates the flow rate of the refrigerant diverted from the main flow path 8, in other words, the flow rate of the refrigerant diverted from the main flow path 8 and flowing through the first branch path 81. That is, the first expansion valve 812 regulates an injection amount (injection refrigerant amount) of the liquid-phase refrigerant or gas-liquid two-phase refrigerant condensed by the outdoor heat exchanger 203 or by the indoor heat exchanger 402 to be injected into the compressor 202. The first expansion valve 812 has a valve structure in which a narrowing-down amount of the refrigerant is adjusted by controlling the degree of opening of the valve between, for example, the lower limit degree of opening and upper limit degree of opening and is configured as s a pulse motor valve (PMV) in which the degree of opening is continuously changed according to the number of supplied drive pulses. The first expansion valve 812 is subjected to degree-of-opening adjustment by the controller 6 and provides a value of the current degree of opening (actual degree of opening) to the controller 6 by wire or wirelessly.

[0029] The controller 6 controls the operation of each of the outdoor unit 2 and indoor unit 4. The controller 6 includes a CPU, memory, storage device (nonvolatile memory), input/output circuit, timer, and the like and executes predetermined arithmetic processing. For example, the controller 6 reads various data items by means of the input/output circuit, executes the arithmetic processing by using programs read from the storage device into the memory and by means of the CPU, and carries out motion control of the compressor 202, outdoor air blower 204, outdoor expansion valve 205, four-way valve 207, discharge temperature detector 208, suction pressure detector 209, discharge pressure detector 210, refrigerant pressure detector 211, indoor air blower 403, indoor expansion valve 404, and the like on the basis of the processing result.

[0030] The controller 6 includes a motion controller 61 configured to carry out the aforementioned motion control. The motion controller 61 is configured as a program (motion control program) used to make the CPU execute the predetermined arithmetic processing configured to control the motion of each of the aforementioned constituents (motion control objects), for example, startup (start of operation), shutoff, and the like. The motion controller 61 is stored in, for example, the storage device (nonvolatile memory) of the controller 6 and is read into the memory at the time of the execution. The motion controller 61 transmits/ receives control signals and data signals to/from the motion control objects by wire or wirelessly. That is, the motion controller 61 and each of motion control objects are electrically connected to each other by wire or wirelessly.

[0031] Further, the controller 6 controls the degree of opening of the first expansion valve 812. As such degree-of-opening control, the controller 6 sets an upper limit degree of opening of the first expansion valve 812 and corrects the set upper limit degree of opening. The upper limit degree of opening is less than, for example, the maximum value of the degree of opening that can be taken by the first expansion valve 812 and is an operational upper limit value of the degree of opening having a margin relative to the aforementioned maximum value. In order to carry out control (hereinafter referred to as the upper limit degree-of-opening control processing) of the aforementioned upper limit degree of opening of the first expansion valve 812, the controller 6 includes an upper limit degree-of-opening controller 62. The upper limit degree-of-opening controller 62 is configured as a program (upper limit degree-of-opening control program) used to make the CPU execute the predetermined arithmetic processing configured to carry out, for example, setting and correction of the upper limit degree of opening of the first expansion valve 812. The upper limit degree-of-opening controller 62 is stored in, for example, the storage device (nonvolatile memory) of the controller 6 and is read into the memory at the time of the execution.

[0032] In the upper limit degree-of-opening control processing, the upper limit degree-of-opening controller 62 sets the upper limit degree of opening of the first expansion valve 812 by means of a predetermined parameter. In this embodiment, the rotational speed of the compressor 202 and at least one of the suction pressure of the refrigerant and discharge pressure of the refrigerant are used as the parameters. When setting the upper limit degree of opening of the first expansion valve 812, the upper limit degree-of-opening controller 62 acquires the rotational speed from the compressor 202 in operation, acquires the suction pressure of the refrigerant detected by the suction pressure detector 209, and acquires the discharge pressure of the refrigerant detected by the discharge pressure detector 210. The acquired rotational speed, suction pressure, and discharge pressure are retained in the memory of the controller 6 and are read as the parameters to be used at the time of setting of the upper limit degree of opening of the first expansion valve 812. It should be noted that as such parameters, in addition to the rotational speed of the compressor 202, suction pressure and discharge pressure of the refrigerant described above, for example, the discharge degree of superheat (dSH) which is a difference between the discharge temperature of the refrigerant and discharge pressure thereof may also be used.

[0033] As described above, although the upper limit degree of opening of the first expansion valve 812 is set by using the predetermined parameters, the set value thereof is set in such a manner that it becomes possible to hold down the discharge temperature of the refrigerant to a predetermined temperature lower than, for example, a target value (hereinafter referred to as the target discharge temperature) of the discharge temperature of the refrigerant. For example, when the target discharge temperature is 100°C, it is sufficient if the upper limit degree of opening of the first expansion valve 812 is set in such a manner that the discharge temperature of the refrigerant can be held down to about 90°C. By arranging such setting, under a condition of the normal operation, degree-of-opening restriction attributable to the upper limit degree of opening of the first expansion valve 812 hardly occurs, and it is possible to appropriately operation-control the air-conditioning device 1.

[0034] The discharge temperature of the refrigerant is basically proportional to the magnitude of the compression ration of the compressor 202, and hence in order to make the upper limit degree of opening of the first expansion valve 812 the desired degree of opening, it desirable that the aforementioned upper limit degree of opening be set according to the discharge pressure of the refrigerant. Further, the injection amount required to cool the compressor 202 in such a manner that the discharge temperature of the refrigerant becomes the target discharge temperature varies according to, for example, the circulation volume of the refrigerant in the main flow path 8, in other words, the rotational speed of the compressor 202. The injection amount is the amount of the refrigerant (liquid-phase refrigerant or gas-liquid two-phase refrigerant) to be injected into the compressor 202 by the injection. For this reason, in this embodiment, as the setting parameters of the upper limit degree of opening of the first expansion valve 812, at least the discharge pressure of the refrigerant and rotational speed of the compressor 202 are used.

[0035] Further, the injection amount is also dependent on the liquid density of the refrigerant. For this reason, it is possible to further enhance the setting accuracy by using, for example, the liquid pipe pressure detected by the refrigerant pressure detector 211 as the setting parameter of the upper limit degree of opening of the first expansion valve 812 to thereby set the upper limit degree of opening of the first expansion valve 812. At that time, in place of or in addition to the liquid pipe pressure, the temperature of the gas-liquid two-phase refrigerant or liquid-phase refrigerant flowing through the liquid pipe 80 may also be made the setting parameter of the upper limit degree of opening of the first expansion valve 812.

[0036] It should be noted that when the condition of the outdoor air is liable to largely vary in the environment in which the air-conditioning device 1 is operated or when the environment is an operation environment in which the cooling capability or heating capability of the air-conditioning device 1 is liable to largely vary, it is desirable that the upper limit degree of opening of the first expansion valve 812 be set by using both the suction pressure and discharge pressure of the refrigerant. However, it is also possible to set the desired upper limit degree of opening by using only one of the suction temperature and discharge temperature of the refrigerant as the parameter.

