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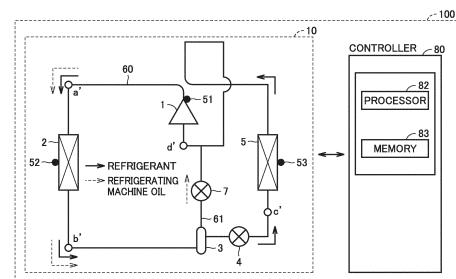
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(54) **REFRIGERATION CYCLE APPARATUS**

(57) A refrigeration cycle apparatus (100) comprises: a compressor (1); a first heat exchanger (2); a second heat exchanger (5); a first decompressing apparatus (4); an oil separator (3); a first circulation pathway in which a refrigerant circulates in an order of the compressor (1), the first heat exchanger (2), the oil separator (3), the first decompressing apparatus (4), and the second heat exchanger (5); an oil-returned pathway connecting between the oil separator (3) and a suction side of the compressor (1); a second decompressing apparatus (7) provided in the oil-returned pathway; and a controller (80) configured to control the first decompressing apparatus (4) and the second decompressing apparatus (7). The controller (80) is configured to set an operation mode to an oil collection mode (S106 in Fig. 6 and S202 in Fig. 7) in which the oil-returned pathway (61) is opened by adjusting a degree of decompression of the first decompressing apparatus (4) and a degree of decompression of the second decompressing apparatus (7) when the refrigerant and a refrigerating machine oil flowing in the first circulation pathway are separated in the oil separator (3).

FIG.2



Description

TECHNICAL FIELD

[0001] The present disclosure relates to a refrigeration cycle apparatus.

BACKGROUND ART

[0002] There has been conventionally known a refrigeration cycle apparatus comprising an oil separator configured to separate a refrigerating machine oil, which is discharged from a compressor together with a refrigerant, from the refrigerant. For example, PTL 1 describes that a refrigerating machine oil is separated to be located on the upper side with respect to a refrigerant in an oil separator provided on the outlet side of a condenser and is returned to a compressor via a capillary tube.

CITATION LIST

PATENT LITERATURE

[0003] PTL 1: Japanese Patent Laying-Open No. 08-086519

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0004] When the oil separator is provided on the outlet side of the condenser rather than on the discharge side of the compressor, performance of refrigeration cycle can be prevented from being decreased due to discharge pressure loss, advantageously. However, when the temperature of the refrigerant flowing into the oil separator is too high, the refrigerant and the refrigerating machine oil are not sufficiently separated in the oil separator. In this case, the refrigerant flows out to an oil-returned pathway extending from the oil separator to the compressor, thus resulting in low efficiency of collecting the refrigerating machine oil.

[0005] It is an object of the present disclosure to provide a refrigeration cycle apparatus to improve efficiency of collecting a refrigerating machine oil.

SOLUTION TO PROBLEM

[0006] The present disclosure is directed to a refrigeration cycle apparatus comprising: a compressor; a first heat exchanger; a second heat exchanger; a first decompressing apparatus; an oil separator; a first circulation pathway in which a refrigerant circulates in an order of the compressor, the first heat exchanger, the oil separator, the first decompressing apparatus, and the second heat exchanger; an oil-returned pathway connecting between the oil separator and a suction side of the compressor; a second decompressing apparatus provided in

the oil-returned pathway; and a controller configured to control the first decompressing apparatus and the second decompressing apparatus, the controller being configured to set an operation mode to an oil collection mode in which the oil-returned pathway is opened by adjusting a degree of decompression of the first decompressing apparatus and a degree of decompression of the second decompressing apparatus when the refrigerant and a refrigerating machine oil flowing in the first circulation pathway are separated in the oil separator.

ADVANTAGEOUS EFFECTS OF INVENTION

[0007] According to the present disclosure, a refrigeration cycle apparatus can be provided to improve efficiency of collecting a refrigerating machine oil.

BRIEF DESCRIPTION OF DRAWINGS

[0008]

Fig. 1 is a diagram showing a configuration of a refrigeration cycle apparatus according to a first embodiment (normal mode).

Fig. 2 is a diagram showing the configuration of the refrigeration cycle apparatus according to the first embodiment (oil collection mode).

Fig. 3 is a graph showing a relation between a separation temperature and a saturation solubility ratio of the refrigerating machine oil.

Fig. 4 is a diagram showing a structure of an oil separator functioning as a liquid-liquid separator.

Fig. 5 is a p-h diagram showing a state change of a refrigerant in the refrigeration cycle apparatus according to the first embodiment.

Fig. 6 is a flowchart showing control for switching between the normal mode and the oil collection mode at the time of starting.

Fig. 7 is a flowchart showing control for switching between the normal mode and the oil collection mode during an operation.

Fig. 8 is a flowchart showing control in the normal mode.

Fig. 9 is a flowchart showing control in the oil collection mode.

Fig. 10 is a diagram showing a configuration of a refrigeration cycle apparatus according to a second embodiment (oil collection mode).

Fig. 11 is a p-h diagram showing a state change of a refrigerant in the refrigeration cycle apparatus according to the second embodiment.

Fig. 12 is a diagram showing a configuration of a refrigeration cycle apparatus according to a third embodiment.

Fig. 13 is a diagram showing a structure of an oil separator functioning as a gas-liquid separator.

Fig. 14 is a p-h diagram showing a state change of a refrigerant in the refrigeration cycle apparatus ac-

cording to the third embodiment.

Fig. 15 is a diagram showing a configuration of a refrigeration cycle apparatus according to a fourth embodiment (oil collection mode).

Fig. 16 is a flowchart showing control in the normal mode according to the fourth embodiment.

Fig. 17 is a flowchart showing control in the oil collection mode according to the fourth embodiment.

DESCRIPTION OF EMBODIMENTS

[0009] Hereinafter, embodiments of the present disclosure will be described in detail with reference to figures. It should be noted that in the figures, the same or corresponding portions are denoted by the same reference characters, and will not be described repeatedly.

First Embodiment.

[0010] Each of Figs. 1 and 2 is a diagram showing a configuration of a refrigeration cycle apparatus 100 according to a first embodiment. Solid-line arrows shown in each of Figs. 1 and 2 represent a direction in which a refrigerant flows. Broken-line arrows shown in Figs. 1 and 2 represent a direction in which a refrigerating machine oil flows. Fig. 1 shows the flows of the refrigerant and the refrigerating machine oil when refrigeration cycle apparatus 100 is operated in a normal mode. Fig. 2 shows the flows of the refrigerant and the refrigerating machine oil when refrigeration cycle apparatus 100 is operated in an oil collection mode.

[0011] Circuit configuration and operation of refrigeration cycle apparatus 100 will be described with reference to Fig. 1. Refrigeration cycle apparatus 100 comprises a refrigerant circuit 10 and a controller 80 configured to control refrigerant circuit 10.

<Configuration of Refrigerant Circuit 10>

[0012] Refrigerant circuit 10 comprises a compressor 1, a first heat exchanger 2, an oil separator 3, a first decompressing apparatus 4, a second heat exchanger 5, a second decompressing apparatus 7, and refrigerant tubes 60 that connect them together. Of refrigerant tubes 60, a tube connecting between oil separator 3 and second decompressing apparatus 7 is referred to as an oil-returned tube 61. For ease of description, symbols a, b, c, and d indicating respective positions of refrigerant tubes 60 are provided in Fig. 1.

[0013] In refrigerant circuit 10, a refrigerant such as chlorofluorocarbon circulates. Ammonia, carbon dioxide, propane, or the like may be used as a refrigerant other than chlorofluorocarbon. A first circulation pathway in which the refrigerant circulates is constituted of a circulation pathway in which the refrigerant circulates in the order of compressor 1, first heat exchanger 2, oil separator 3, first decompressing apparatus 4, second heat exchanger 5, and compressor 1. An oil-returned pathway

is constituted of a pathway returning from oil separator 3 to compressor 1 via oil-returned tube 61 and second decompressing apparatus 7.

[0014] Compressor 1 circulates the refrigerant in refrigerant circuit 10 by increasing the pressure of the suctioned refrigerant and then discharging the refrigerant. The refrigerating machine oil is sealed in compressor 1. The refrigerating machine oil serves to attain a lubrication function, a sealing function, an corrosion prevention function, and the like for compressor 1. A first temperature sensor 51 configured to detect a discharge temperature of the refrigerant is provided on the discharge side of the compressor 1.

[0015] First heat exchanger 2 exchanges heat between outdoor air and the refrigerant flowing in first heat exchanger 2. High-temperature and high-pressure refrigerant in a gaseous state flows from compressor 1 to first heat exchanger 2. Accordingly, first heat exchanger 2 is provided with a second temperature sensor 52 configured to detect a condensation temperature of the refrigerant.

[0016] First decompressing apparatus 4 comprises a pressure reducing valve (not shown) to adjust a degree of decompression, and has a function of adjusting a degree of opening of the pressure reducing valve. First decompressing apparatus 4 adjusts flow rate and pressure of the refrigerant by adjusting the degree of opening of the pressure reducing valve. As the degree of opening of the pressure reducing valve of first decompressing apparatus 4 is smaller, a decompressing effect is higher.

[0017] Second heat exchanger 5 exchanges heat between the outdoor air and the refrigerant flowing in second heat exchanger 5. Low-temperature and low-pressure refrigerant in a liquid state flows from first decompressing apparatus 4 into second heat exchanger 5. Accordingly, second heat exchanger 5 functions as an evaporator. Second heat exchanger 5 is provided with a third temperature sensor 53 configured to detect an evaporation temperature of the refrigerant.

[0018] Oil separator 3 has a function of returning the refrigerating machine oil to compressor 1 when the refrigerant and the refrigerating machine oil are separated in oil separator 3. Generally, when compressor 1 discharges the high-pressure refrigerant gas, part of the refrigerating machine oil sealed in compressor 1 is discharged together with the high-pressure refrigerant gas. Oil separator 3 is used to separate the refrigerating machine oil, which is discharged from compressor 1, from the refrigerant and return it to compressor 1. Oil separator 3 guides the refrigerant to first decompressing apparatus 4, and guides the refrigerating machine oil to second decompressing apparatus 7 via oil-returned tube 61.

<Configuration of Controller 80>

[0019] Controller 80 comprises a control board 81. A processor 82 and a memory 83 are mounted on control board 81. Processor 82 executes operating system and

application programs stored in memory 83. Processor 82 executes an application program and makes reference to various types of data stored in memory 83. Memory 83 stores respective detection values of first temperature sensor 51, second temperature sensor 52, and third temperature sensor 53 provided in refrigerant circuit 10.

[0020] Memory 83 comprises, for example, a ROM (Read Only Memory), a RAM (Random Access Memory), and a flash memory. The flash memory stores the operating system and the application programs.

[0021] Based on the detection values of first temperature sensor 51, second temperature sensor 52, and third temperature sensor 53, controller 80 determines a state of separation between the refrigerant and the refrigerating machine oil flowing in refrigerant tube 60. Specifically, based on the detection values of first temperature sensor 51, second temperature sensor 52, and third temperature sensor 53, controller 80 determines whether or not the temperature of the refrigerant in oil separator 3 is equal to or less than a separation temperature of the refrigerating machine oil.

[0022] When it is determined that the temperature of the refrigerant in oil separator 3 is equal to or less than the separation temperature of the refrigerating machine oil, controller 80 controls the degree of opening of the pressure reducing valve of first decompressing apparatus 4 and the degree of opening of the pressure reducing valve of second decompressing apparatus 7 so as to switch the operation mode of refrigeration cycle apparatus 100 from the normal mode to the oil collection mode. In the oil collection mode, the refrigerating machine oil separated to be located on the upper side with respect to the refrigerant in oil separator 3 is returned to compressor 1 via second decompressing apparatus 7.

<Relation between Separation Temperature of Refrigerating Machine Oil and Saturation Solubility Ratio>

[0023] Fig. 3 is a graph showing a relation between the separation temperature and saturation solubility ratio of the refrigerating machine oil. The saturation solubility ratio of the refrigerating machine oil with respect to the refrigerant is determined by a type of the refrigerant and a type of the refrigerating machine oil. Fig. 3 shows a relation between the separation temperature and saturation solubility ratio of the refrigerating machine oil when the refrigerating machine oil and the refrigerant in the present embodiment are used. Generally, as the temperature of the refrigerant is lower, the saturation solubility ratio of the refrigerating machine oil with respect to the refrigerant is smaller. As shown in Fig. 3, by determining the saturation solubility ratio serving as a reference, the separation temperature with respect to the saturation solubility ratio is found.

[0024] In the first embodiment, the separation temperature of the refrigerating machine oil is specified in advance with reference to the graph shown in Fig. 3. The data of the separation temperature is stored in memory

83 of controller 80. Controller 80 uses the data of the separation temperature stored in memory 83 to determine whether to set the operation mode of refrigeration cycle apparatus 100 to the normal mode or the oil collection mode.

<Normal Mode>

[0025] The normal mode will be described with reference to Fig. 1. The normal mode is a mode in which compressor 1, first heat exchanger 2, second heat exchanger 5, first decompressing apparatus 4, second decompressing apparatus 7, and the like are controlled to attain discharge temperature and pressure corresponding to target performance of refrigeration cycle apparatus 100. In the normal mode of the first embodiment, the refrigerant circulates in the order of compressor 1, first heat exchanger 2, oil separator 3, first decompressing apparatus 4, and second heat exchanger 5.

[0026] In the normal mode, controller 80 adjusts the degree of opening of the pressure reducing valve of first decompressing apparatus 4 to attain the discharge temperature and pressure corresponding to the target performance of refrigeration cycle apparatus 100.

[0027] In the normal mode, controller 80 decreases the degree of opening of the pressure reducing valve of second decompressing apparatus 7 to reduce an amount of the refrigerant flowing from oil separator 3 into oil-returned tube 61. As a result, the degree of decompression of second decompressing apparatus 7 becomes high. Desirably, controller 80 decreases the degree of opening of the pressure reducing valve of second decompressing apparatus 7 to close the oil-returned pathway extending from oil-returned tube 61 to compressor 1 via second decompressing apparatus 7. That is, the degree of opening of the pressure reducing valve of second decompressing apparatus 7 is set to 0%. Thus, the refrigerant can be blocked from flowing to compressor 1 via the oil-returned pathway. As a result, the amount of refrigerant supplied to second heat exchanger 5 via oil separator 3 can be prevented from being decreased. It should be noted that the degree of opening of the pressure reducing valve of second decompressing apparatus 7 does not necessarily need to be reduced to 0%, and may be set to a degree of opening by which part of the refrigerant can be prevented from flowing into the oil-returned pathway.

