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(54) **REFRIGERATION CYCLE APPARATUS**

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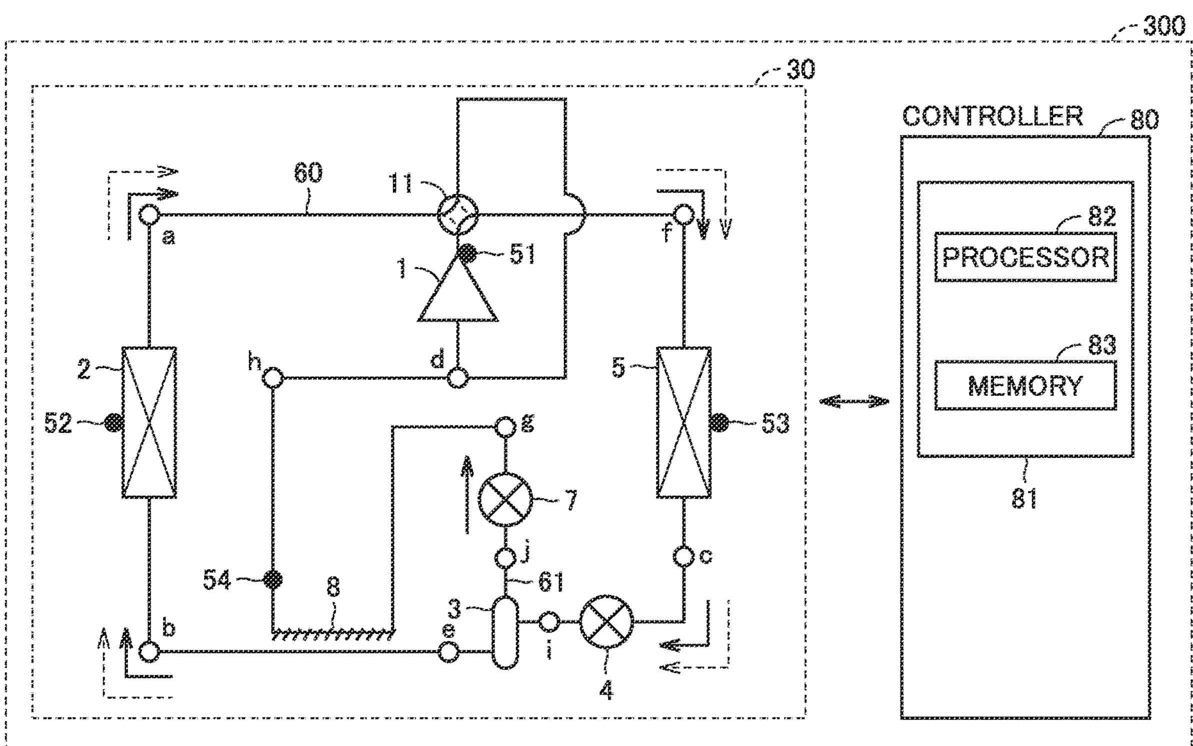
(57) **ABSTRACT**

A refrigeration cycle apparatus comprises: 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 is configured to set an operation mode to an oil collection mode 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.