[0037] Upon completion of setting of the upper limit degree of opening of the first expansion valve 812, the upper limit degree-of-opening controller 62 corrects the set upper limit degree of opening on the basis of the discharge temperature of the refrigerant. When carrying out such correction, the upper limit degree-of-opening controller 62 acquires the discharge temperature of the refrigerant detected by the discharge temperature detector 208. The acquired discharge temperature is retained in the memory of the controller 6 and is read as the parameter to be used at the time of correction of the set upper limit degree of opening of the first expansion valve 812.

[0038] The upper limit degree-of-opening controller 62 corrects the set upper limit degree of opening of the first expansion valve 812 in such a manner that the higher the discharge temperature of the refrigerant, the greater the upper limit degree of opening of the first expansion valve 812 becomes and, the lower the aforementioned discharge temperature, the less the upper limit degree of opening of the first expansion valve 812 becomes. For example, the upper limit degree-of-opening controller 62 sets the target discharge temperature as the criterion, corrects, when the discharge temperature of the refrigerant is higher than the target discharge temperature, the upper limit degree of opening of the first expansion valve 812 in the positive direction (so as to increase the upper limit degree of opening), and corrects, when the discharge temperature of the refrigerant is lower than the target discharge temperature, the upper limit degree of opening of the first expansion valve 812 in the negative direction (so as to decrease the upper limit degree of opening). Further, for example, the upper limit degree-of-opening controller 62 may correct the upper limit degree of opening of the first expansion valve 812 in such a manner that the higher the discharge temperature of the refrigerant, the greater the correction value to be used is and, the lower the aforementioned discharge temperature, the less the correction value to be used is.

[0039] The target discharge temperature is stored in, for example, the storage device (nonvolatile memory) of the controller 6 and is read into the memory as the parameter to be used at the time of correction of the upper limit degree of opening of the first expansion valve 812. In this case, when correcting the set upper limit degree of opening of the first expansion valve 812, the upper limit degree-of-opening controller 62 acquires the discharge temperature of the refrigerant detected by the discharge temperature detector 208. The acquired discharge temperature is retained in the memory of the controller 6, is read as the parameter to be used at the time of correction of the set upper limit degree of opening of the first expansion valve 812, and is compared with the target discharge temperature.

[0040] The set upper limit degree of opening of the first expansion valve 812 is corrected in the manner described above, whereby when the discharge temperature of the refrigerant is higher than the target discharge temperature, the aforementioned upper limit degree of opening is relaxed (is made greater), and it becomes possible to appropriately maintain the discharge temperature of the refrigerant. Conversely, when the discharge temperature of the refrigerant is lower than the target discharge temperature, the set upper limit degree of opening of the first expansion valve 812 is restrained (is made less). Thereby, even in a situation where the degree-of-opening control of the first expansion valve 812 is behind expectation (insufficient), it is possible to lower the upper limit degree of opening. That is, it is possible to control the degree of opening of the first expansion valve 812 within a range less than or equal to the lowered upper limit degree of opening, and hence it is possible to prevent the compressor 202 from being undercooled, i.e., it is possible to prevent excessive injection from being carried out.

[0041] In FIG. 2, an effect of the cooling control of the compressor 202 based on the injection in this embodiment is shown by means of an example of time transition of each of the discharge temperature of the refrigerant and degree of opening of the first expansion valve 812. In FIG. 2, the transverse axis indicates time, vertical axis on the left side indicates the discharge temperature (refrigerant discharge temperature) of the refrigerant, and vertical axis on the right side indicates a value of each degree of opening (expansion valve degree of opening) of the first expansion valve 812. Further, in FIG. 2, L21, L22, and L23 respectively indicate examples of time transition (loci) with respect to the discharge temperature of the refrigerant, degree of opening of the first expansion valve 812, and upper limit degree of opening of the first expansion valve 812. Further, a broken line L24 indicates the value of the target discharge temperature of the refrigerant.

[0042] In the example shown in FIG. 2, within the time range shown in FIG. 2, the discharge temperature (L21) of the refrigerant transitions approximately in accordance with the target discharge temperature (L24). Further, the degree of opening (L22) of the first expansion valve 812 transitions at all times as a value less than the upper limit degree of opening (L23). That is, FIG. 2 exemplifies an appropriate relationship between the time transitions of the degree of opening of the first expansion valve 812 and upper limit degree of opening thereof in a state where the air-conditioning device 1 is in operation in an adequate situation, e.g., in a situation where the compressor 202 operates without being undercooled. For example, the degree of opening of the first expansion valve 812 is set at any time on the basis of the rotational speed of the compressor 202 and discharge pressure of the refrigerant, and the aforementioned set degree of opening is corrected at any time on the basis of the discharge temperature of the refrigerant. Accordingly, the relationship between the degree of opening of the first expansion valve 812 and upper limit degree of opening thereof becomes the relationship shown in FIG. 2.

[0043] The upper limit degree of opening of the first expansion valve 812 is calculated by, for example, the following formula (1).

$$\text{(upper limit degree of opening)}=\text{(upper limit degree-of-opening calculation term)}+\text{(discharge temperature correction term)} \quad \cdots (1)$$

[0044] In the formula (1), the upper limit degree of opening is the value of the upper limit degree of opening of the first expansion valve 812 controlled by the upper limit degree-of-opening control processing, upper limit degree-of-opening calculation term is the set value of the degree of opening of the first expansion valve 812, and discharge temperature correction term is the correction value of the set value of the degree of opening of the first expansion valve 812. The upper limit degree-of-opening calculation term is calculated by the following formula (2).

$$\text{(upper limit degree-of-opening correction term)}=\text{(coefficient A)}\times\text{(PMVcA)\^{}2}+\text{(coefficient B)}\times\text{(PMVcA)}+\text{(coefficient C)} \quad \cdots (2)$$

[0045] Further, in the formula (2), PMVc is calculated by the following formula (3).

$$\text{(PMVc)}=\text{(compressor rotational speed)}\times\text{(compression ratio)}\times\text{((discharge pressure)\^{}(coefficient C))}\times\text{(coefficient E)} \quad \cdots (3)$$

[0046] In the formula (3), the compressor rotational speed is the value of the rotational speed of the compressor 202, compression ratio is the value of the compression ratio of the compressor 202, and discharge pressure is the value of the discharge pressure of the refrigerant. Further, in the formula (2) and formula (3), the coefficients A to E are, for example, predetermined coefficients calculated by tests.

[0047] The discharge temperature correction term is set in advance to a value, for example, in such a manner that the higher the discharge temperature of the refrigerant, the greater the set value is and, the lower the aforementioned discharge temperature, the less the set value is.