<Oil Collection Mode>

[0028] Referring to Fig. 2, the oil collection mode will be described. The oil collection mode is a mode in which the refrigerating machine oil separated to be located on the upper side with respect to the refrigerant in oil separator 3 is returned to compressor 1 via oil-returned tube 61. In the oil collection mode, the degree of opening of the pressure reducing valve of first decompressing apparatus 4 is less than that in the normal mode, whereas

the degree of opening of the pressure reducing valve of second decompressing apparatus 7 is more than that in the normal mode. As a result, the degree of decompression of first decompressing apparatus 4 is more than that in the normal mode, and the degree of decompression of second decompressing apparatus 7 is less than that in the normal mode.

[0029] This promotes the flow of the refrigerating machine oil from oil separator 3 to oil-returned tube 61. Desirably, second decompressing apparatus 7 sets the degree of opening of the pressure reducing valve to 100%. However, the degree of opening of the pressure reducing valve of second decompressing apparatus 7 is not necessarily required to be increased to 100%, and may be a degree of opening by which the flow of the refrigerating machine oil from oil separator 3 into oil-returned tube 61 is promoted.

[0030] In the oil collection mode, by decreasing the degree of opening of the pressure reducing valve of first decompressing apparatus 4, the decompressing effect by first decompressing apparatus 4 is improved more than that in the normal mode. As a result, the temperature of the refrigerant flowing from first heat exchanger 2 into oil separator 3 is decreased. Thus, the temperature of the refrigerant mixed with the refrigerating machine oil can be more securely decreased to the separation temperature of the refrigerating machine oil. As a result, separation between the refrigerant and the refrigerating machine oil is promoted. Therefore, efficiency of collecting the refrigerating machine oil can be increased. The degree of opening of the pressure reducing valve of first decompressing apparatus 4 in the oil collection mode can be appropriately determined in consideration of the effect of decreasing the temperature of the refrigerant.

[0031] According to the first embodiment, by adjusting the degree of decompression of first decompressing apparatus 4, the flow of the refrigerating machine oil from oil separator 3 into oil-returned tube 61 can be promoted and the temperature of the refrigerant mixed with the refrigerating machine oil can be securely made less than the separation temperature of the refrigerating machine oil. It should be noted that decompressing apparatus 7 may be constituted of an electromagnetic valve that changes oil-returned tube 61 between an opened state and a closed state.

[0032] The refrigerating machine oil separated to be located on the upper side with respect to the refrigerant in oil separator 3 is returned to compressor 1 via second decompressing apparatus 7. On the other hand, the refrigerant from oil separator 3 is decompressed in first decompressing apparatus 4 and flows into second heat exchanger 5. The refrigerant having flowed into second heat exchanger 5 exchanges heat with the outdoor air, and then is returned to compressor 1.

<Structure of Oil Separator>

[0033] Fig. 4 is a diagram showing a structure of oil

separator 3 functioning as a liquid-liquid separator. Oil separator 3 has a main body portion 31 in which the refrigerant and the refrigerating machine oil are accumulated. Main body portion 31 is provided with a first tube 32, a second tube 33, and a third tube 34, each of which communicates with main body portion 31. First tube 32 is connected to refrigerant tube 60 extending from first heat exchanger 2 to oil separator 3. Second tube 33 is connected to refrigerant tube 60 extending from first decompressing apparatus 4 to oil separator 3. Third tube 34 is connected to refrigerant tube 60 extending from second decompressing apparatus 7 to oil separator 3.

[0034] First tube 32 is provided at a lower portion of main body portion 31. Therefore, when the refrigerant in the liquid state and the refrigerating machine oil flow from first tube 32 into main body portion 31, the refrigerant and the refrigerating machine oil are separated from each other due to a density difference between the refrigerant and the refrigerating machine oil. As a result, a boundary surface 41 between the refrigerant and the refrigerating machine oil is formed in main body portion 31. The refrigerating machine oil is separated to be located on the upper side with respect to the refrigerant. Since third tube 34 is provided at an upper portion of main body portion 31, the refrigerating machine oil separated to be located on the upper side with respect to the refrigerant can be guided to second decompressing apparatus 7. Second tube 33 is provided in main body portion 31 at a position higher than first tube 32. The refrigerant in the liquid state separated to be located on the lower side with respect to the refrigerating machine oil is guided to first decompressing apparatus 4 via second tube 33.

<P-H Diagram>

[0035] Fig. 5 is a p-h diagram showing a state change of the refrigerant in the refrigeration cycle apparatus according to the first embodiment. In Fig. 5, the horizontal axis represents a specific enthalpy. The vertical axis in Fig. 5 represents a pressure. In Fig. 5, L1 represents a saturation liquid line and a saturation vapor line of the refrigerant, and L2 and L3 represent state changes of the refrigerant circulating in refrigerant circuit 10. Symbols a to d represent states of the refrigerant at the respective positions of symbols a to d in refrigerant circuit 10 shown in Fig. 1. Symbols b' and c' represent states of the refrigerant at the respective positions of symbols b' and c' in refrigerant circuit 10 shown in Fig. 2.

[0036] In the normal mode, refrigeration cycle apparatus 100 is operated in the following refrigeration cycle as shown in Fig. 5: a→b→c→d→a. On the other hand, in the oil collection mode, the degree of opening of the pressure reducing valve of first decompressing apparatus 4 is decreased, so that the temperature of the refrigerant flowing from first heat exchanger 2 to oil separator 3 is decreased. Further, the degree of opening of the pressure reducing valve of second decompressing apparatus 7 is increased. For this reason, in the oil collection mode,

refrigeration cycle apparatus 100 is operated in the following refrigeration cycle: $a \rightarrow b' \rightarrow c' \rightarrow d \rightarrow a$.

<Flowchart>

[0037] Fig. 6 is a flowchart showing control for switching between the normal mode and the oil collection mode at the time of starting. When starting refrigeration cycle apparatus 100, controller 80 performs the control based on Fig. 6 so as to switch the operation mode of refrigeration cycle apparatus 100 between the normal mode and the oil collection mode.

[0038] When refrigeration cycle apparatus 100 is started, controller 80 obtains a discharge temperature Td of compressor 1 from first temperature sensor 51 (step S100). Next, controller 80 obtains a condensation temperature CT of first heat exchanger 2 from second temperature sensor 52 (step S101). Next, controller 80 obtains an evaporation temperature ET of second heat exchanger 5 from third temperature sensor 53 (step S102).

[0039] Next, controller 80 calculates a discharge SH (Super Heat) (step S103). Discharge SH is calculated by calculating "discharge temperature Td - condensation temperature CT". Next, controller 80 determines whether or not discharge SH is smaller than a determination value (step S104). The determination value for determining a degree of discharge SH can be appropriately set, and for example, the determination value may be set to 10°C. As discharge SH is larger, the degree of superheat of the refrigerant is higher, and the temperature of the refrigerant can be estimated to be equal to or more than the separation temperature of the refrigerating machine oil. On the other hand, for example, when discharge SH is less than the determination value, the temperature of the refrigerant can be estimated to be less than the separation temperature of the refrigerating machine oil.

[0040] When it is determined in step S104 that discharge SH is less than the determination value, controller 80 performs the operation in the oil collection mode (step S106). In the oil collection mode, controller 80 controls first decompressing apparatus 4 and second decompressing apparatus 7 at degrees of opening determined in accordance with the oil collection mode. Thus, the refrigerating machine oil separated from the refrigerant in oil separator 3 is efficiently collected in compressor 1. The flow of control in the oil collection mode will be described later with reference to Fig. 8.

[0041] On the other hand, when it is determined in step S104 that discharge SH is equal to or more than the determination value, controller 80 determines whether or not evaporation temperature ET is equal to or less than the oil separation temperature (step S105). As the oil separation temperature used for the determination, there may be employed a value corresponding to the saturation solubility ratio serving as a reference determined in advance as described with reference to Fig. 3. When it is determined in step S105 that evaporation temperature ET is equal to or less than the oil separation temperature,

controller 80 performs the operation in the oil collection mode (step S106). On the other hand, when it is determined in step S104 that evaporation temperature ET is more than the oil separation temperature, controller 80 performs the operation in the normal mode (step S107). The flow of control in the normal mode will be described later with reference to Fig. 8.

[0042] It should be noted that instead of determining whether or not discharge SH is less than the determination value in step S104, it may be determined whether or not discharge temperature Td of compressor 1 is less than a determination value. In this case, the magnitude of the determination value to be compared with discharge temperature Td is made different from the magnitude of the determination value to be compared with discharge SH.

[0043] The flowchart shown in Fig. 6 discloses control for performing the operation in the oil collection mode when discharge SH is less than the determination value or evaporation temperature ET is equal to or less than the oil separation temperature at the time of starting. However, when discharge SH is less than the determination value at the time of starting, the operation may be performed in the oil collection mode, and when discharge SH is equal to or more than the determination value, the operation may be performed in the normal mode. Alternatively, when evaporation temperature ET is equal to or less than the oil separation temperature at the time of starting, the operation may be performed in the oil collection mode, and when evaporation temperature ET is more than the oil separation temperature, the operation may be performed in the normal mode.

[0044] Fig. 7 is a flowchart showing control for switching between the normal mode and the oil collection mode during the operation. Controller 80 switches the operation mode of refrigeration cycle apparatus 100 between the normal mode and the oil collection mode by performing the control based on Fig. 7 when the operation is continued after ending the starting of refrigeration cycle apparatus 100.

[0045] First, controller 80 obtains evaporation temperature ET of second heat exchanger 5 from third temperature sensor 53 (step S200). Next, controller 80 determines whether or not evaporation temperature ET is equal to or less than the oil separation temperature (step S201). As the oil separation temperature used in the determination, there may be employed a value corresponding to the saturation solubility ratio serving as a reference determined in advance as described with reference to Fig. 3. When it is determined in step S201 that evaporation temperature ET is equal to or less than the oil separation temperature, controller 80 performs the operation in the oil collection mode (step S202). Details of the control in the oil collection mode will be described later with reference to Fig. 9. On the other hand, when it is determined in step S201 that evaporation temperature ET is more than the oil separation temperature, controller 80 performs the operation in the normal mode (step S203).

Details of the control in the normal mode will be described later with reference to Fig. 8.

<Flow of Control in Normal Mode>

[0046] Fig. 8 is a flowchart showing the control in the normal mode. When refrigeration cycle apparatus 100 is operated in the normal mode, controller 80 controls first decompressing apparatus 4 and second decompressing apparatus 7 as follows. First, controller 80 adjusts the degree of opening of the pressure reducing valve of first decompressing apparatus 4 to attain the discharge temperature and pressure corresponding to the target performance of refrigeration cycle apparatus 100 (step S300).

[0047] Next, controller 80 decreases the degree of opening of the pressure reducing valve of second decompressing apparatus 7 to a first degree of opening (step S301). The first degree of opening is a degree of opening required to decrease an amount of refrigerant flowing from oil separator 3 into oil-returned tube 61 per unit time. For example, the first degree of opening is 0%.

[0048] Controller 80 controls first decompressing apparatus 4 and second decompressing apparatus 7 as in steps S300 and S301, thereby implementing the normal mode. It should be noted that controller 80 may perform step S301 prior to step S300.

<Flow of Control in Oil Collection Mode>

[0049] Fig. 9 is a flowchart showing the control in the oil collection mode. When refrigeration cycle apparatus 100 is operated in the oil collection mode, controller 80 controls first decompressing apparatus 4 and second decompressing apparatus 7 as follows. First, controller 80 decreases the degree of opening of the pressure reducing valve of first decompressing apparatus 4 to a third degree of opening (step S400). The third degree of opening is a degree of opening smaller than the degree of opening of first decompressing apparatus 4 in the normal mode. By decreasing the degree of opening of the pressure reducing valve of first decompressing apparatus 4, the decompressing effect by first decompressing apparatus 4 is improved more than that in the normal mode. As a result, the temperature of the refrigerant flowing from first heat exchanger 2 into oil separator 3 can be decreased.

[0050] Next, controller 80 increases the degree of opening of the pressure reducing valve of second decompressing apparatus 7 to a second degree of opening larger than the first degree of opening (step S401). Thus, the flow of refrigerating machine oil from oil separator 3 into oil-returned tube 61 is promoted. For example, the second degree of opening is 100%.

[0051] Controller 80 controls first decompressing apparatus 4 and second decompressing apparatus 7 as in steps S400 and S401, thereby implementing the oil collection mode. It should be noted that controller 80 may

perform step S401 prior to step S400.

[0052] As described above, refrigeration cycle apparatus 100 according to the first embodiment is operated in the normal mode when it is considered that the refrigerating machine oil is not separated from the refrigerant, and is operated in the oil collection mode when it is considered that the refrigerating machine oil is separated from the refrigerant. It should be noted that controller 80 may implement the oil collection mode by performing only step S401 without performing step 400. That is, by controlling second decompressing apparatus 7 as in step S401, the refrigerating machine oil can flow from oil separator 3 into oil-returned tube 61, thereby implementing the oil collection mode.

[0053] In the normal mode, refrigeration cycle apparatus 100 controls oil-returned tube 61 to come into a closed state or a substantially closed state by adjusting the degree of decompression of first decompressing apparatus 4 and the degree of decompression of second decompressing apparatus 7. In refrigeration cycle apparatus 100, when the refrigerant and the refrigerating machine oil are not separated in oil separator 3, the degree of decompression of first decompressing apparatus 4 and the degree of decompression of second decompressing apparatus 7 are adjusted to implement the normal mode in which the oil-returned pathway is in the substantially closed state or the substantially closed state. Thus, in the normal mode, adjustment can be made to avoid the refrigerant from flowing from oil separator 3 into compressor 1 via oil-returned tube 61. As a result, a sufficient amount of refrigerant can be supplied to second heat exchanger 5.

[0054] On the other hand, in the oil collection mode, refrigeration cycle apparatus 100 can be adjusted to a state in which the oil-returned pathway extending from oil-returned tube 61 to compressor 1 is opened. In refrigeration cycle apparatus 100, when the refrigerant and the refrigerating machine oil are separated in oil separator 3, the degree of decompression of first decompressing apparatus 4 and the degree of decompression of second decompressing apparatus 7 are adjusted to open the oil-returned pathway extending from oil-returned tube 61 to compressor 1. Thus, in the oil collection mode, the flow rate of the refrigerating machine oil from oil separator 3 to compressor 1 via oil-returned tube 61 can be adjusted to be high. As a result, the refrigerating machine oil can be efficiently collected in compressor 1.