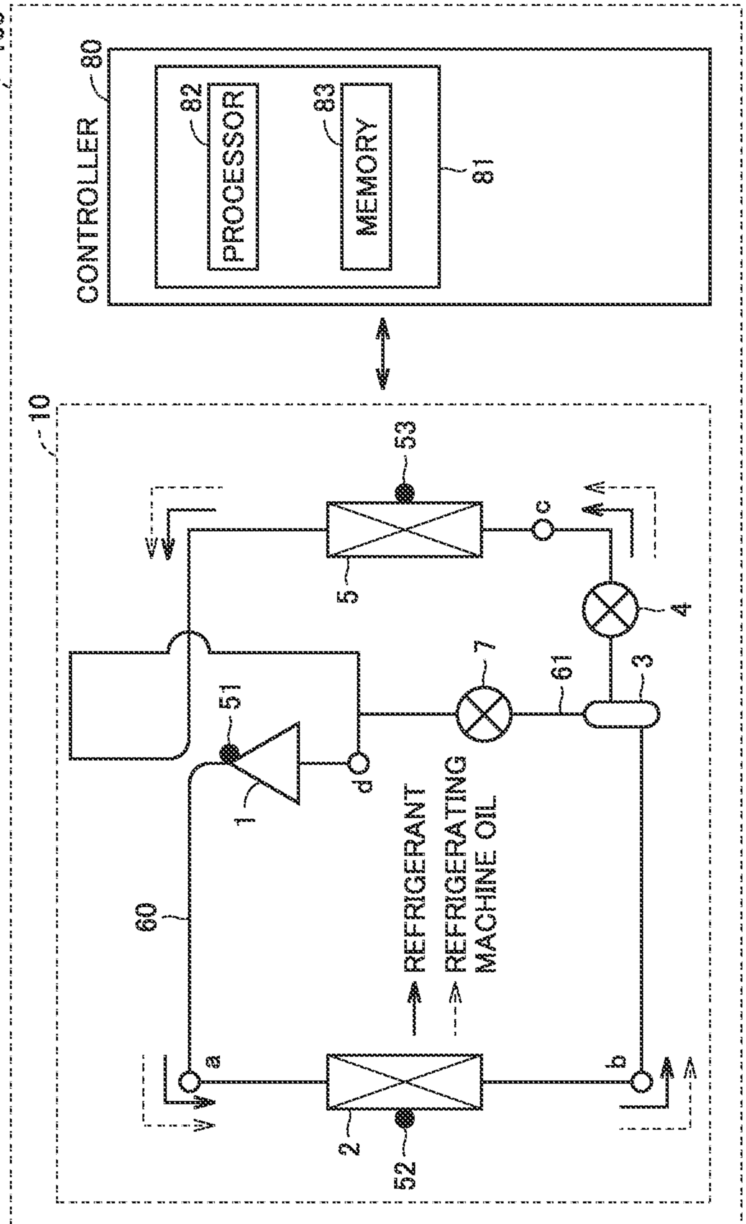
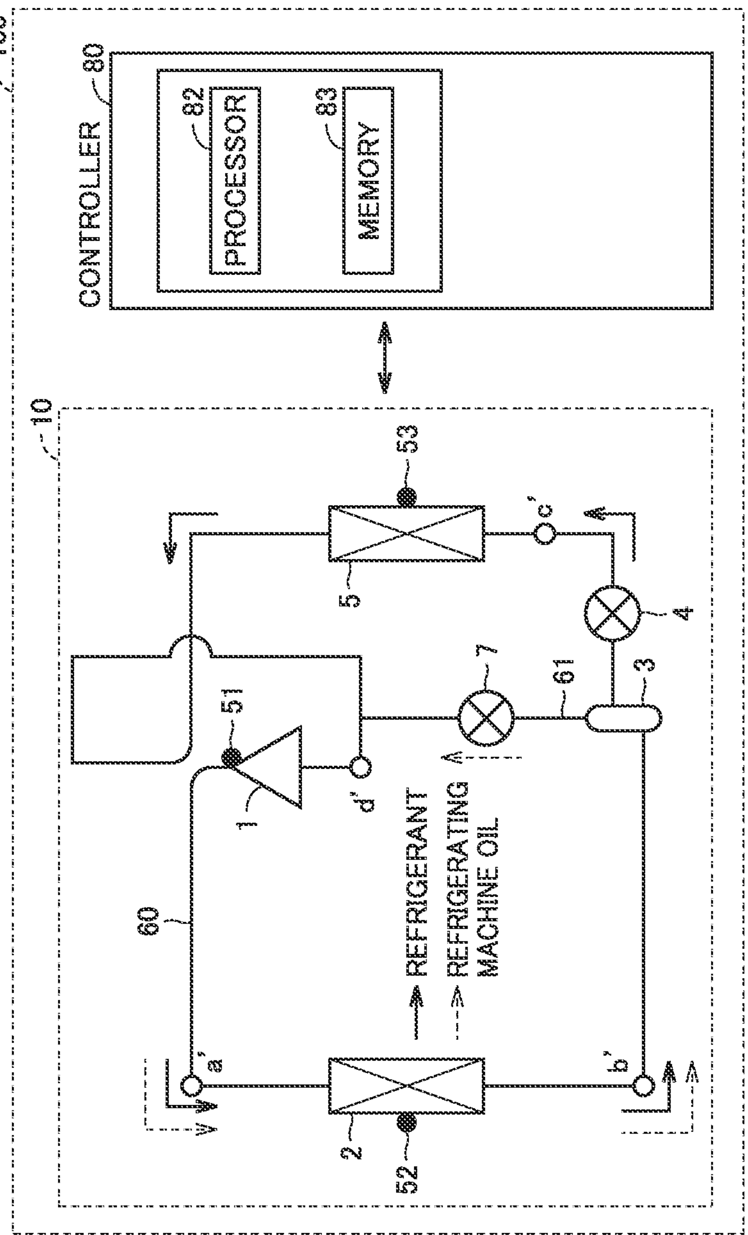