[0048] It should be noted that the calculation formula of the upper limit degree of opening of the first expansion valve 812 is not limited to the formula (1). That is, the upper limit degree of opening of the first expansion valve 812 may also be calculated by using a calculation formula different from the formula (1). For example, in place of the compression ratio of the compressor 202, a compression difference between the discharge pressure and suction pressure of the refrigerant may be used, and a coefficient F may further be added.

[0049] When the refrigeration cycle device 1 includes an outdoor unit and a plurality of indoor units, and is capable of operating in the cooling operation mode, heating operation mode, and simultaneous heating and cooling operation mode, it is possible to set the upper limit degree of opening of the first expansion valve 812 to values different from each other in these operation modes. The cooling operation mode is an operational state where each of the plurality of indoor units carries out a cooling operation. The heating operation mode is an operational state where each of the plurality of indoor units carries out a heating operation. The simultaneous heating and cooling operation mode is an operational state where indoor units carrying out cooling operations and indoor units carrying out heating operations are mixed together in the plurality of indoor units. For example, in the heating operation mode, the liquid pipe pressure is liable to lower due to retention of the refrigerant in the indoor units 4. Further, in the simultaneous heating and cooling operation mode, the liquid pipe pressure is liable to lower due to retention of the refrigerant in the yet-to-be-used high-pressure gas pipes and the like. Accordingly, by setting the upper limit degree of opening of the first expansion valve 812 to different values according to the operation modes, it is possible to suppress such lowering of the liquid pipe pressure.

[0050] In each of FIG. 3 and FIG. 4, an example of time transition of each of the discharge temperature of the refrigerant and degree of opening of the first expansion valve 812 in the case where the liquid pipe pressure lowers is shown. FIG. 3 is a view showing an example of a case of a comparative example where control of the upper limit degree of opening of the first expansion valve 812 is not carried out unlike this embodiment. FIG. 4 is a view showing an example of a case of this embodiment where control of the upper limit degree of opening of the first expansion valve 812 is carried out. In FIG. 3 and FIG. 4, the transverse axis indicates time, vertical axis on the left side indicates the discharge temperature (refrigerant discharge temperature) of the refrigerant, and vertical axis on the right side indicates a value of each degree of opening (expansion valve degree of opening) of the first expansion valve 812. Further, in FIG. 3 and FIG. 4, L31 and L41 each indicate examples of time transitions (loci) with respect to the discharge temperature of the refrigerant, L32 and L42 each indicate examples of time transitions (loci) with respect to the degree of opening of the expansion valve, and L43 indicates an example of time transition (locus) with respect to the upper limit degree of opening of the expansion valve. Further, the broken lines L34 and L44 each indicate the values of the target discharge temperature of the refrigerant.

[0051] As in the case of the comparative example shown in FIG. 3, in the transient state shortly after the operation startup of the air-conditioning device, the air-conditioning device is in a state where the discharge temperature (L31) of the refrigerant does not become lower than or equal to the target discharge temperature (L34) for the reason or the like that the refrigerant is retained in, for example, the accumulator and the like, and liquid pipe pressure lowers. Thereafter, when the operation is continued and liquid pipe pressure is restored to a certain degree, the degree of opening (L32) of the expansion valve (corresponding to the first expansion valve 812 in this embodiment) of the injection flow path becomes larger. Thereby, the refrigerant abruptly begins to flow through the aforementioned expansion valve. As a result, there is sometimes a case where the discharge temperature (L31) is abruptly made lower than the target discharge temperature (L34) by excessive cooling as indicated in FIG. 3 by DT3.

[0052] Conversely, according to this embodiment, as indicated by the formula (1), it is possible to apply the discharge temperature correction term in calculating the upper limit degree of opening of the first expansion valve 812, i.e., it is possible to correct the set upper limit degree of opening on the basis of the discharge temperature of the refrigerant. Accordingly, as shown in FIG. 4, it is possible to largely lower the upper limit degree of opening (L43) of the first expansion valve 812 in conjunction with the lowering of the discharge temperature (L41) of the refrigerant. Accordingly, the degree of opening (L42) of the first expansion valve 812 never becomes greater than the lowered, i.e., corrected upper limit degree of opening. That is, the degree of opening (L42) of the first expansion valve 812 peaks out at the upper limit degree of opening (L43), and transitions as a value less than or equal to the lowered (corrected) upper limit degree of opening without transitioning as a large value shown by, for example, the broken line L421. Accordingly, the discharge temperature (L41) of the refrigerant does not abruptly lower unlike the broken line L31, and it is possible to suppress lowering of the aforementioned discharge temperature (L41) ($DT4<DT3$) in comparison with the comparative example shown in FIG. 3. Thereby, it is possible to prevent the discharge temperature (L41) from being abruptly made lower than the target discharge temperature (L44) by excessive cooling.

[0053] For example, even when the load variation is great as in the case of a refrigeration cycle such as variable refrigeration flow (VRF) or the like, refrigerant is retained in the indoor unit, accumulator, and the like, and liquid pipe pressure largely varies to thereby make the phase state (dryness fraction) of the liquid pipe 80 liable to change, it is possible, according to this embodiment, to carry out the following control. When the discharge temperature of the refrigerant is higher than the target discharge temperature, it is possible to make the upper limit degree of opening of the first expansion valve 812 large on the basis of a determination that the liquid-phase refrigerant is flashing. Conversely, when the discharge temperature of the refrigerant is lower than the target temperature, it is possible to make the upper limit degree of opening of the first expansion valve 812 small on the basis of a determination that excessive injection is occurring. Thereby, it is possible to control the upper limit degree of opening of the first expansion valve 812 by a feed-forward-wise operation, and suppress temperature enhancement of the compressor 202 due to injection deficiency or excessive cooling of the compressor 202 due to an excess of injection.

[0054] The parameter to be used at the time of correction of the upper limit degree of opening of the first expansion valve 812 is not limited to the discharge temperature of the refrigerant. The upper limit degree-of-opening controller 62 may use, in place of or in addition to, for example, the discharge temperature of the refrigerant, another parameter to correct the upper limit degree of opening of the first expansion valve 812. As another parameter, at least one of, for example, the surface temperature of the housing of the compressor 202 and temperature of the refrigeration machine oil can be used. The surface temperature of the housing of the compressor 202 and temperature of the refrigeration machine oil exhibit values correlating with the discharge temperature of the refrigerant, and hence these temperatures can be used as parameters substituting for the aforementioned discharge temperature. In this case, it is sufficient if a temperature sensor (thermistor) or the like configured to detect the surface temperature of the housing of the compressor 202 or temperature of the refrigeration machine oil is provided in the compressor 202.

[0055] Further, the upper limit degree-of-opening controller 62 may use, as still another parameter, the liquid pipe pressure detected by the refrigerant pressure detector 211 to correct the set upper limit degree of opening of the first expansion valve 812. For example, when the liquid pipe pressure lowers, the flash gas is temporarily created inside the liquid pipe 80, whereby the injection amount is made deficient in some cases. By correcting the set upper limit degree of opening of the first expansion valve 812 on the basis of the liquid pipe pressure, it is possible to suppress deficiency of the injection amount due to occurrence of such flash gas.