Second Embodiment.

[0055] In a second embodiment, a refrigeration cycle apparatus 200 comprising a third heat exchanger 8 will be described.

[0056] Fig. 10 is a diagram showing a configuration of refrigeration cycle apparatus 200 according to the second embodiment. In particular, Fig. 10 shows flows of refrigerant and refrigerating machine oil when refrigeration cycle apparatus 200 is operated in the oil collection

mode. Refrigeration cycle apparatus 200 comprises a refrigerant circuit 20 and a controller 80. Refrigerant circuit 20 comprises third heat exchanger 8 in addition to the configuration of refrigerant circuit 10. Third heat exchanger 8 is provided between a refrigerant tube 60 extending between an outlet b of first heat exchanger 2 and oil separator 3 and a refrigerant tube 60 extending between an outlet g of second decompressing apparatus 7 and a position h located before compressor 1. Third heat exchanger 8 exchanges heat between the refrigerant in refrigerant tube 60 extending between first heat exchanger 2 and oil separator 3 and the refrigerant in refrigerant tube 60 extending between second decompressing apparatus 7 and compressor 1. Therefore, third heat exchanger 8 is an internal heat exchanger configured to exchange heat between parts of the refrigerant flowing in refrigerant circuit 20.

[0057] In refrigeration cycle apparatus 200, in the oil collection mode, as with refrigeration cycle apparatus 100 according to the first embodiment, the degree of opening of the pressure reducing valve of first decompressing apparatus 4 is decreased to be less than that in the normal mode, and the degree of opening of the pressure reducing valve of second decompressing apparatus 7 is increased to be more than that in the normal mode. As a result, in the oil collection mode, the degree of decompression of first decompressing apparatus 4 is increased to be more than that in the normal mode, and the degree of decompression of second decompressing apparatus 7 is decreased to be less than that in the normal mode. Here, the following describes a function of third heat exchanger 8 with reference to Fig. 11.

<P-H Diagram>

[0058] Fig. 11 is a p-h diagram showing a state change of the refrigerant in the refrigeration cycle apparatus according to the second embodiment. Symbols a to h represent states of the refrigerant at the respective positions of symbols a to h in refrigerant circuit 20 shown in Fig. 10. In refrigeration cycle apparatus 200 according to the second embodiment, third heat exchanger 8 is provided at a position shown in Fig. 10. Therefore, heat exchange of the refrigerant is performed in a section between outlet b of first heat exchanger 2 and inlet e of oil separator 3, and in a section between outlet g of second decompressing apparatus 7 and outlet h of third heat exchanger 8. Therefore, in oil-returned tube 61, the state of the refrigerant is changed as shown in Fig. 11 as follows: e→g→h.

[0059] Further, in refrigerant tube 60 extending from oil separator 3 to first decompressing apparatus 4, the state of the refrigerant is changed as shown in Fig. 11 as follows: e→c→f. The refrigerant having flowed into second heat exchanger 5 is merged at position d with the refrigerant having flowed through third heat exchanger 8, and is then returned to compressor 1. In Fig. 11, a broken line connecting between b and e and a broken line connecting between g and h indicate that heat ex-

change is performed between the section from b to e and the section from g to h.

[0060] The refrigerant having flowed out from outlet b of first heat exchanger 2 is cooled by third heat exchanger 8 before flowing into inlet e of oil separator 3. Therefore, the temperature of the refrigerant flowing from first heat exchanger 2 to oil separator 3 is further decreased, thus resulting in an improved degree of separation of the refrigerating machine oil from the refrigerant. According to the second embodiment, since the degree of separation of the refrigerating machine oil in oil separator 3 can be improved, the refrigerating machine oil can be more efficiently collected in compressor 1.

[0061] It should be noted that refrigeration cycle apparatus 200 according to the second embodiment can be operated in the normal mode by performing the same control as that of refrigeration cycle apparatus 100 according to the first embodiment, and can switch the operation mode between the normal mode and the oil collection mode.

Third Embodiment.

[0062] In a third embodiment, the following describes a refrigeration cycle apparatus 300 obtained by providing a four-way valve 11 in refrigeration cycle apparatus 200 according to the second embodiment.

[0063] Fig. 12 is a diagram showing a configuration of refrigeration cycle apparatus 300 according to the third embodiment. Refrigeration cycle apparatus 300 comprises a refrigerant circuit 30 and a controller 80. Refrigerant circuit 30 comprises a four-way valve 11 in addition to the configuration of refrigerant circuit 20 according to the second embodiment. Four-way valve 11 is provided on the discharge side of compressor 1. Further, refrigerant circuit 30 comprises a fourth temperature sensor 54 in addition to the configuration of refrigerant circuit 20. Four-way valve 11 replaces a destination to which the discharge port of compressor 1 is connected with a destination to which the suction port of compressor 1 is connected. By switching the manner of connection of four-way valve 11, the heat exchanger connected to the discharge side of compressor 1 can be switched between second heat exchanger 5 and first heat exchanger 2.

[0064] Fig. 12 shows an example in which second heat exchanger 5 is connected to the discharge side of compressor 1. Since second heat exchanger 5 is connected to the discharge side of compressor 1, the refrigerant flows in a direction toward first decompressing apparatus 4 through compressor 1 and second heat exchanger 5. Thus, a second circulation pathway for circulating the refrigerant in the order of compressor 1, second heat exchanger 5, first decompressing apparatus 4, oil separator 3, first heat exchanger 2, and compressor 1 is formed. Accordingly, first heat exchanger 2 functions as an evaporator, and second heat exchanger 5 functions as a condenser.

[0065] Refrigeration cycle apparatus 300 according to

the third embodiment controls compressor 1, first heat exchanger 2, second heat exchanger 5, first decompressing apparatus 4, second decompressing apparatus 7, and the like to attain the discharge temperature and target pressure corresponding to the target performance in the normal mode. It should be noted that when second heat exchanger 5 is connected to the discharge side of compressor 1 as shown in Fig. 12, the direction of circulation of the refrigerant is opposite to that in refrigeration cycle apparatus 100 according to the first embodiment.

[0066] The refrigerant discharged from compressor 1 flows into second heat exchanger 5 together with the refrigerating machine oil. The refrigerant condensed in second heat exchanger 5 flows into first decompressing apparatus 4, is decompressed, and then flows into oil separator 3. Therefore, the refrigerant in a gas-liquid two-phase state and the refrigerating machine oil flow from first decompressing apparatus 4 to oil separator 3. On this occasion, oil separator 3 functions as a gas-liquid separator configured to separate the refrigerant in the liquid state and the refrigerant in the gaseous state. The function of oil separator 3 as a gas-liquid separator will be described with reference to Fig. 13.

[0067] Fig. 13 is a diagram showing a structure of oil separator 3 functioning as a gas-liquid separator. The refrigerant in the gas-liquid two-phase state and the refrigerating machine oil flow from first decompressing apparatus 4 into main body portion 31 of oil separator 3 via second tube 33. The refrigerant in the gaseous state is moved to an upper portion of main body portion 31. The refrigerant in the liquid state and the refrigerating machine oil are moved to a lower portion of main body portion 31. Therefore, the refrigerant in the gaseous state and the refrigerant in the liquid state are separated in oil separator 3. As a result, a boundary surface 42 between the refrigerant in the gaseous state and the refrigerant in the liquid state is formed in main body portion 31. It should be noted that boundary surface 42 illustrated in the figure is conceptual, and actually the refrigerant in the gaseous state and the refrigerant in the liquid state are both present at the boundary. The refrigerant in the gaseous state having been moved to the upper portion of main body portion 31 is guided from third tube 34 to second decompressing apparatus 7 via oil-returned tube 61 shown in Fig. 12. Thus, oil-returned tube 61 functions as a gas injection circuit. The refrigerant in the liquid state having been moved to the lower portion of main body portion 31 is guided to third heat exchanger 8 via first tube 32.

[0068] Referring to Fig. 12 again, a function of third heat exchanger 8 will be described. The refrigerant in the gaseous state separated in oil separator 3 is decompressed by second decompressing apparatus 7 and is therefore cooled. The cooled refrigerant passes through third heat exchanger 8 and then is returned to compressor 1. Fourth temperature sensor 54 is provided at the outlet portion of third heat exchanger 8. Fourth temperature sensor 54 detects the temperature of the refrigerant

at the outlet portion of third heat exchanger 8. The detected temperature of the refrigerant is input to controller 80.

[0069] On the other hand, the refrigerant in the liquid state separated in oil separator 3 flows into third heat exchanger 8 before flowing into first heat exchanger 2. Therefore, in third heat exchanger 8, the refrigerant flowing from oil separator 3 to first heat exchanger 2 is cooled by the refrigerant flowing from second decompressing apparatus 7 to compressor 1. As a result, when the refrigerant flowing from oil separator 3 to first heat exchanger 2 comprises a small amount of refrigerant in the gaseous state, the refrigerant flowing from second decompressing apparatus 7 to compressor 1 moistens the refrigerant in the gaseous state.

[0070] Controller 80 adjusts the degree of opening of the pressure reducing valve of second decompressing apparatus 7 based on the temperature detected by fourth temperature sensor 54, so as to control the temperature of the refrigerant flowing from second decompressing apparatus 7 to compressor 1. Thus, the degree of cooling of the refrigerant flowing from oil separator 3 to first heat exchanger 2 is adjusted. As a result, the state of the refrigerant flowing from oil separator 3 to first heat exchanger 2 can be controlled to be an ideal state in the refrigeration cycle.

<P-H Diagram>

[0071] Fig. 14 is a p-h diagram showing a state change of the refrigerant in the refrigeration cycle apparatus according to the third embodiment. Symbols a to j indicate states of the refrigerant at the respective positions of symbols a to j in refrigerant circuit 30 shown in Fig. 12. In refrigerant circuit 30 of Fig. 12, compressor 1 discharges high-temperature and high-pressure refrigerant to its discharge side f. It should be noted that part of the refrigerating machine oil is discharged from compressor 1 together with the refrigerant. The refrigerant discharged from compressor 1 to discharge side f flows into second heat exchanger 5 functioning as a condenser. As a result, the refrigerant transitions from state f to state c as shown in Fig. 14.

[0072] Further, the refrigerant flows into first decompressing apparatus 4 and is decompressed. As a result, the refrigerant transitions to state i as shown in Fig. 14, and is brought into the gas-liquid two-phase state. The refrigerant in the gas-liquid two-phase state flows into oil separator 3 functioning as a gas-liquid separator together with the refrigerating machine oil. In oil separator 3, the refrigerant in the gas state is separated to be located on the upper side, and the refrigerant in the liquid state is separated to be located on the lower side. It should be noted that the refrigerating machine oil having flowed into oil separator 3 is separated to be located on the lower side of oil separator 3 together with the refrigerant in the liquid state.

[0073] The refrigerant in the gaseous state separated

to be located on the upper side of oil separator 3 flows out from oil separator 3, flows into second decompressing apparatus 7, and is decompressed. Thus, the refrigerant in the gas state separated to be located on the upper side of oil separator 3 transitions from state j to state g as shown in Fig. 14. The refrigerant having transitioned to state g flows to third heat exchanger 8. On the other hand, the refrigerant in the liquid state separated to be located on the lower side of oil separator 3 flows out from oil separator 3 to third heat exchanger 8. The refrigerant on this occasion is in state j as shown in Fig. 14.

[0074] The refrigerant in state g and the refrigerant in state e exchange heat in third heat exchanger 8. As a result, the state of the former refrigerant transitions from g to h, and the state of the latter refrigerant transitions from e to b. The refrigerant in state h flows to compressor 1. On the other hand, the refrigerant in state b flows to first heat exchanger 2 functioning as an evaporator. Third heat exchanger 8 can transition the state of the refrigerant flowing to first heat exchanger 2 from e to b, thereby improving heat transfer performance of first heat exchanger 2. It should be noted that the refrigerant discharged from first heat exchanger 2 is in state a as shown in Fig. 14.

[0075] It should be noted that in the third embodiment, when the connection of four-way valve 11 is switched to connect first heat exchanger 2 to the discharge side of compressor 1, first heat exchanger 2 functions as a condenser and second heat exchanger 5 functions as an evaporator. The flows of the refrigerant and the refrigerating machine oil in this case has been already described with reference to Fig. 10, and therefore will not be described repeatedly here. Also, since the operation of refrigerant circuit 30 comprising third heat exchanger 8 is the same as the operation of refrigerant circuit 20 described with reference to Fig. 10, the operation of refrigerant circuit 30 will not be described repeatedly here. It should be noted that in refrigeration cycle apparatus 300, oil separator 3 functions as a liquid-liquid separator configured to separate the refrigerating machine oil and the refrigerant in the liquid state as in the second embodiment.

Fourth Embodiment.

[0076] In a fourth embodiment, the following describes a refrigeration cycle apparatus 400 obtained by providing a third decompressing apparatus 12 in refrigeration cycle apparatus 300 according to the third embodiment. In refrigeration cycle apparatus 300 described above, four-way valve 11 replaces a destination to which the discharge port of compressor 1 is connected with a destination to which the suction port of compressor 1 is connected, thereby changing the function of oil separator 3 between the liquid-liquid separator and the gas-liquid separator. On the other hand, in refrigeration cycle apparatus 400 according to the fourth embodiment, oil separator 3 functions as a liquid-liquid separator regardless of the manner of switching of four-way valve 11. Hereinafter, the fourth embodiment will be described in detail with reference to figures.

arator 3 functions as a liquid-liquid separator regardless of the manner of switching of four-way valve 11. Hereinafter, the fourth embodiment will be described in detail with reference to figures.

[0077] Fig. 15 is a diagram showing a configuration of refrigeration cycle apparatus 400 according to the fourth embodiment. Refrigeration cycle apparatus 400 comprises a refrigerant circuit 40 and a controller 80. Refrigerant circuit 40 comprises third decompressing apparatus 12 in addition to the configuration of refrigerant circuit 30. Third decompressing apparatus 12 is provided at a certain portion of a refrigerant tube 60 connecting between oil separator 3 and first heat exchanger 2. More specifically, third decompressing apparatus 12 is located between oil separator 3 and third heat exchanger 8.