100
80
CONTROLLER
82
PROCESSOR
83
MEMORY
81
10
53
5
c
4
7
61
3
51
1
d
60
REFRIGERANT
REFRIGERATING MACHINE OIL
a
b
2
52

FIG.1


100
80
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53
5
c'
4
3
61
7
51
1
d'
60
a'
2
52
b'
REFRIGERANT
REFRIGERATING MACHINE OIL

FIG.2

FIG.3

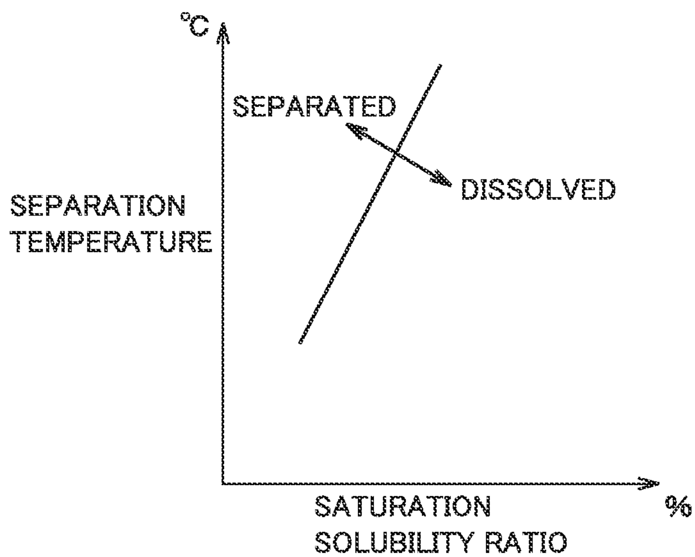

°C
SEPARATED
DISSOLVED
SEPARATION
TEMPERATURE
SATURATION
SOLUBILITY RATIO
%

FIG.4