[0056] As described above, in this embodiment, the upper limit degree of opening of the first expansion valve 812 is controlled according to the discharge temperature of the refrigerant and, at the same time, cooling control of the compressor 202 based on injection is carried out. In the cooling control of the compressor 202, for example, at least three temperature indices including the temperature (hereinafter referred to as the cooling start temperature) at which cooling of the compressor 202 is started, discharge temperature (hereinafter referred to as the target discharge temperature) of the refrigerant made the target, and temperature (hereinafter referred to as the cooling end temperature) at which cooling is terminated are used. In other words, the cooling start temperature corresponds to the temperature at which control of the upper limit degree of opening of the first expansion valve 812 is started, and cooling end temperature corresponds to the temperature at which control of the aforementioned upper limit degree of opening is terminated. Each of the cooling start temperature, target temperature, and cooling end temperature can arbitrarily be set within, for example, a range not adversely affecting the reliability of the compressor 202. However, the cooling end temperature is set to a temperature lower than the cooling start temperature.

[0057] Here, the configuration of the refrigeration cycle device capable of carrying out injection by the aforementioned upper limit degree-of-opening control processing is not limited to the refrigeration cycle device 1 shown in FIG. 1. For example, even a refrigeration cycle device 11 including a refrigeration cycle shown in FIG. 5 is also capable of carrying out injection by the upper limit degree-of-opening control processing in the same manner, and is capable of exhibiting the same function/advantageous effect as the refrigeration cycle device 1. Hereinafter, the refrigeration cycle device 11 including the refrigeration cycle shown in FIG. 5 will be described as a second embodiment. It should be noted that the fundamental configuration of the refrigeration cycle device 11 in the second embodiment is identical to the refrigeration cycle device 1 of the first embodiment shown in FIG. 1. Accordingly, hereinafter configurations different from the refrigeration cycle device 1 will be described in detail. Configurations identical to or similar to the refrigeration cycle device 1 are denoted by reference symbols identical to the refrigeration cycle device 1 on the drawings, and descriptions of these configurations are omitted or simplified.

(Second Embodiment)

[0058] FIG. 5 is a circuit diagram schematically showing a refrigeration cycle of an air-conditioning device (hereinafter referred to as the air-conditioning device 11) which is an example of a refrigeration cycle device 11 according to this embodiment. As shown in FIG. 5, the air-conditioning device 11 includes an outdoor unit 21 and indoor unit 41 connected to each other by a main flow path 8, and controller 6 configured to control operations of the outdoor unit 21 and indoor unit 41.

[0059] In this embodiment, as shown in FIG. 5, the main flow path 8 is bifurcated by a first branch path 81, and is further bifurcated by a second branch path 82. The second branch path 82 is a refrigerant flow path diverting part of the refrigerant flowing from the condenser into the evaporator from the main flow path 8 at a position further downstream from the first branch path 81, and leading to the accumulator 206. In the example shown in FIG. 5, the bifurcation point P2 of the second branch path 82 at the liquid pipe 80 serving as a part of the main flow path 8 is positioned on the further downstream side of the bifurcation point P1 of the first branch path 81 along the flow of the refrigerant. Thereby, the refrigerant flowing from the condenser into the evaporator is diverted into the compressor 202 by the first branch path 81 and is further diverted into the accumulator 206 by the second branch path 82.

[0060] Accordingly, when the air-conditioning device 11 carries out a cooling operation, part of the liquid-phase refrigerant condensed by the outdoor heat exchanger 203 is diverted from the main flow path 8 by the second branch path 82 and flows into the accumulator 206. Further, when the air-conditioning device 11 carries out a heating operation, part of the liquid-phase refrigerant or gas-liquid two-phase refrigerant condensed by the indoor heat exchanger 402 is diverted from the main flow path 8 by the second branch path 82 and flows into the accumulator 206. In the example shown in FIG. 5, the second branch path 82 is configured as the piping branching off from the outdoor side piping 201 (liquid pipe 80) and leading to the accumulator 206.

[0061] Along the second branch path 82, an expansion valve (hereinafter referred to as the second expansion valve)

821 and undercooling heat exchanger 822 are arranged.

[0062] The second expansion valve 821 is a regulating valve capable of regulating the flow rate of the refrigerant according to the degree of opening thereof. Accordingly, the second expansion valve 821 regulates the flow rate of the refrigerant diverted from the main flow path 8, in other words, the flow rate of the refrigerant diverted from the main flow path 8 and flowing through the second branch path 82. That is, the second expansion valve 821 regulates the inflow rate of the liquid-phase refrigerant or gas-liquid two-phase refrigerant condensed by the outdoor heat exchanger 203 or indoor heat exchanger 402 flowing into the accumulator 206. The second expansion valve 821 has a valve structure in which a narrowing-down amount of the refrigerant is adjusted by controlling the degree of opening of the valve between, for example, the lower limit degree of opening and upper limit degree of opening and is configured as pulse motor valve (PMV) in which the degree of opening is continuously changed according to the number of supplied drive pulses. The second expansion valve 821 is subjected to degree-of-opening adjustment by the controller 6 and provides a value of the current degree of opening (actual degree of opening) to the controller 6 by wire or wirelessly.

[0063] The undercooling heat exchanger 822 carries out heat exchange between the refrigerant passing through the second expansion valve 821 and flowing through the second branch path 82 and refrigerant flowing through the liquid pipe 80 of the main flow path 8 from the condenser toward the evaporator. The undercooling heat exchanger 822 includes a main flow side flow path 823 and branch flow side flow path 824. The main flow side flow path 823 is connected to the liquid pipe 80 of the main flow path 8 at both ends thereof and constitutes a part of the main flow path 8. The branch flow side flow path 824 is connected to the second branch path 82 at both ends thereof and constitutes a part of the second branch path 82. Thereby, heat exchange is carried out between the refrigerant flowing through the main flow side flow path 823 and refrigerant flowing through the branch flow side flow path 824.