<Case Where Second Heat Exchanger 5 is Connected to Discharge Side of Compressor 1>

[0078] Fig. 15 shows an example in which second heat exchanger 5 is connected to the discharge side of compressor 1 by four-way valve 11. Since second heat exchanger 5 is connected to the discharge side of compressor 1, the refrigerant flows in a direction toward first decompressing apparatus 4 through compressor 1 and second heat exchanger 5. Thus, first heat exchanger 2 functions as an evaporator, and second heat exchanger 5 functions as a condenser. Third decompressing apparatus 12 is located on the downstream side with respect to oil separator 3 in the direction of flow of the refrigerant and is located on the upstream side with respect to first heat exchanger 2 functioning as an evaporator. Such an arrangement of third decompressing apparatus 12 is the same as the arrangement of first decompressing apparatus 4 of refrigeration cycle apparatus 100 (see Fig. 1) according to the first embodiment. That is, in refrigerant circuit 10 shown in Fig. 1, first decompressing apparatus 4 is located on the downstream side with respect to oil separator 3 in the direction of flow of the refrigerant and is located on the upstream side with respect to second heat exchanger 5 functioning as an evaporator.

[0079] For comparison, assuming that there is no first decompressing apparatus 4 shown in Fig. 15, it will be more readily understood that the flow of the refrigerant in the order of second heat exchanger (condenser) 5, oil separator 3, third decompressing apparatus 12, and first heat exchanger (evaporator) 2 in refrigerant circuit 40 corresponds to the flow of the refrigerant in the order of first heat exchanger (condenser) 2, oil separator 3, first decompressing apparatus 4, and second heat exchanger (evaporator) 5 in refrigerant circuit 10. Further, refrigerant circuit 10 and refrigerant circuit 40 are the same in that oil separator 3 and the suction side of compressor 1 are connected together via second decompressing apparatus 7.

[0080] As understood from these circuit configurations, as with refrigeration cycle apparatus 100 (see Fig. 2) according to the first embodiment, refrigeration cycle ap-

paratus 400 shown in Fig. 15 can implement the oil collection mode when the refrigerant flows as shown in the figure.

[0081] Specifically, the oil collection mode can be implemented by adjusting the decompressing effect of first decompressing apparatus 4 to be negligible by maximizing the degree of opening of the pressure reducing valve of first decompressing apparatus 4, and adjusting the degree of opening of the pressure reducing valve of second decompressing apparatus 7 and the degree of opening of the pressure reducing valve of third decompressing apparatus 12. Each of the degrees of opening of the pressure reducing valves of first decompressing apparatus 4, second decompressing apparatus 7, and third decompressing apparatus 12 is adjusted by controller 80 of refrigeration cycle apparatus 400.

[0082] The degree of opening of the pressure reducing valve of third decompressing apparatus 12 may be adjusted in accordance with the degree of opening of the pressure reducing valve of first decompressing apparatus 4 for implementing the oil collection mode according to the first embodiment. The degree of opening of the pressure reducing valve of second decompressing apparatus 7 may be adjusted in accordance with the degree of opening of the pressure reducing valve of second decompressing apparatus 7 for implementing the oil collection mode according to the first embodiment. It should be noted that the degree of opening of the pressure reducing valve of first decompressing apparatus 4 in the oil collection mode is not necessarily required to be adjusted to the maximum degree of opening as long as the degree of decompression is negligible. The flow of control in the oil collection mode will be described later with reference to Fig. 17.

[0083] Further, refrigeration cycle apparatus 400 shown in Fig. 15 can implement the normal mode in the same manner as in refrigeration cycle apparatus 100 (see Fig. 1) according to the first embodiment when the refrigerant flows as shown in the figure.

[0084] Specifically, the normal mode can be implemented by adjusting the decompressing effect of first decompressing apparatus 4 to be negligible by maximizing the degree of opening of the pressure reducing valve of first decompressing apparatus 4, and adjusting the degree of opening of the pressure reducing valve of third decompressing apparatus 12 and the degree of opening of the pressure reducing valve of second decompressing apparatus 7. Each of the degrees of opening of the pressure reducing valves of first decompressing apparatus 4, second decompressing apparatus 7, and third decompressing apparatus 12 is adjusted by controller 80 of refrigeration cycle apparatus 400.

[0085] The degree of opening of the pressure reducing valve of third decompressing apparatus 12 may be adjusted in accordance with the degree of opening of the pressure reducing valve of first decompressing apparatus 4 for implementing the normal mode according to the first embodiment. The degree of opening of the pressure

reducing valve of second decompressing apparatus 7 may be adjusted in accordance with the degree of opening of the pressure reducing valve of second decompressing apparatus 7 for implementing the normal mode according to the first embodiment. It should be noted that the degree of opening of the pressure reducing valve of first decompressing apparatus 4 in the normal mode is not necessarily required to be adjusted to the maximum degree of opening as long as the degree of decompression is negligible. The flow of control in the normal mode will be described later with reference to Fig. 16.

[0086] As with refrigeration cycle apparatus 100 according to the first embodiment, refrigeration cycle apparatus 400 shown in Fig. 15 can switch the operation mode between the normal mode and the oil collection mode when the refrigerant flows as shown in the figure. The flow of control in refrigeration cycle apparatus 400 to switch the operation mode between the normal mode and the oil collection mode corresponds to the flow of control shown in each of Figs. 6 and 7.

[0087] It should be noted that in refrigeration cycle apparatus 400, the temperature detected by second temperature sensor 52 is evaporation temperature ET of first heat exchanger 2 functioning as an evaporator, and the temperature detected by third temperature sensor 53 is condensation temperature CT of second heat exchanger 5 functioning as a condenser. Therefore, when refrigeration cycle apparatus 400 performs the control in accordance with the flowchart of Fig. 6 or 7, condensation temperature CT is obtained from the detection value of third temperature sensor 53 in step S101, and evaporation temperature ET is obtained from the detection value of second temperature sensor 52 in each of steps S102 and S200.

<Flow of Control in Normal Mode (Fourth Embodiment)>

[0088] Fig. 16 is a flowchart showing the control in the normal mode. In particular, this flowchart is directed to the control in the normal mode when second heat exchanger 5 is connected to the discharge side of compressor 1 as shown in Fig. 15.

[0089] When refrigeration cycle apparatus 400 in a state in which second heat exchanger 5 is connected to the discharge side of compressor 1 is operated in the normal mode, controller 80 controls first decompressing apparatus 4, second decompressing apparatus 7, and third decompressing apparatus 12 as follows. First, controller 80 sets the degree of opening of the pressure reducing valve of first decompressing apparatus 4 to maximum (100%) (step S500). Thus, the decompression effect of first decompressing apparatus 4 is negligible.

[0090] Next, controller 80 decreases the degree of opening of the pressure reducing valve of second decompressing apparatus 7 to the first degree of opening (step S501). The first degree of opening is a degree of opening necessary to decrease an amount of refrigerant flowing from oil separator 3 into oil-returned tube 61. For

example, the first degree of opening is 0%.

[0091] Next, controller 80 adjusts the degree of opening of the pressure reducing valve of first decompressing apparatus 4 to attain discharge temperature and pressure corresponding to target performance of refrigeration cycle apparatus 400 (step S502).

[0092] Controller 80 controls first decompressing apparatus 4, second decompressing apparatus 7, and third decompressing apparatus 12 to implement the normal mode as in steps S500 to S502. The order in which controller 80 performs steps S500 to S502 may be changed to any order.

<Flow of Control in Oil Collection Mode (Fourth Embodiment)>

[0093] Fig. 17 is a flowchart showing the control in the oil collection mode. In particular, this flowchart is directed to the control in the oil collection mode when second heat exchanger 5 is connected to the discharge side of compressor 1 as shown in Fig. 15.

[0094] When refrigeration cycle apparatus 400 in the state in which second heat exchanger 5 is connected to the discharge side of compressor 1 is operated in the oil collection mode, controller 80 controls first decompressing apparatus 4, second decompressing apparatus 7, and third decompressing apparatus 12 as follows. First, controller 80 sets the degree of opening of the pressure reducing valve of first decompressing apparatus 4 to maximum (100%) (step S600). Thus, the decompression effect of first decompressing apparatus 4 is negligible.

[0095] Next, controller 80 increases the degree of opening of the pressure reducing valve of second decompressing apparatus 7 to a second degree of opening larger than the first degree of opening (step S601). This promotes the flow of refrigerating machine oil from oil separator 3 to oil-returned tube 61. For example, the second degree of opening is 100%.

[0096] Next, controller 80 decreases the degree of opening of the pressure reducing valve of third decompressing apparatus 12 to a third degree of opening (step S602). The third degree of opening is a degree of opening smaller than the degree of opening of first decompressing apparatus 4 in the normal mode. By decreasing the degree of opening of the pressure reducing valve of third decompressing apparatus 12, the decompressing effect by third decompressing apparatus 12 is improved more than that in the normal mode. As a result, the temperature of the refrigerant flowing from second heat exchanger 5 to oil separator 3 can be decreased.

[0097] Controller 80 implements the oil collection mode by controlling first decompressing apparatus 4, second decompressing apparatus 7, and third decompressing apparatus 12 as in steps S600 to S602. The order in which controller 80 performs steps S600 to S602 is not limited to the order shown in Fig. 17, and any of the steps may be performed prior to the other steps. Further, controller 80 may implement the oil collection mode

without performing step 602. That is, by controlling first decompressing apparatus 4 and second decompressing apparatus 7 as in steps S600 and S601, the refrigerating machine oil can be caused to flow from oil separator 3 into oil-returned tube 61, thereby implementing the oil collection mode.

<Case Where First Heat Exchanger 2 is Connected to Discharge Side of Compressor 1>

[0098] Referring to Fig. 15 again, the following describes the operation of refrigeration cycle apparatus 400 when first heat exchanger 2 is connected to the discharge side of compressor 1. When first heat exchanger 2 is connected to the discharge side of compressor 1 by four-way valve 11 as indicated by broken lines, the refrigerant flows in the order of compressor 1, first heat exchanger 2, third decompressing apparatus 12, oil separator 3, and second heat exchanger 5. As a result, first heat exchanger 2 functions as a condenser, and second heat exchanger 5 functions as an evaporator. Refrigeration cycle apparatus 400 in this case is compared with refrigeration cycle apparatus 200 shown in Fig. 10. On this occasion, it is understood that refrigeration cycle apparatus 400 and refrigeration cycle apparatus 200 are the same except that refrigeration cycle apparatus 400 comprises third decompressing apparatus 12 and fourth temperature sensor 54.

[0099] Here, consider a case where the degree of opening of the pressure reducing valve of third decompressing apparatus 12 is maximized in refrigeration cycle apparatus 400 when first heat exchanger 2 is connected to the discharge side of compressor 1. In this case, refrigeration cycle apparatus 400 has substantially the same configuration as that of refrigeration cycle apparatus 200 shown in Fig. 10 except that refrigeration cycle apparatus 400 comprises fourth temperature sensor 54. Therefore, in refrigeration cycle apparatus 400, when first heat exchanger 2 is connected to the discharge side of compressor 1, the operation mode can be switched between the normal mode and the oil collection mode by controller 80 controlling the degree of opening of the pressure reducing valve of third decompressing apparatus 12 to be maximum and adjusting the degree of opening of the pressure reducing valve of first decompressing apparatus 4 and the degree of opening of the pressure reducing valve of second decompressing apparatus 7 in the same manner as in refrigeration cycle apparatus 200 shown in Fig. 10.

<Modification 1>

[0100] In each of step S 102 of Fig. 6 and step S200 of Fig. 7, outdoor air temperature T_{out} may be obtained instead of or in addition to evaporation temperature ET . Here, outdoor air temperature T_{out} means a temperature of outdoor air around the heat exchanger functioning as an evaporator. In refrigeration cycle apparatus 100

shown in Fig. 1, the temperature of the outdoor air around second heat exchanger 5 corresponds to outdoor air temperature T_{out} . For example, it is considered that outdoor air temperature T_{out} is detected by a temperature sensor provided at a suction port of a fan (not shown) of second heat exchanger 5.

[0101] When outdoor air temperature T_{out} is obtained in each of step S 102 of Fig. 6 and step S200 of Fig. 7, it may be determined whether or not the temperature of the refrigerant is equal to or less than the oil separation temperature by comparing outdoor air temperature T_{out} with a reference value in each of step S105 of Fig. 6 and step S201 of Fig. 7. Normally, outdoor air temperature T_{out} is considered to be higher than evaporation temperature E_T . For this reason, when determination is made as to "outdoor air temperature $T_{out} \leq$ reference value?" instead of "evaporation temperature $E_T \leq$ oil separation temperature?", the "reference value" may be a value obtained by adding a "certain value" to the "oil separation temperature". Here, the "certain value" can be found from a relation between the outdoor air temperature and the evaporation temperature. The relation between the outdoor air temperature and the evaporation temperature can be specified by operating a refrigeration cycle apparatus provided with a sensor configured to detect the condensation temperature and a sensor configured to detect the outdoor air temperature, and by obtaining detection values of the both sensors.

<Modification 2>

[0102] In step S104 of Fig. 6, instead of discharge SH , discharge temperature T_d may be determined with respect to a reference value so as to estimate whether or not the temperature of the refrigerant is less than the separation temperature of the refrigerating machine oil.

<Modification 3>

[0103] Condensation temperature C_T may be calculated from a detection value of a pressure sensor provided on the discharge side of compressor 1.

<Modification 4>

[0104] Evaporation temperature E_T may be calculated from a detection value of a pressure sensor provided on the suction side of compressor 1.

<Modification 5>

[0105] In the flowchart of Fig. 6, determination may be made in only one of step S 104 and step S105. For example, when NO is determined in step S104, the process proceeds to step S107 to perform the operation in the normal mode. Alternatively, the process proceeds from step S103 to step S105 directly. When YES is determined in step S105, the operation is performed in the oil collec-

tion mode (step S106), and when NO is determined in step S105, the operation is performed in the normal mode (step S107).

5 (Conclusion)

[0106] The present embodiment is concluded as follows.