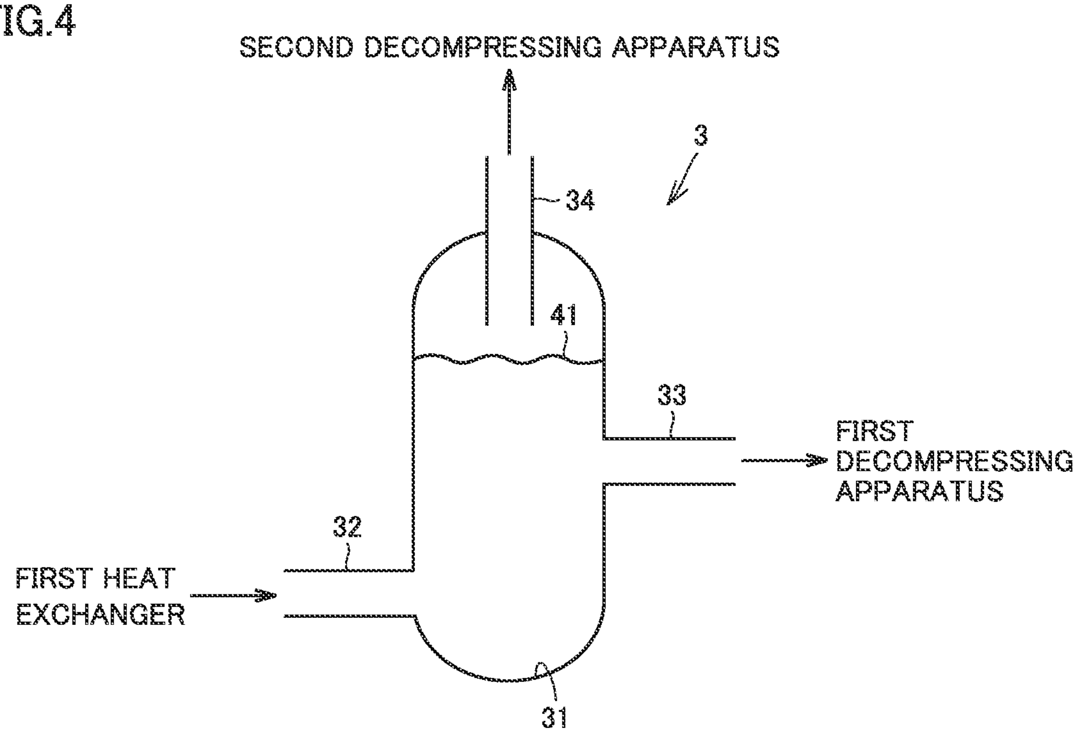

SECOND DECOMPRESSING APPARATUS
3
34
41
33
FIRST
DECOMPRESSING
APPARATUS
32
FIRST HEAT
EXCHANGER
31

FIG.5

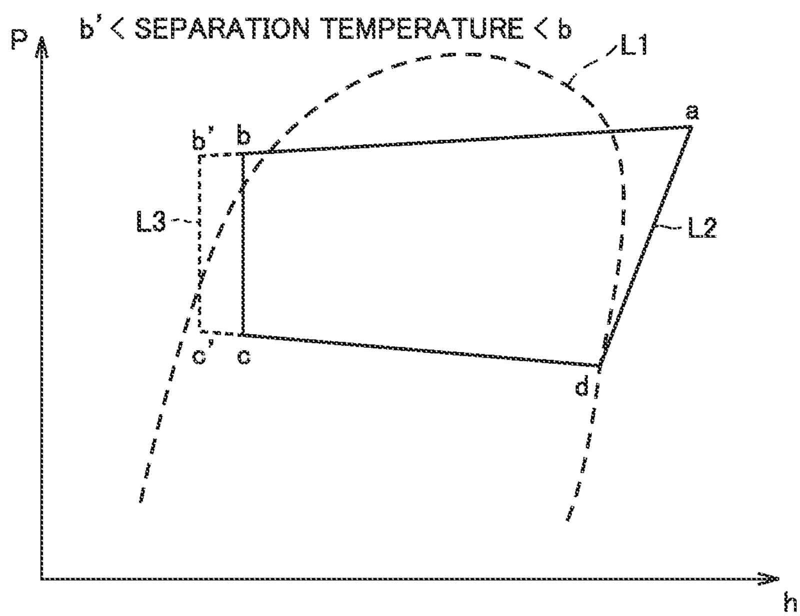
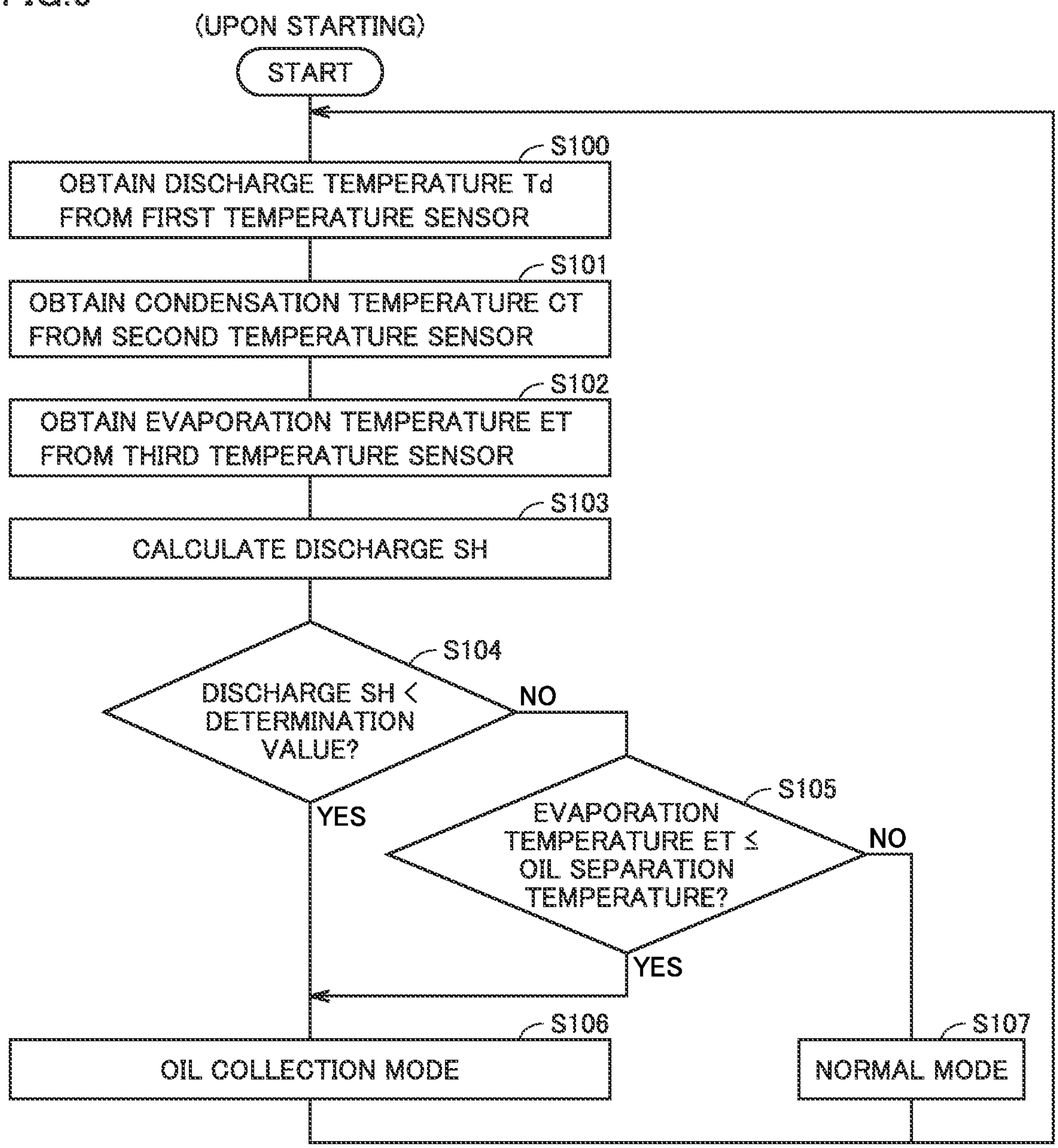