[0064] Further, the outdoor unit 21 of the air-conditioning device 11 includes a first refrigerant temperature detector 212 and second refrigerant temperature detector 213. The first refrigerant temperature detector 212 detects a first temperature (hereinafter referred to as the first liquid pipe temperature) of the refrigerant flowing through the liquid pipe 80 on one side of the undercooling heat exchanger 822 interposed between the detectors 212 and 213 along the flow direction of the refrigerant. The second refrigerant temperature detector 213 detects a second temperature (hereinafter referred to as the second liquid pipe temperature) of the refrigerant flowing through the liquid pipe 80 on the other side of the undercooling heat exchanger 822 interposed between the detectors 212 and 213 along the flow direction of the refrigerant, i.e., on the opposite side of the first refrigerant temperature detector 212. The refrigerant flowing through the liquid pipe 80 is the refrigerant (gas-liquid two-phase or liquid-phase refrigerant) flowing from the condenser to the evaporator and, in short, is the refrigerant flowing into the second branch path 82. That is, the first refrigerant temperature detector 212 and second refrigerant temperature detector 213 each detect the temperature of the refrigerant flowing into the second branch path 82 on the mutually opposite sides with the undercooling heat exchanger 822 interposed between them. Each of the first refrigerant temperature detector 212 and second refrigerant temperature detector 213 is, for example, a temperature sensor (thermistor) or the like a temperature-sensitive element of which is arranged inside the liquid pipe 80 or the like and which is configured to detect the temperature of the refrigerant flowing through the liquid pipe 80. Each of the first refrigerant temperature detector 212 and second refrigerant temperature detector 213 provides a value of each detected liquid pipe temperature to the controller 6 by wire or wirelessly.

[0065] In this embodiment, the upper limit degree-of-opening controller 62 corrects the set upper limit degree of opening of the first expansion valve 812 according to the degree of opening of the second expansion valve 821. The degree of opening of the second expansion valve 821 is retained in the memory of the controller 6 and is read as the parameter to be used at the time of correction of the set upper limit degree of opening of the first expansion valve 812.

[0066] Further, the upper limit degree-of-opening controller 62 may also correct the set upper limit degree of opening of the first expansion valve 812 according to the first liquid pipe temperature and second liquid pipe temperature of the refrigerant, in other words, according to the liquid pipe temperatures before and behind the undercooling heat exchanger 822. The first liquid pipe temperature of the refrigerant is detected by the first refrigerant temperature detector 212, second liquid pipe temperature of the refrigerant is detected by the second refrigerant temperature detector 213, and the detected temperature values are each retained in the memory of the controller 6. The retained first liquid pipe temperature and second liquid pipe temperature are each read by the upper limit degree-of-opening controller 62 as the parameters to be used at the time of correction of the set upper limit degree of opening of the first expansion valve 812. The temperature difference between the liquid pipe temperatures before and behind the undercooling heat exchanger 822 is the difference between the first liquid pipe temperature and second liquid pipe temperature.

[0067] By providing the undercooling heat exchanger 822 as in the case of this embodiment, a state where the refrigerant flowing through the liquid pipe 80 is liquefied and refrigerant passing through the first expansion valve 812 is undercooled is brought about. Accordingly, even when the refrigerant flowing through the liquid pipe 80 is somewhat in the gas-liquid two-phase, it is possible to appropriately carry out injection to thereby cool the compressor 202. At the time, the entrance liquid density of the first expansion valve 812 varies depending on whether or not the undercooling heat exchanger 822 is used. Accordingly, it is possible to determine whether or not the undercooling heat exchanger 822 is used on the basis of the degree of opening of the second expansion valve 821 or on the basis of the liquid pipe temperatures before and behind the undercooling heat exchanger 822. When the undercooling heat exchanger 822 is used, in such a manner that the set upper limit degree of opening of the first expansion valve 812 becomes smaller, the aforementioned upper limit degree of opening is corrected. Conversely, when the undercooling heat exchanger 822 is not used, in such a manner that the set upper limit degree of opening of the first expansion valve 812 becomes larger, the aforementioned upper limit degree of opening is corrected. Thereby, it becomes possible to further enhance the accuracy of correction of the set upper limit degree of opening of the first expansion valve 812.

[0068] As described above, according to the air-conditioning devices 1 and 11 according to the aforementioned first embodiment and second embodiment, it is possible to appropriately stabilize the refrigeration cycle in which liquid injection is carried out.

[0069] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

Claims

1. A refrigeration cycle device (1, 11) **characterized by** comprising:

   a compressor (202) which sucks a refrigerant from a suction pipe (201a), compresses the sucked refrigerant, and discharges the compressed refrigerant into a discharge pipe (201b);
   a condenser (203, 402) which condenses the refrigerant;
   an evaporator (203, 402) which evaporates the refrigerant;
   a main flow path (8) which includes the suction pipe (201a) and the discharge pipe (201b) and through which the refrigerant circulates by way of the compressor (202), the condenser (203, 402), and the evaporator (203, 402);
   a first branch path (81) which diverts part of the refrigerant flowing from the condenser (203, 402) to the evaporator (203, 402) from the main flow path (8) at a position downstream from the condenser (203, 402) and guides the diverted refrigerant to the compressor (202);
   a first expansion valve (812) a degree of opening of which is controlled between a lower limit degree of opening and an upper limit degree of opening and which regulates a flow rate of the refrigerant flowing through the first branch path (81) according to the degree of opening;
   a discharge temperature detector (208) which detects a discharge temperature of the refrigerant discharged from the compressor (202) into the discharge pipe (201b);
   a suction pressure detector (209) which detects a suction pressure of the refrigerant sucked from the suction pipe (201a) into the compressor (202);
   a discharge pressure detector (210) which detects a discharge pressure of the refrigerant discharged from the compressor (202) into the discharge pipe (201b); and
   a controller (6) which controls operations of the compressor (202), the first expansion valve (812), the discharge temperature detector (208), the suction pressure detector (209), and the discharge pressure detector (210), wherein
   the controller (6) sets the upper limit degree of opening of the first expansion valve on the basis of at least one of the suction pressure detected by the suction pressure detector (209) and the discharge pressure detected by the discharge pressure detector (210) and a rotational speed of the compressor (202), and corrects the set upper limit degree of opening of the first expansion valve on the basis of the discharge temperature detected by the discharge temperature detector (208).

2. The refrigeration cycle device (1, 11) of claim 1, **characterized in that**
   the controller (6) corrects the upper limit degree of opening of the first expansion valve (812) in such a manner that the higher the discharge temperature detected by the discharge temperature detector (208), the greater the upper limit degree of opening of the first expansion valve (812) becomes and, the lower the discharge temperature, the less the upper limit degree of opening of the first expansion (812) becomes.

3. The refrigeration cycle device (1, 11) of claim 1, **characterized by** comprising:

   an outdoor unit (2, 21); and

a plurality of indoor units (4, 41), wherein
the refrigeration cycle device (1, 11) is capable of operating in a cooling operation mode in which each of the plurality of indoor units (4, 41) carries out a cooling operation, a heating operation mode in which each of the plurality of indoor units (4, 41) carries out a heating operation, and a simultaneous heating and cooling operation mode in which indoor units carrying out cooling operations and indoor units carrying out heating operations are mixed together in the plurality of indoor units (4, 41), and
the controller (6) sets the upper limit degree of opening of the first expansion valve (812) to values different from each other in the cooling operation mode, the heating operation mode, and the simultaneous heating and cooling operation mode.