[0107] The present disclosure is directed to a refrigeration cycle apparatus (100 to 400). The refrigeration cycle apparatus (100 to 400) comprises: a compressor (1); a first heat exchanger (2); a second heat exchanger (5); a first decompressing apparatus (4); an oil separator (3); a first circulation pathway in which a refrigerant circulates in an order of the compressor (1), the first heat exchanger (2), the oil separator (3), the first decompressing apparatus (4), and the second heat exchanger (5); an oil-returned pathway (61) connecting between the oil separator (3) and a suction side of the compressor (1); a second decompressing apparatus (7) provided in the oil-returned pathway; and a controller (80) configured to control the first decompressing apparatus (4) and the second decompressing apparatus (7), the controller (80) being configured to set an operation mode to an oil collection mode (S106 in Fig. 6 and S202 in Fig. 7) in which the oil-returned pathway (61) is opened by adjusting a degree of decompression of the second decompressing apparatus (7) when the refrigerant and a refrigerating machine oil flowing in the first circulation pathway are separated in the oil separator (3).

[0108] With such a configuration, the refrigerating machine oil is collected when the refrigerant and the refrigerating machine oil are separated in the oil separator, thereby providing the refrigeration cycle apparatus to improve the efficiency of collecting the refrigerating machine oil.

[0109] Preferably, the controller (80) is configured to set the operation mode to a normal mode (S107 in Fig. 6 and S203 in Fig. 7) in which the oil-returned pathway is closed by adjusting the degree of decompression of the second decompressing apparatus (7) when the refrigerant and the refrigerating machine oil flowing in the first circulation pathway are not separated in the oil separator (3).

[0110] With such a configuration, since the operation is performed in the normal mode when the refrigerant and the refrigerating machine oil are not separated in the oil separator, it is possible to prevent a decrease of an amount of the refrigerant circulating via the first heat exchanger and the second heat exchanger.

[0111] Preferably, in the oil collection mode (S106 in Fig. 6 and S202 in Fig. 7), the controller is configured to adjust a degree of decompression of the first decompressing apparatus to suppress an amount of the refrigerant flowing from the oil separator into the first decompressing apparatus and decrease a temperature of the refrigerant flowing into the oil separator as compared with the normal mode.

[0112] With such a configuration, the separation between the refrigerant and the refrigerating machine oil can be promoted.

[0113] Preferably, the controller is configured to circulate the refrigerant in the first circulation pathway in a state in which the oil-returned pathway (61) is closed by adjusting a degree of decompression of the first decompressing apparatus (4) and the degree of decompression of the second decompressing apparatus (7).

[0114] Preferably, the refrigeration cycle apparatus further comprises a first temperature sensor (51) configured to detect a temperature of the refrigerant flowing on a discharge side of the compressor (1), wherein the controller (80) is configured to determine whether to set the operation mode to the oil collection mode (S106 in Fig. 6 and S202 in Fig. 7) by using the temperature detected by the first temperature sensor (51) when the refrigeration cycle apparatus (100 to 400) is started.

[0115] Preferably, the refrigeration cycle apparatus further comprises a second temperature sensor (52) configured to detect a temperature of the refrigerant flowing in the first heat exchanger (2), wherein the controller is configured to determine whether to set the operation mode to the oil collection mode (S106 in Fig. 6) based on a degree of superheat calculated from the temperature detected by the first temperature sensor (51) and the temperature detected by the second temperature sensor (52) (S104 in Fig. 6).

[0116] Preferably, the refrigeration cycle apparatus further comprises a third temperature sensor (53) configured to detect a temperature of the refrigerant flowing in the second heat exchanger (5) or a temperature of outdoor air around the second heat exchanger (5), wherein the controller (80) is configured to determine whether to set the operation mode to the oil collection mode (S202 in Fig. 7) by using the temperature detected by the third temperature sensor (53) during an operation of the refrigeration cycle apparatus (100 to 400) (S201 in Fig. 7).

[0117] Preferably, the refrigeration cycle apparatus further comprises a third heat exchanger (8) configured to exchange heat between the refrigerant flowing between the first heat exchanger (2) and the oil separator (3) and the refrigerant flowing between the second decompressing apparatus (7) and the compressor (1).

[0118] Preferably, the refrigeration cycle apparatus further comprises a four-way valve (11), wherein the four-way valve (11) is configured to switch a direction of circulation of the refrigerant between the first circulation pathway and a second circulation pathway, in the second circulation pathway, the refrigerant circulates in an order of the compressor (1), the second heat exchanger (5), the first decompressing apparatus (4), the oil separator (3), and the first heat exchanger (2), and the oil separator (3) is configured to return the refrigerant in a gaseous state to the compressor (1) via the oil-returned pathway (61) when the refrigerant circulates in the second circulation pathway.

[0119] Preferably, the refrigeration cycle apparatus further comprises a four-way valve (11) and a third decompressing apparatus (12) provided in a pathway for the refrigerant flowing between the oil separator (3) and the first heat exchanger (2), wherein the four-way valve (11) is configured to switch a direction of circulation of the refrigerant between the first circulation pathway and a second circulation pathway, in the second circulation pathway, the refrigerant circulates in an order of the compressor (1), the second heat exchanger (5), the first decompressing apparatus (4), the oil separator (3), and the first heat exchanger (2), and the controller (80) is configured to set the operation mode to the oil collection mode by adjusting a degree of decompression of the first decompressing apparatus (4) and the second decompressing apparatus (7) when the refrigerant and the refrigerating machine oil flowing in the second circulation pathway are separated in the oil separator (3).

[0120] Preferably, the controller (80) is configured to set the oil collection mode (S106 in Fig. 6 and S202 in Fig. 7) by adjusting the degree of decompression of the first decompressing apparatus (1) to suppress an amount of the refrigerant flowing from the oil separator (3) to the first decompressing apparatus (4) and by adjusting the degree of decompression of the second decompressing apparatus (7) to increase an amount of the refrigerating machine oil flowing from the oil separator (3) to the oil-returned pathway (61).

[0121] Preferably, the controller (80) is configured to set the operation mode to the oil collection mode in which the oil-returned pathway is opened to the oil separator (3) that separates the refrigerant and the refrigerating machine oil by adjusting the degree of decompression of the first decompressing apparatus (1) and the degree of decompression of the second decompressing apparatus (7).

[0122] The embodiments disclosed herein are illustrative and non-restrictive in any respect. The scope of the present disclosure is defined by the terms of the claims, rather than the embodiments described above, and is intended to include any modifications within the scope and meaning equivalent to the terms of the claims.

REFERENCE SIGNS LIST

[0123] 1: compressor; 2: first heat exchanger; 3: oil separator; 4: first decompressing apparatus; 5: second heat exchanger; 7: second decompressing apparatus; 8: third heat exchanger; 10, 20, 30: refrigerant circuit; 11: four-way valve; 12: third decompressing apparatus; 31: main body portion; 32: first tube; 33: second tube; 34: third tube; 41: boundary surface; 42: boundary surface; 51: first temperature sensor; 52: second temperature sensor; 53: third temperature sensor; 54: fourth temperature sensor; 60: refrigerant tube; 61: oil-returned tube; 80: controller; 81: control board; 82: processor; 83: memory; 100, 200, 300: refrigeration cycle apparatus.

Claims**1.** A refrigeration cycle apparatus comprising:

a compressor;
 a first heat exchanger;
 a second heat exchanger;
 a first decompressing apparatus;
 an oil separator;
 a first circulation pathway in which a refrigerant circulates in an order of the compressor, the first heat exchanger, the oil separator, the first decompressing apparatus, and the second heat exchanger;
 an oil-returned pathway connecting between the oil separator and a suction side of the compressor;
 a second decompressing apparatus provided in the oil-returned pathway; and
 a controller configured to control the first decompressing apparatus and the second decompressing apparatus, the controller being configured to set an operation mode to an oil collection mode in which the oil-returned pathway is opened by adjusting a degree of decompression of the second decompressing apparatus when the refrigerant and a refrigerating machine oil flowing in the first circulation pathway are separated in the oil separator.

2. The refrigeration cycle apparatus according to claim 1, wherein

the controller is configured to set the operation mode to a normal mode in which the oil-returned pathway is closed by adjusting the degree of decompression of the second decompressing apparatus when the refrigerant and the refrigerating machine oil flowing in the first circulation pathway are not separated in the oil separator.

3. The refrigeration cycle apparatus according to claim 2, wherein in the oil collection mode, the controller is configured to adjust a degree of decompression of the first decompressing apparatus to suppress an amount of the refrigerant flowing from the oil separator into the first decompressing apparatus and decrease a temperature of the refrigerant flowing into the oil separator as compared with the normal mode.**4.** The refrigeration cycle apparatus according to any one of claims 1 to 3, further comprising a first temperature sensor configured to detect a temperature of the refrigerant flowing on a discharge side of the compressor, wherein the controller is configured to determine whether to set the operation mode to the oil collection mode by using the temperature detected by the first temper-

ature sensor when the refrigeration cycle apparatus is started.

5. The refrigeration cycle apparatus according to claim 4, further comprising a second temperature sensor configured to detect a temperature of the refrigerant flowing in the first heat exchanger, wherein the controller is configured to determine whether to set the operation mode to the oil collection mode based on a degree of superheat calculated from the temperature detected by the first temperature sensor and the temperature detected by the second temperature sensor.**6.** The refrigeration cycle apparatus according to any one of claims 1 to 4, further comprising a third temperature sensor configured to detect a temperature of the refrigerant flowing in the second heat exchanger or a temperature of outdoor air around the second heat exchanger, wherein the controller is configured to determine whether to set the operation mode to the oil collection mode by using the temperature detected by the third temperature sensor during an operation of the refrigeration cycle apparatus.**7.** The refrigeration cycle apparatus according to any one of claims 1 to 6, further comprising a third heat exchanger configured to exchange heat between the refrigerant flowing between the first heat exchanger and the oil separator and the refrigerant flowing between the second decompressing apparatus and the compressor.**8.** The refrigeration cycle apparatus according to any one of claims 1 to 7, further comprising a four-way valve, wherein

the four-way valve is configured to switch a direction of circulation of the refrigerant between the first circulation pathway and a second circulation pathway, in the second circulation pathway, the refrigerant circulates in an order of the compressor, the second heat exchanger, the first decompressing apparatus, the oil separator, and the first heat exchanger, and the oil separator is configured to return the refrigerant in a gaseous state to the compressor via the oil-returned pathway when the refrigerant circulates in the second circulation pathway.

9. The refrigeration cycle apparatus according to any one of claims 1 to 7, further comprising:

a four-way valve; and
 a third decompressing apparatus provided in a pathway for the refrigerant flowing between the

oil separator and the first heat exchanger,
wherein
the four-way valve is configured to switch a di-
rection of circulation of the refrigerant between
the first circulation pathway and a second circu- 5
lation pathway,
in the second circulation pathway, the refriger-
ant circulates in an order of the compressor, the
second heat exchanger, the first decompressing
apparatus, the oil separator, the third decom- 10
pressing apparatus, and the first heat exchang-
er, and
the controller is configured to set the operation
mode to the oil collection mode by adjusting a 15
degree of decompression of the first decom-
pressing apparatus and the degree of decom-
pression of the second decompressing appara-
tus when the refrigerant and the refrigerating
machine oil flowing in the second circulation
pathway are separated in the oil separator. 20