FIG.6



(UPON STARTING)
START
S100
OBTAIN DISCHARGE TEMPERATURE Td FROM FIRST TEMPERATURE SENSOR
S101
OBTAIN CONDENSATION TEMPERATURE CT FROM SECOND TEMPERATURE SENSOR
S102
OBTAIN EVAPORATION TEMPERATURE ET FROM THIRD TEMPERATURE SENSOR
S103
CALCULATE DISCHARGE SH
S104
DISCHARGE SH < DETERMINATION VALUE?
NO
YES
S105
EVAPORATION TEMPERATURE ET ≤ OIL SEPARATION TEMPERATURE?
NO
YES
S106
OIL COLLECTION MODE
S107
NORMAL MODE

FIG.7

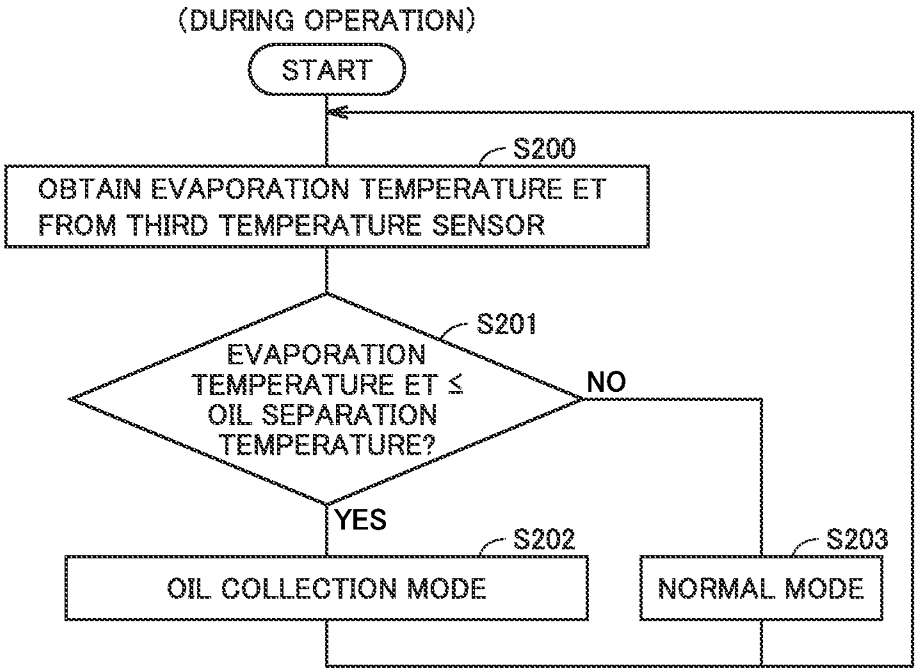

(DURING OPERATION)
START
S200
OBTAIN EVAPORATION TEMPERATURE ET FROM THIRD TEMPERATURE SENSOR
S201
EVAPORATION TEMPERATURE ET ≤ OIL SEPARATION TEMPERATURE?
NO
YES
S202
OIL COLLECTION MODE
S203
NORMAL MODE