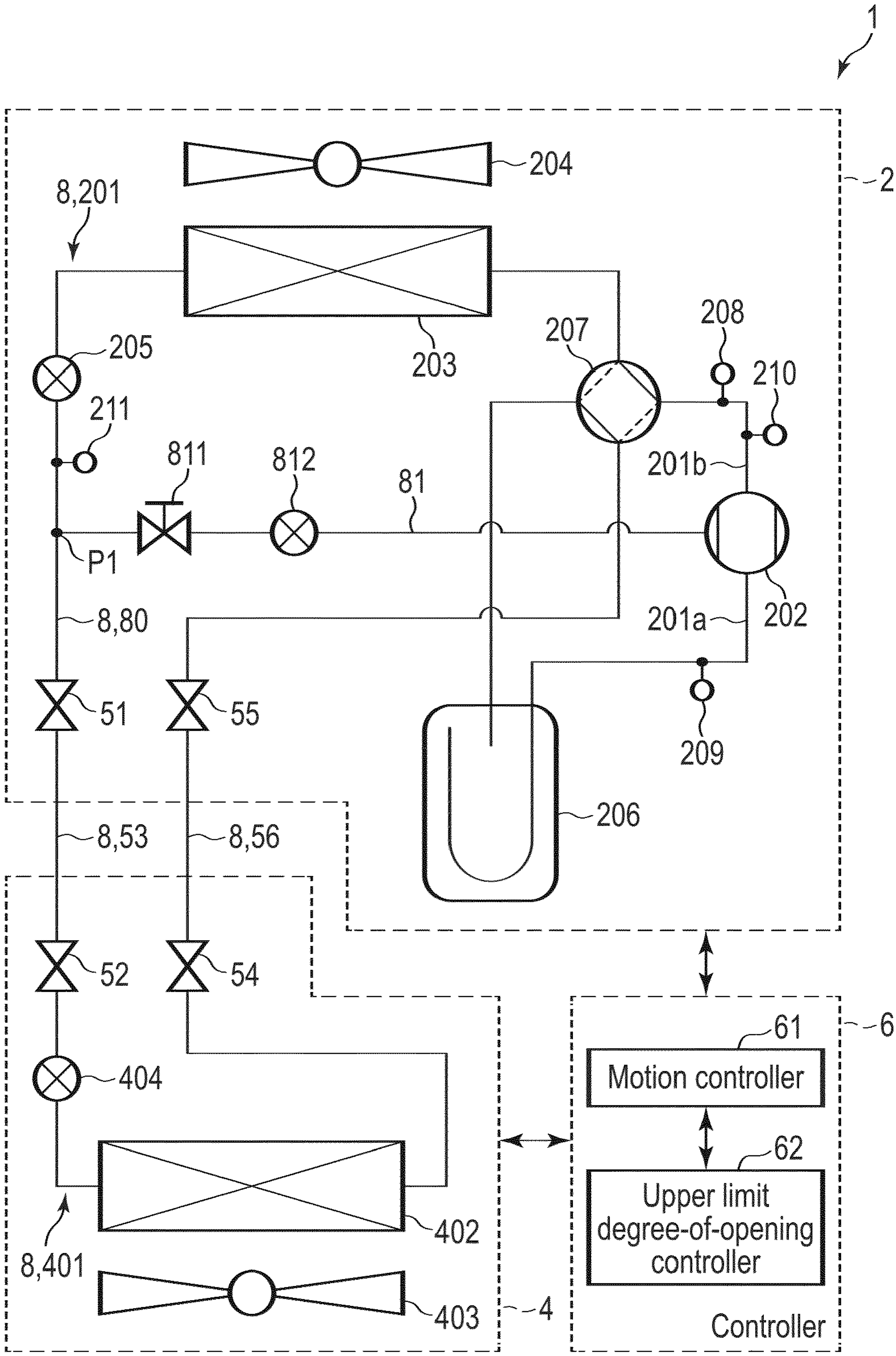
4. The refrigeration cycle device (1, 11) of claim 1, **characterized by** further comprising a refrigerant pressure detector (211) which is operation-controlled by the controller (6) and detects a pressure of the refrigerant flowing from the condenser (203, 402) to the evaporator (203, 402), wherein
the controller (6) corrects the set upper limit degree of opening of the first expansion valve (812) on the basis of the pressure of the refrigerant detected by the refrigerant pressure detector (211).

5. The refrigeration cycle device (11) of claim 1, **characterized by** further comprising:

an accumulator (206) which subjects the refrigerant evaporated by the evaporator (203, 402) to gas-liquid separation;
a second branch path (82) which diverts part of the refrigerant flowing from the condenser (203, 402) into the evaporator (203, 402) from the main flow path (8) at a position further downstream from the condenser (203, 402) than the first branch path (81) and guides the diverted refrigerant to the accumulator (206);
an undercooling heat exchanger (822) which carries out heat exchange between the refrigerant flowing through the second branch path (82) and the refrigerant flowing through the main flow path (8) from the condenser (203, 402) toward the evaporator (203, 402); and
a second expansion valve (821) a degree of opening of which is controlled between a lower limit degree of opening and an upper limit degree of opening and which regulates a flow rate of the refrigerant flowing through the second branch path (82) according to the degree of opening,
wherein the controller (6) corrects the set upper limit degree of opening of the first expansion valve (812) according to the degree of opening of the second expansion valve (821).

6. The refrigeration cycle device (11) of claim 1, **characterized by** further comprising:

an accumulator (206) which subjects the refrigerant evaporated by the evaporator (203, 402) to gas-liquid separation;
a second branch path (82) which diverts part of the refrigerant flowing from the condenser (203, 402) into the evaporator (203, 402) from the main flow path (8) at a position further downstream from the condenser (203, 402) than the first branch path (81) and guides the diverted refrigerant to the accumulator (206);
an undercooling heat exchanger (822) which carries out heat exchange between the refrigerant flowing through the second branch path (82) and the refrigerant flowing through the main flow path (8) from the condenser (203, 402) toward the evaporator (203, 402);
a first refrigerant temperature detector (212) which detects a temperature of the refrigerant flowing from the condenser (203, 402) to the evaporator (203, 402) on one side of the undercooling heat exchanger (822) interposed between two refrigerant temperature detectors including the first refrigerant temperature detector (212) along the flow direction of the refrigerant; and
a second refrigerant temperature detector (213) which detects a temperature of the refrigerant flowing from the condenser (203, 402) to the evaporator (203, 402) on the other side of the undercooling heat exchanger (822) interposed between the first refrigerant temperature detector (212) and the second refrigerant temperature detector (213) along the flow direction of the refrigerant, wherein
the controller (6) corrects the set upper limit degree of opening of the first expansion valve (812) according to the temperature of the refrigerant detected by the first refrigerant temperature detector (212) and the temperature of the refrigerant detected by the second refrigerant temperature detector (213).