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FIG.1

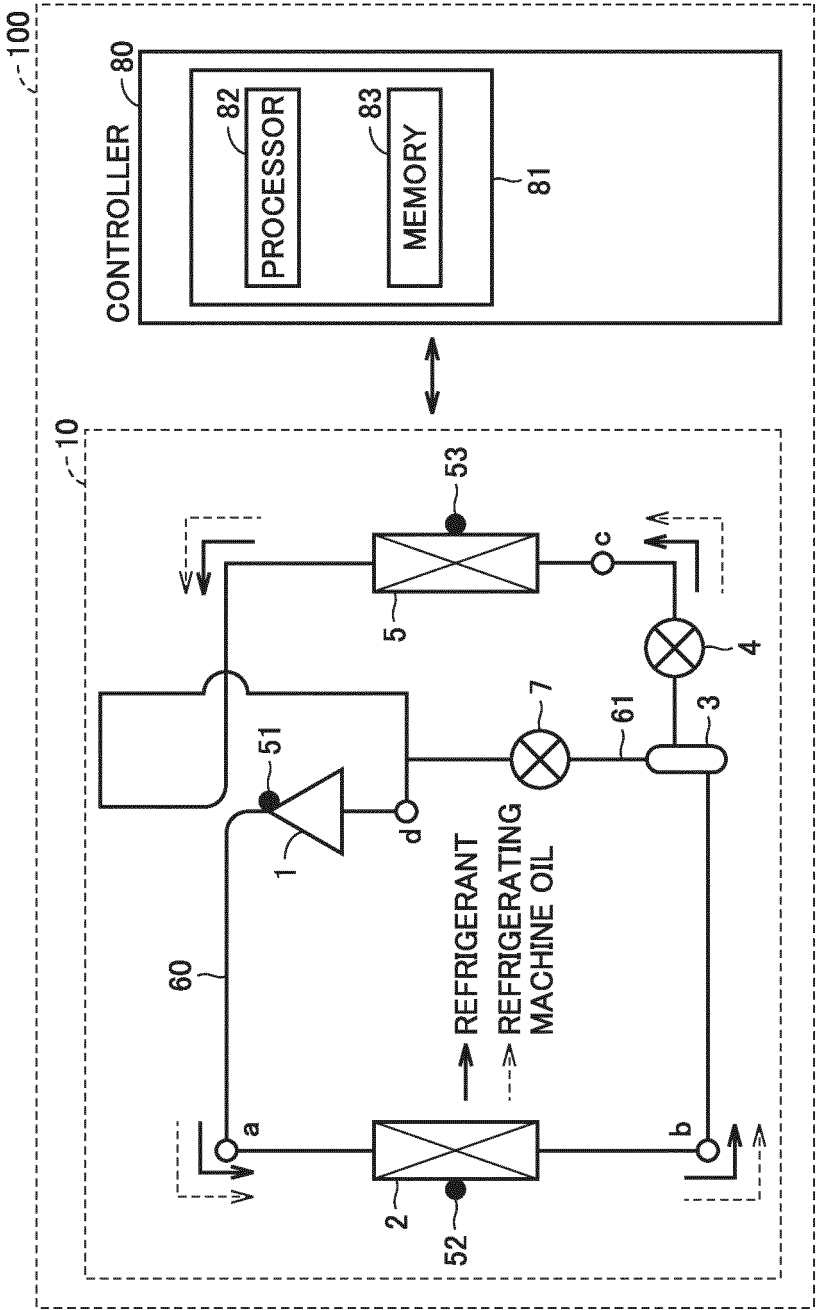


FIG.2

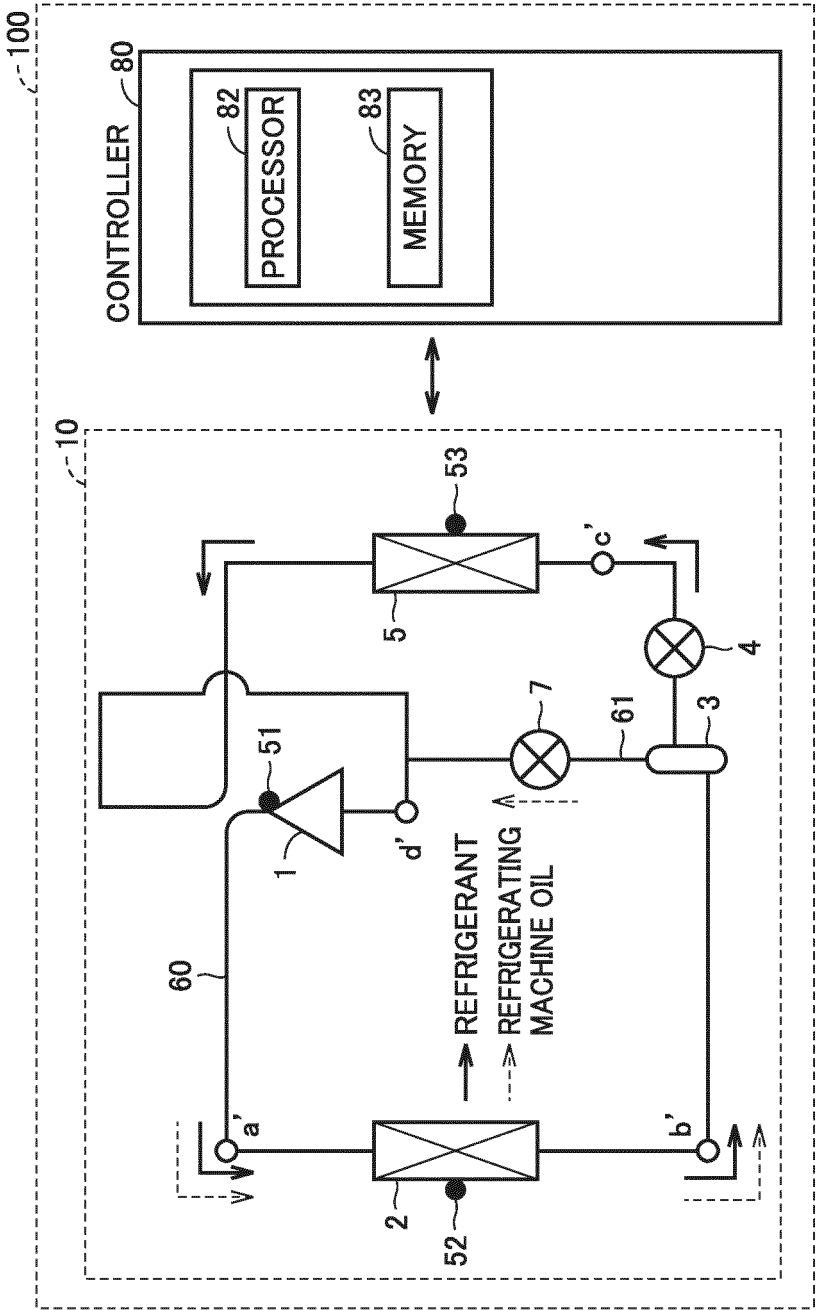


FIG.3

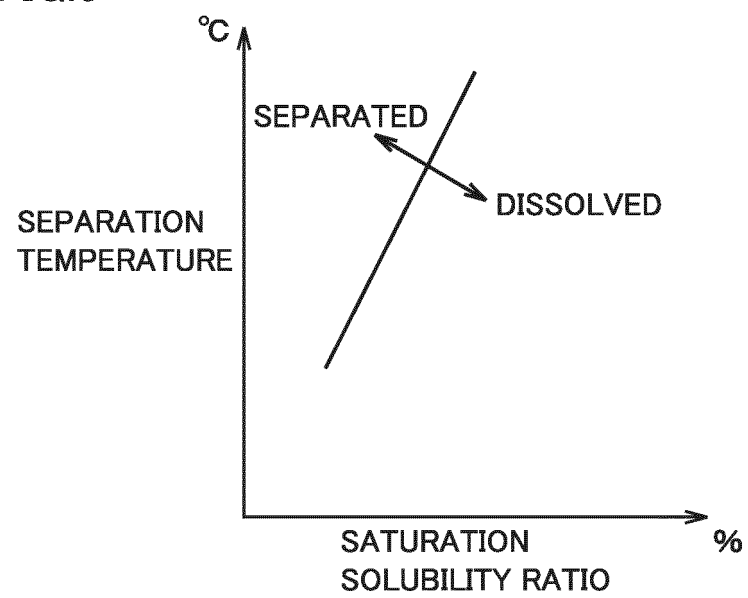


FIG.4

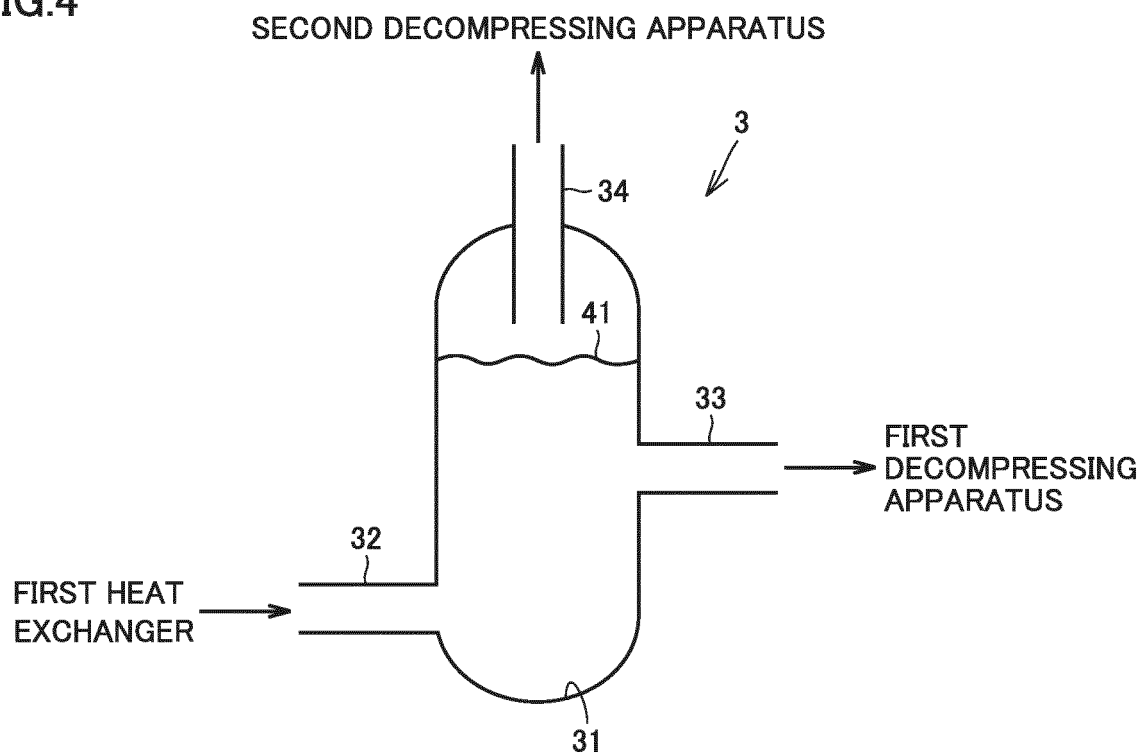


FIG.5

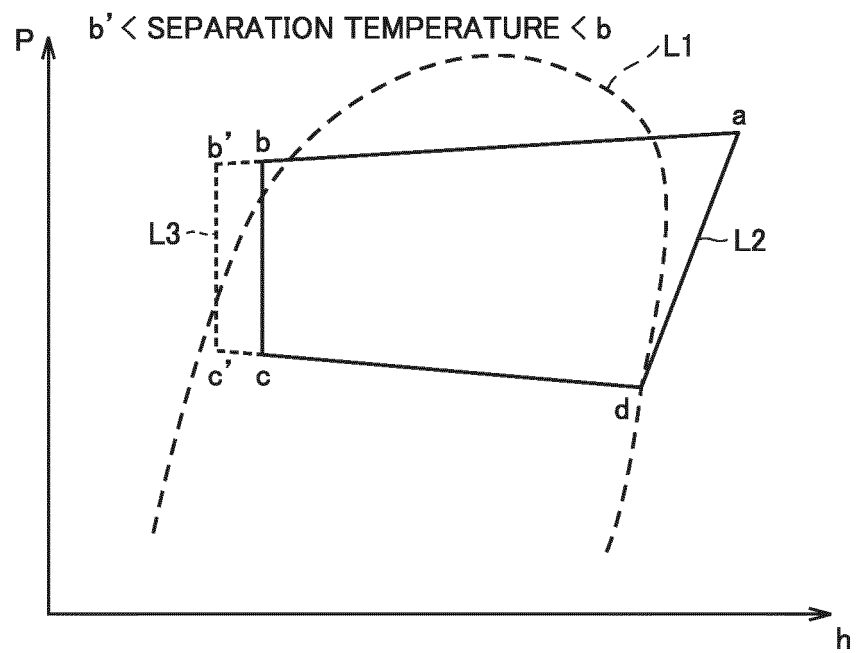


FIG.6

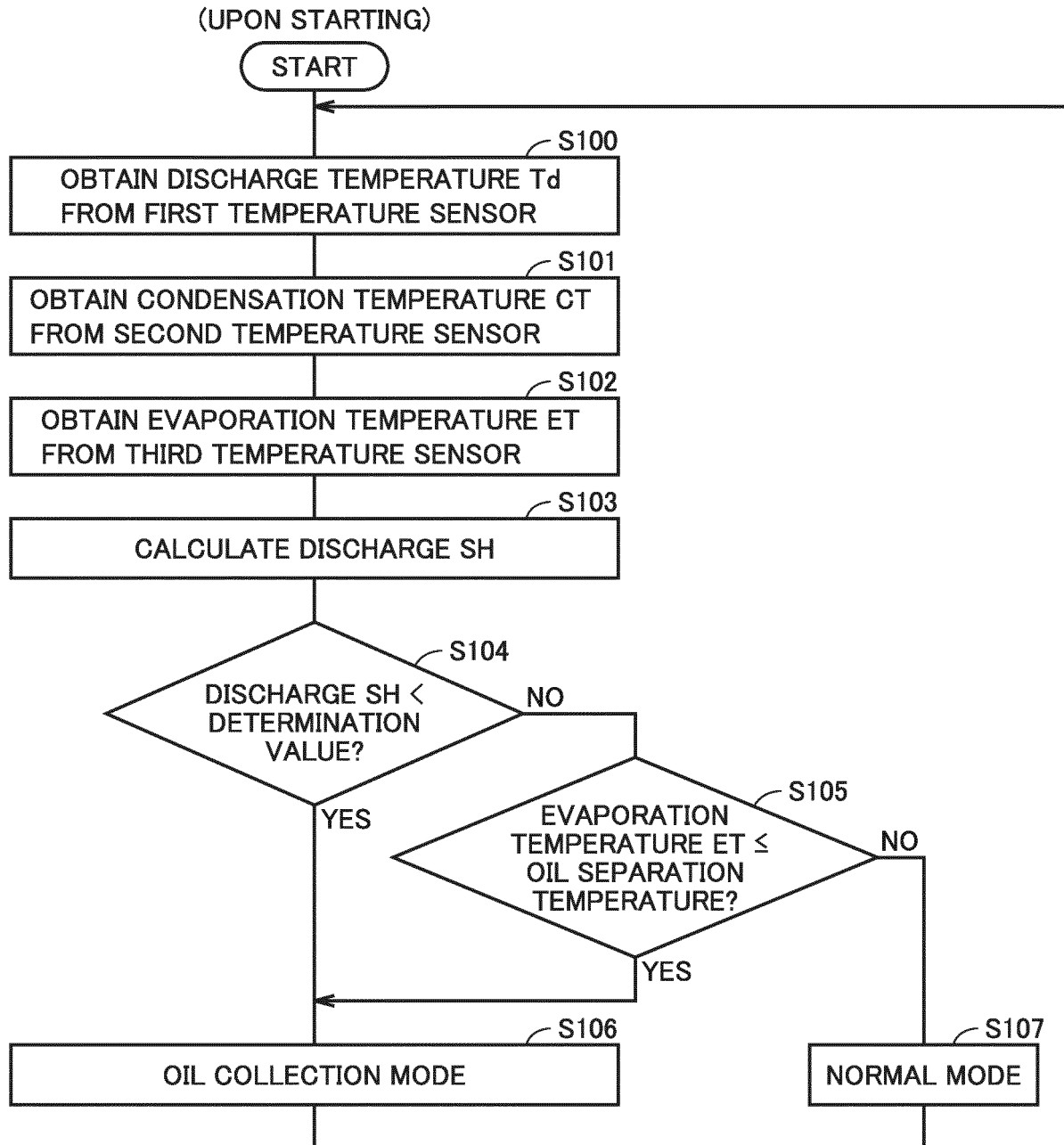


FIG.7

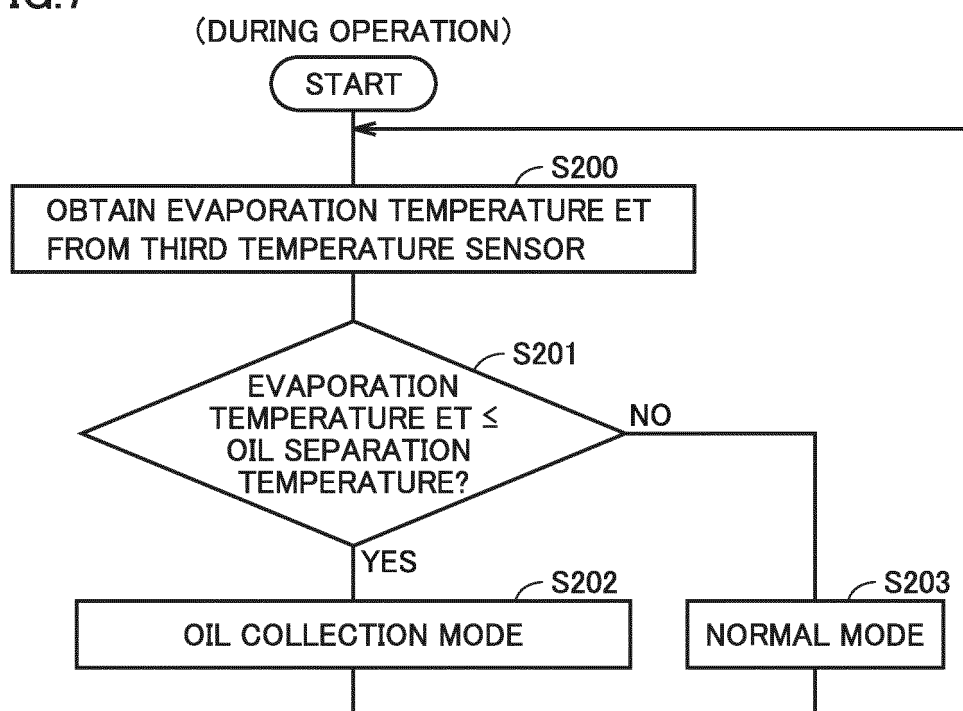


FIG.8

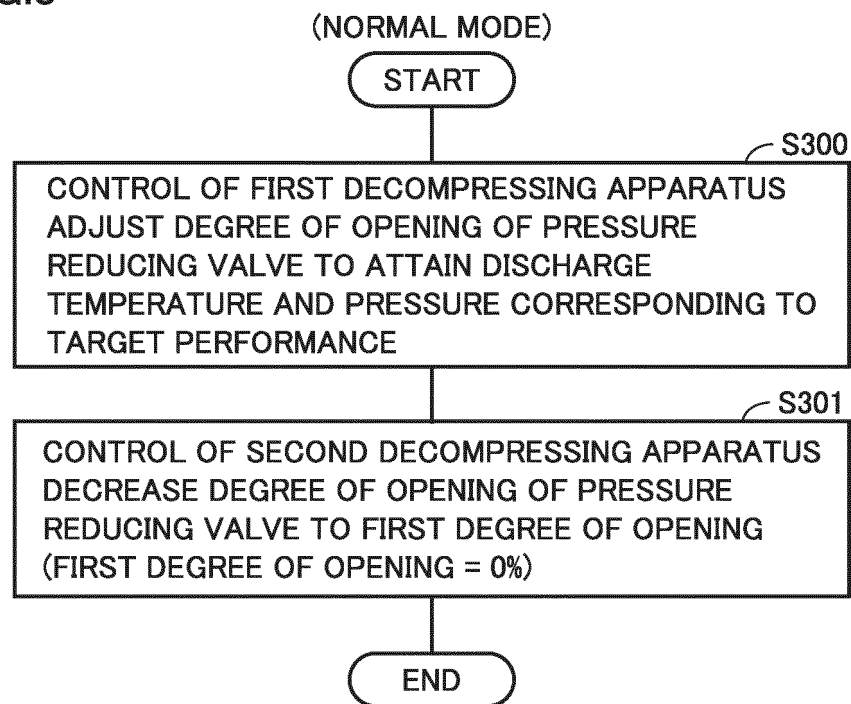


FIG.9

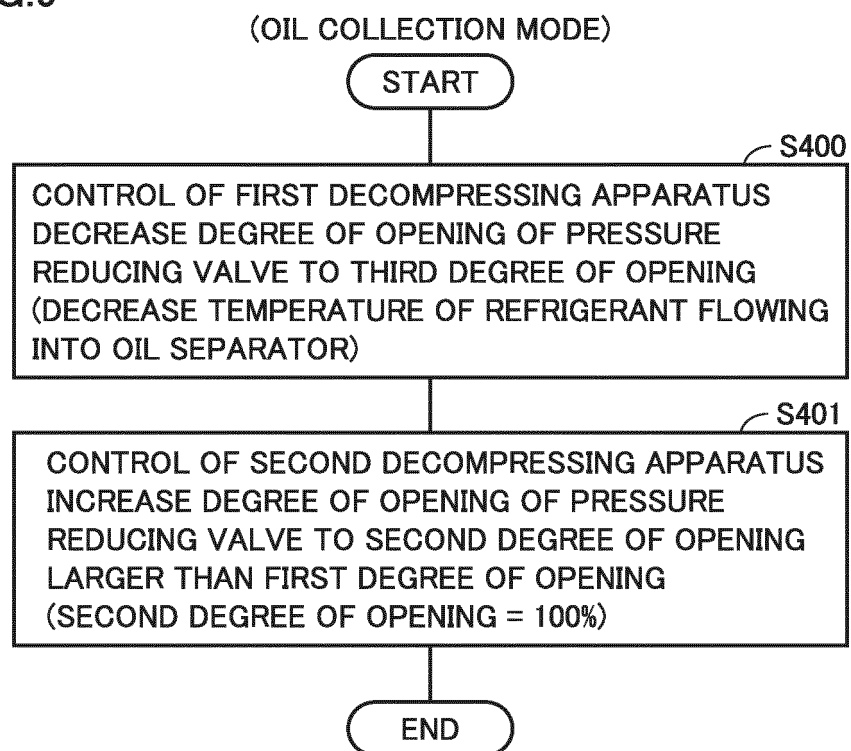


FIG. 10

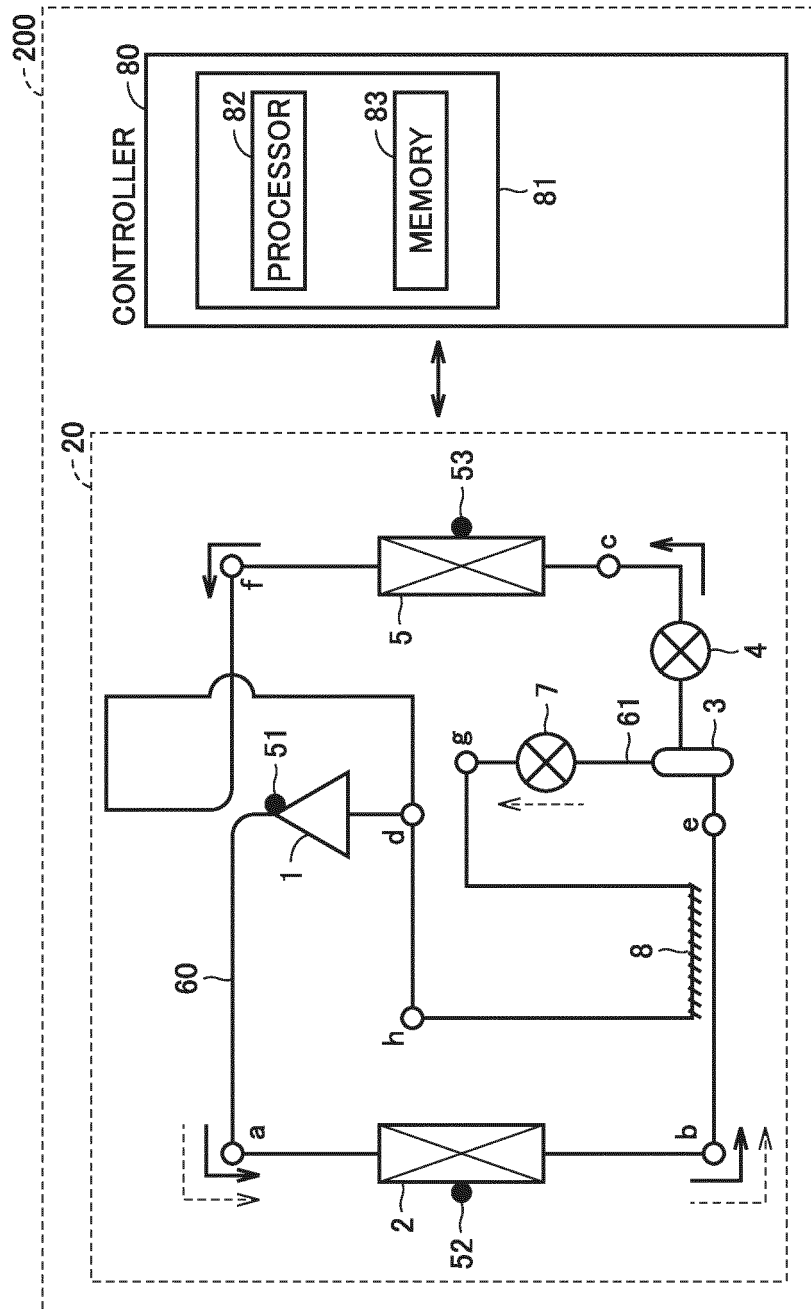


FIG.11

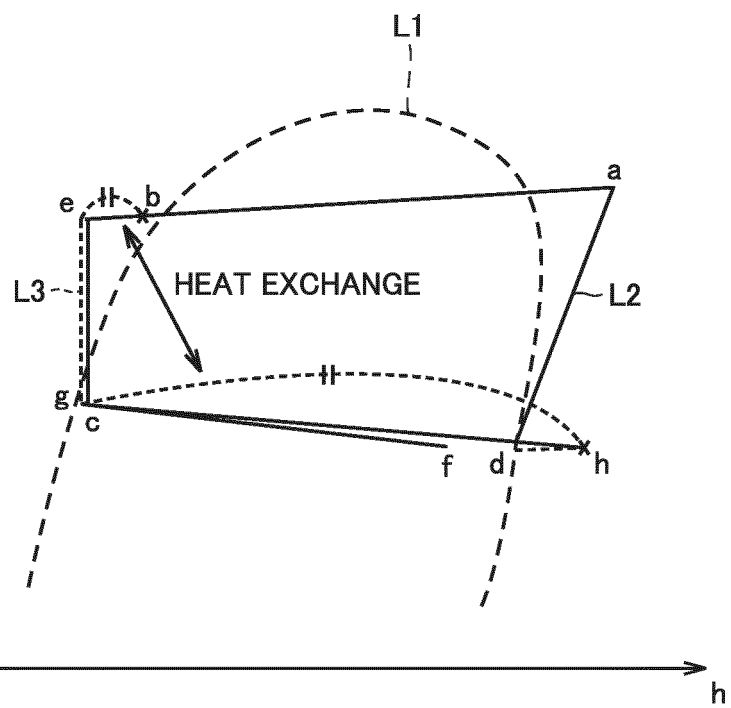


FIG.12

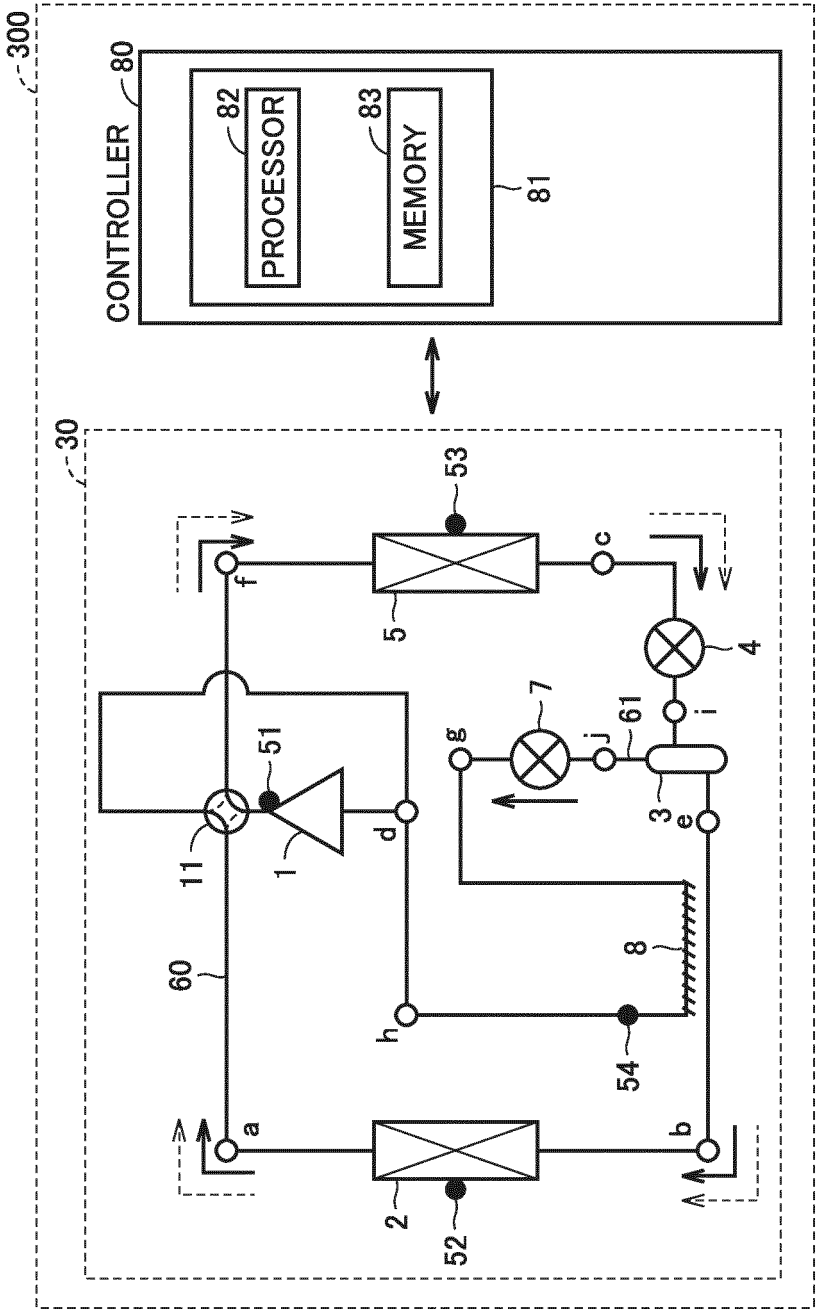


FIG.13

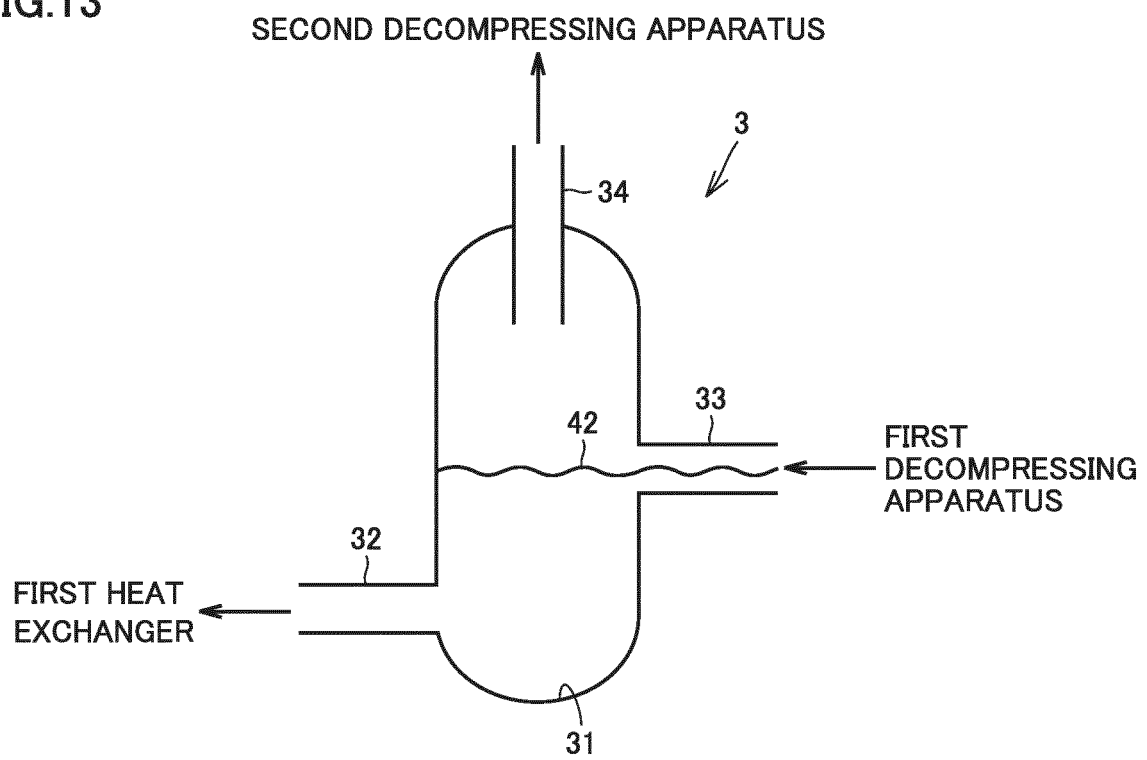


FIG.14

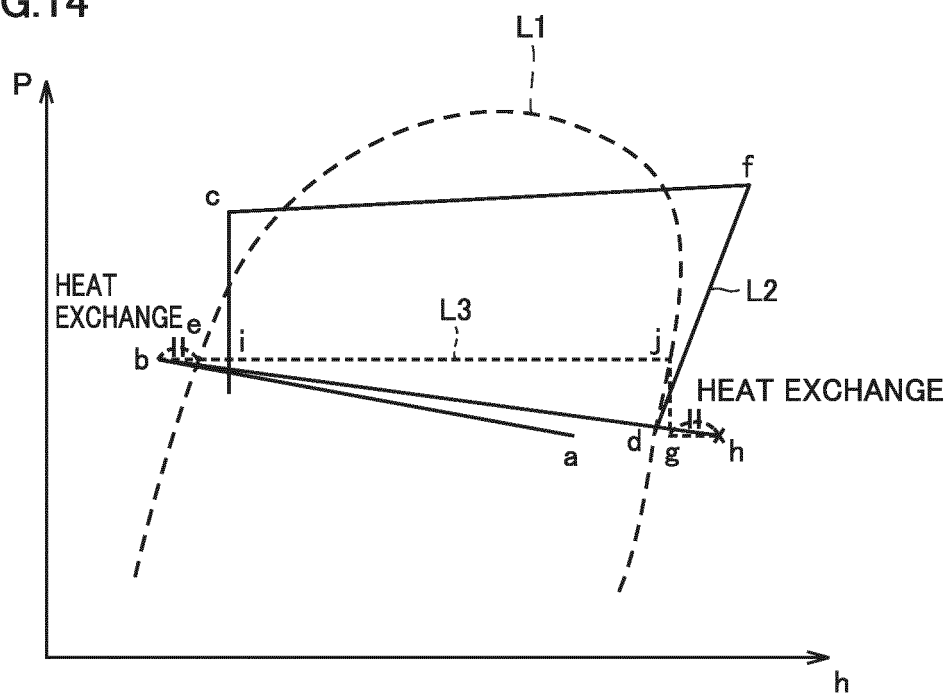


FIG.15

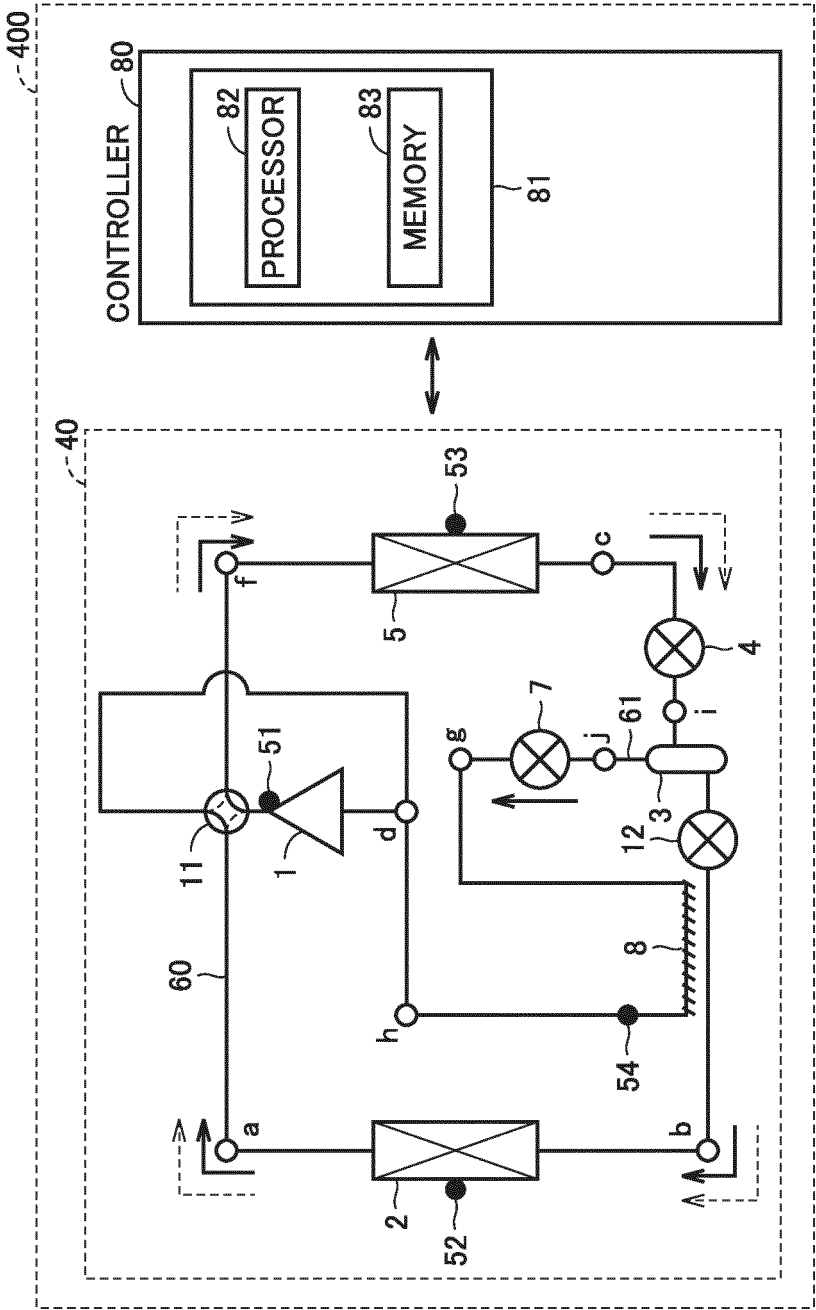


FIG.16

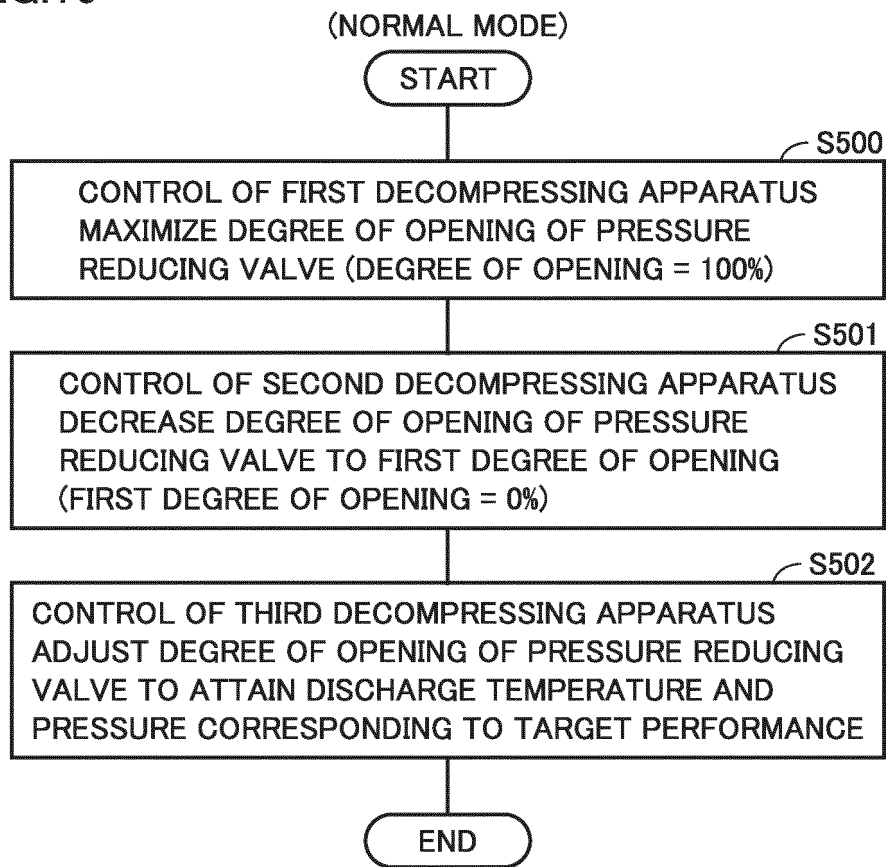
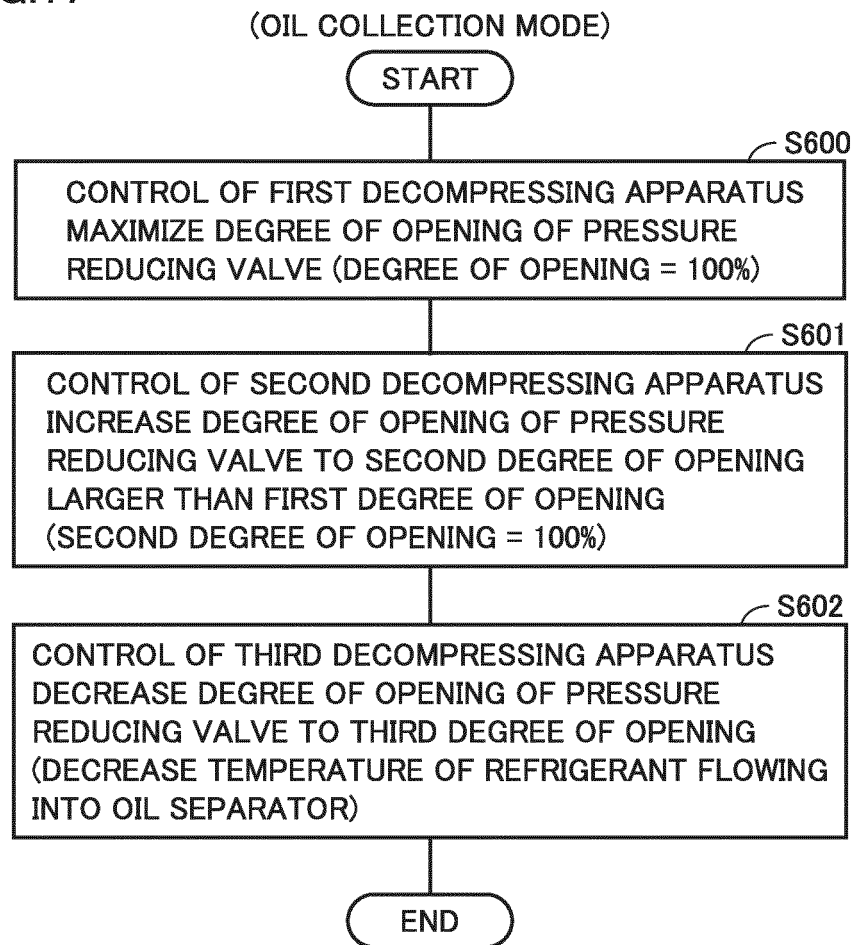


FIG.17



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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/041211