1
2
204
8,201
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201a
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55
209
206
8,53
8,56
52
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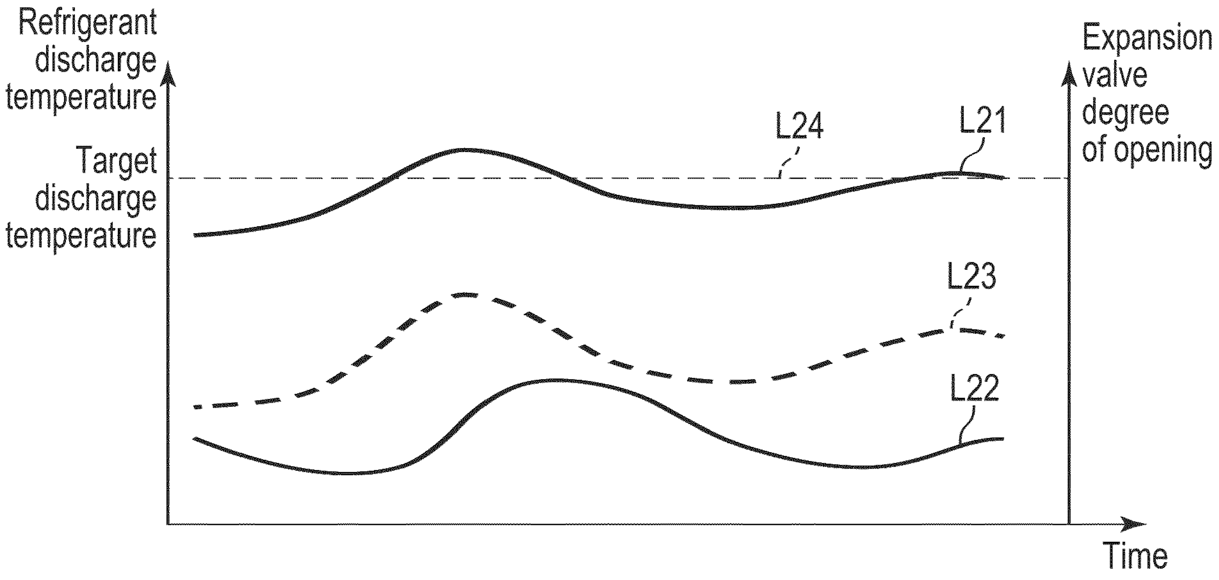
Motion controller
404
62
Upper limit
degree-of-opening
controller
402
8,401
403
4
Controller

F I G. 1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Target discharge temperature
Expansion valve degree of opening
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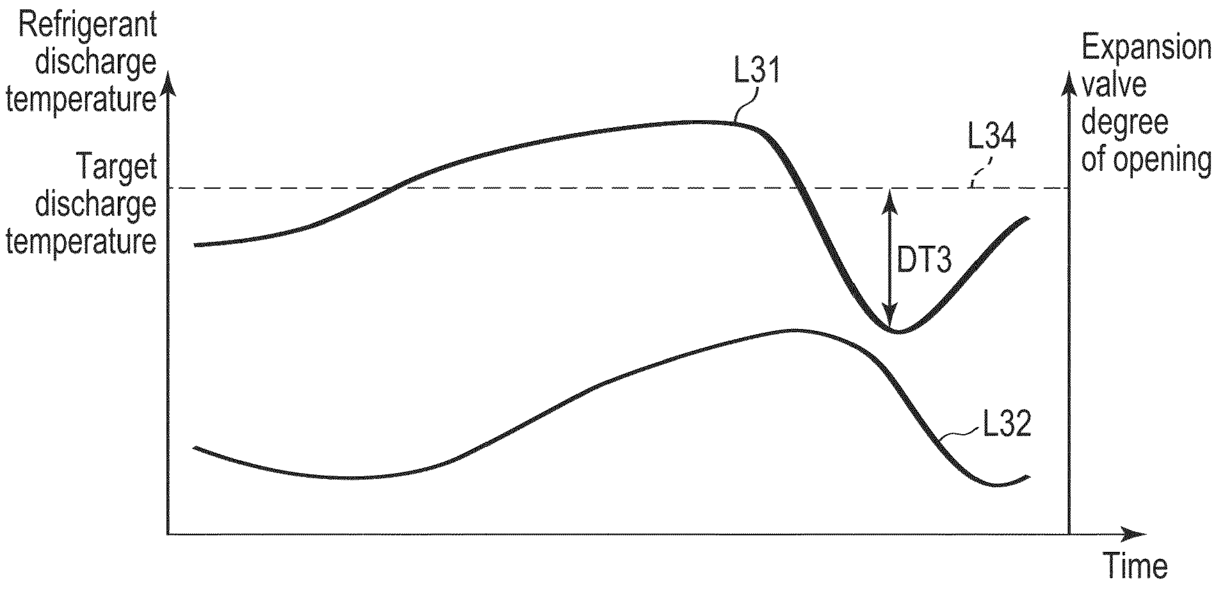
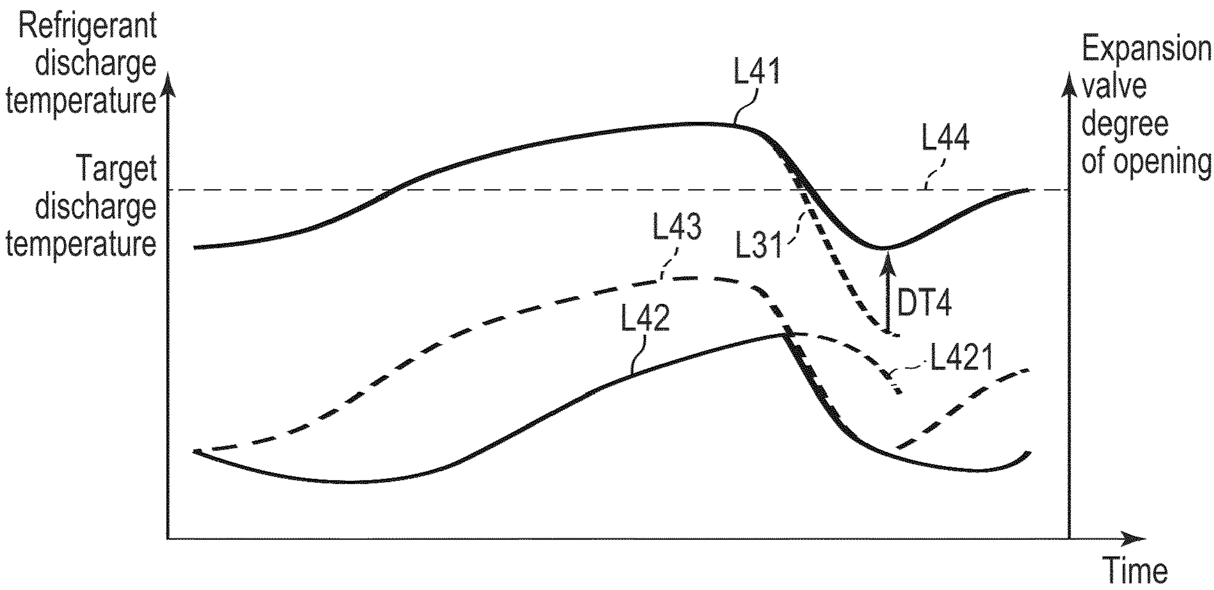
L21
L23
L22
Time

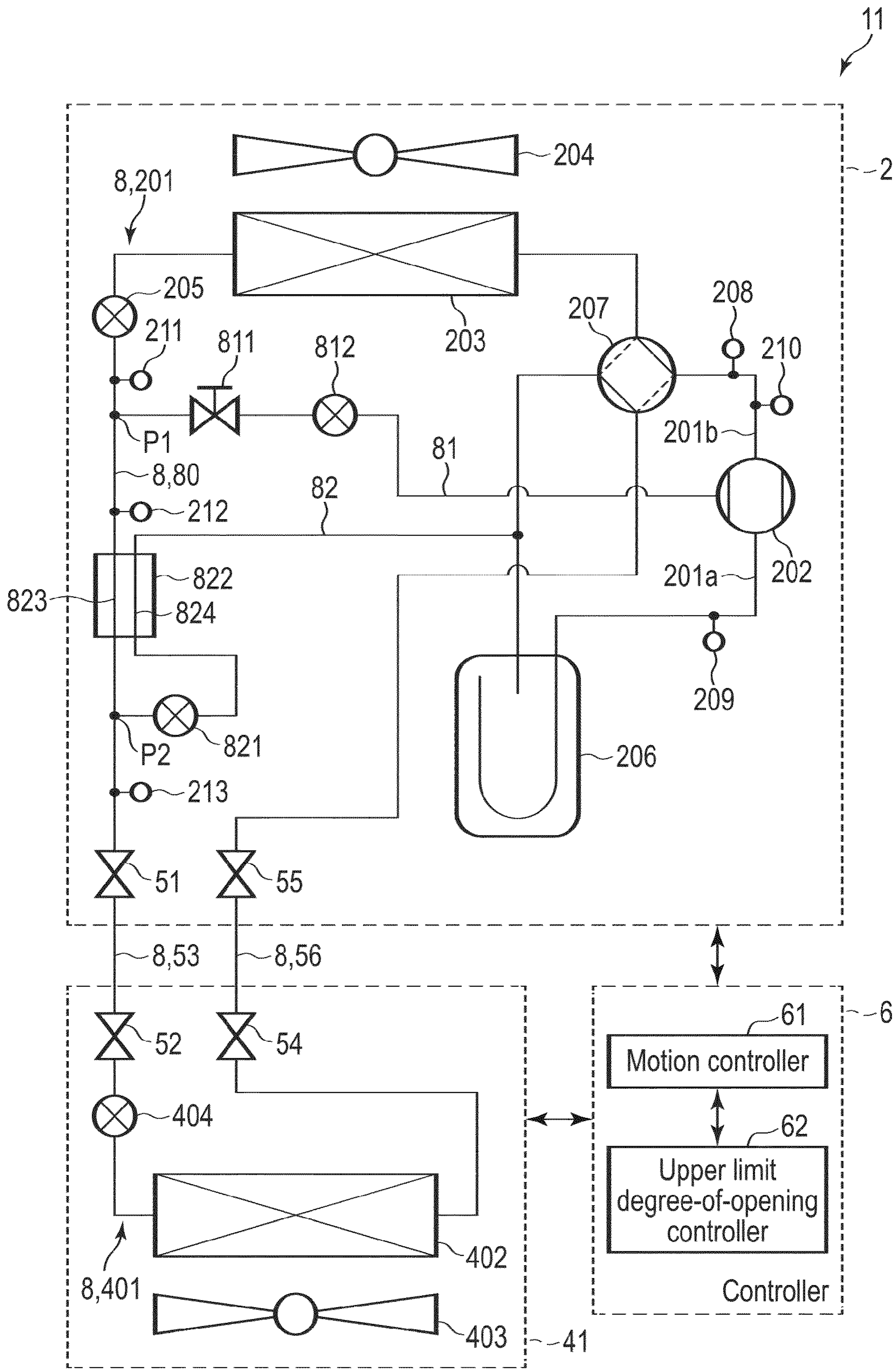
F I G. 2


Refrigerant discharge temperature
Target discharge temperature
Expansion valve degree of opening
L31
L34
DT3
L32
Time

F I G. 3


Refrigerant discharge temperature
Target discharge temperature
Expansion valve degree of opening
L41
L44
L43
L31
DT4
L42
L421
Time

F I G. 4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EUROPEAN SEARCH REPORT

Application Number
EP 24 15 8405

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2015/001613 A1 (MITSUBISHI ELECTRIC CORP [JP]) 8 January 2015 (2015-01-08) * paragraphs [0015] - [0016]; figure 1 *	1,2	INV. F25B13/00 F25B41/39 F25B49/02
X	US 9 869 501 B2 (YAMASHITA KOJI [JP]; MITSUBISHI ELECTRIC CORP [JP]) 16 January 2018 (2018-01-16)	1,2,5,6	
Y	* columns 7-14; figure 3 *	3,4	
Y	US 2018/017300 A1 (SHOCKLEY NICHOLAS [US] ET AL) 18 January 2018 (2018-01-18) * figure 1 *	4	
Y	US 9 618 241 B2 (YAMASHITA KOJI [JP]; MORIMOTO HIROYUKI [JP] ET AL.) 11 April 2017 (2017-04-11) * figure 2 *	3	
A	US 5 253 483 A (POWELL JAMES W [US] ET AL) 19 October 1993 (1993-10-19) * figures 4c,5a *	1	
			TECHNICAL FIELDS SEARCHED (IPC)
			F25B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	7 July 2024	Lepers, Joachim

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CATEGORY OF CITED DOCUMENTS

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07-07-2024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2015001613 A1	08-01-2015	DE 112013007202 T5	17-03-2016
		GB 2530453 A	23-03-2016
		JP 6091616 B2	08-03-2017
		JP WO2015001613 A1	23-02-2017
		WO 2015001613 A1	08-01-2015
US 9869501 B2	16-01-2018	CN 105074351 A	18-11-2015
		EP 2975336 A1	20-01-2016
		JP 5968519 B2	10-08-2016
		JP WO2014141373 A1	16-02-2017
		US 2015354878 A1	10-12-2015
		WO 2014141373 A1	18-09-2014
US 2018017300 A1	18-01-2018	NONE	
US 9618241 B2	11-04-2017	AU 2011358038 A1	20-06-2013
		CN 103261815 A	21-08-2013
		EP 2672201 A1	11-12-2013
		JP 5730335 B2	10-06-2015
		JP WO2012104891 A1	03-07-2014
		US 2013333862 A1	19-12-2013
		WO 2012104891 A1	09-08-2012
US 5253483 A	19-10-1993	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82