A. CLASSIFICATION OF SUBJECT MATTER

F25B 13/00 (2006.01) i; F25B 43/02 (2006.01) i; F25B 1/00 (2006.01) i
 FI: F25B1/00 387B; F25B1/00 101E; F25B1/00 311B; F25B1/00 331E;
 F25B1/00 387L; F25B13/00 311; F25B13/00 331Z; F25B43/02 A;
 F25B43/02 N

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)

F25B13/00; F25B43/02; F25B1/00

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

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	JP 8-86519 A (MITSUBISHI ELECTRIC CORP.) 02 April 1996 (1996-04-02) paragraphs [0127]-[0139], fig. 15-17	1, 9
A	paragraphs [0127]-[0139], fig. 15-17	2-8
A	JP 2005-83704 A (MITSUBISHI ELECTRIC CORP.) 31 March 2005 (2005-03-31) paragraphs [0037]-[0040], fig. 11	1-9
A	JP 6-74579 A (DAIKIN INDUSTRIES, LTD.) 15 March 1994 (1994-03-15) column "abstract"	1-9



Further documents are listed in the continuation of Box C.



See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"I"

later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X"

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"

document member of the same patent family

Date of the actual completion of the international search
30 November 2020 (30.11.2020)Date of mailing of the international search report
08 December 2020 (08.12.2020)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/041211

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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.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 52298/1987 (Laid-open No. 159156/1988) (DAIKIN INDUSTRIES, LTD.) 18 October 1988 (1988-10-18) claim 1, fig. 1	1-9

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2020/041211

10

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 8-86519 A	02 Apr. 1996	(Family: none)	
JP 2005-83704 A	31 Mar. 2005	(Family: none)	
JP 6-74579 A	15 Mar. 1994	(Family: none)	
JP 63-159156 U1	18 Oct. 1988	(Family: none)	

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Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 8086519 A [0003]