FIG.8

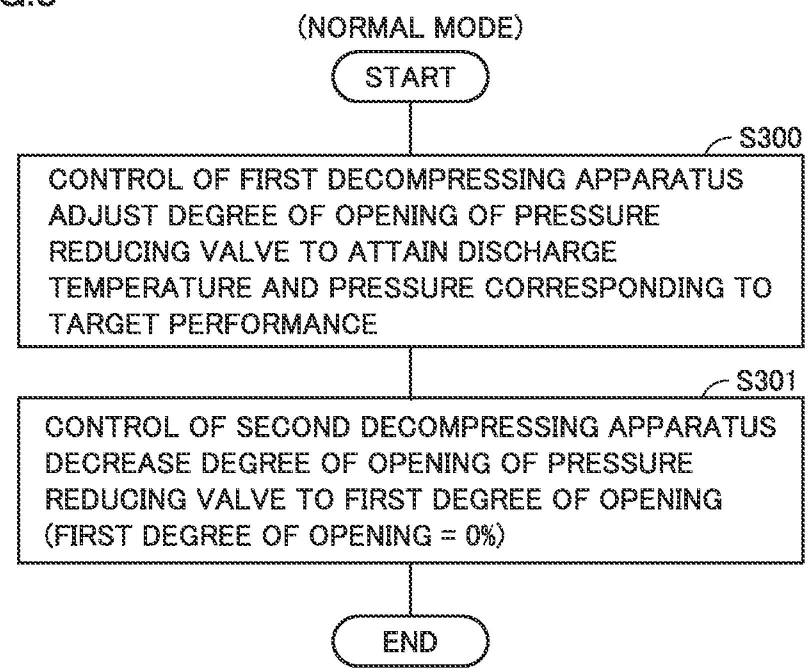
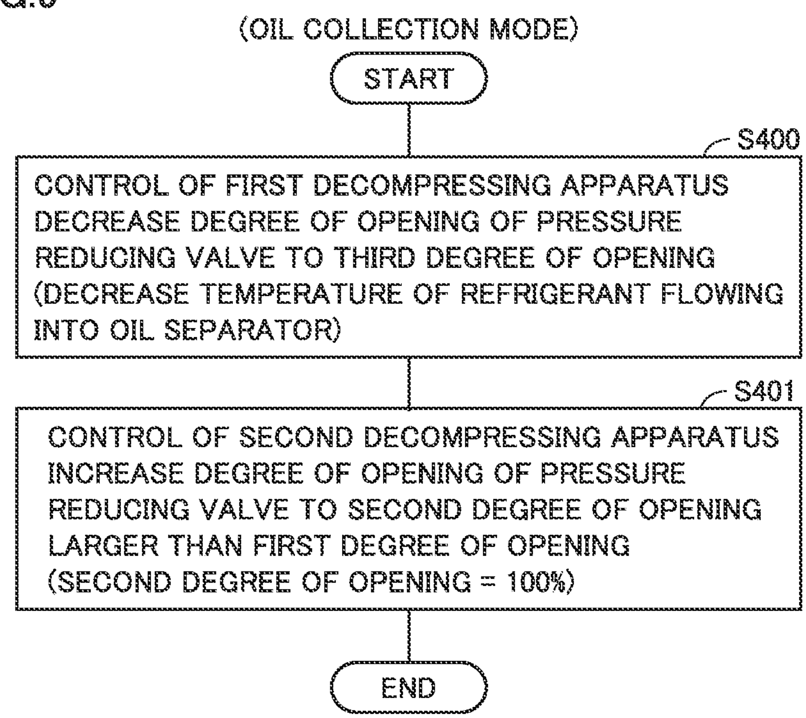

(NORMAL MODE)
START
S300
CONTROL OF FIRST DECOMPRESSING APPARATUS
ADJUST DEGREE OF OPENING OF PRESSURE REDUCING VALVE TO ATTAIN DISCHARGE TEMPERATURE AND PRESSURE CORRESPONDING TO TARGET PERFORMANCE
S301
CONTROL OF SECOND DECOMPRESSING APPARATUS
DECREASE DEGREE OF OPENING OF PRESSURE REDUCING VALVE TO FIRST DEGREE OF OPENING
(FIRST DEGREE OF OPENING = 0%)
END

FIG.9


(OIL COLLECTION MODE)
START
S400
CONTROL OF FIRST DECOMPRESSING APPARATUS
DECREASE DEGREE OF OPENING OF PRESSURE REDUCING VALVE TO THIRD DEGREE OF OPENING
(DECREASE TEMPERATURE OF REFRIGERANT FLOWING INTO OIL SEPARATOR)
S401
CONTROL OF SECOND DECOMPRESSING APPARATUS
INCREASE DEGREE OF OPENING OF PRESSURE REDUCING VALVE TO SECOND DEGREE OF OPENING LARGER THAN FIRST DEGREE OF OPENING
(SECOND DEGREE OF OPENING = 100%)
END

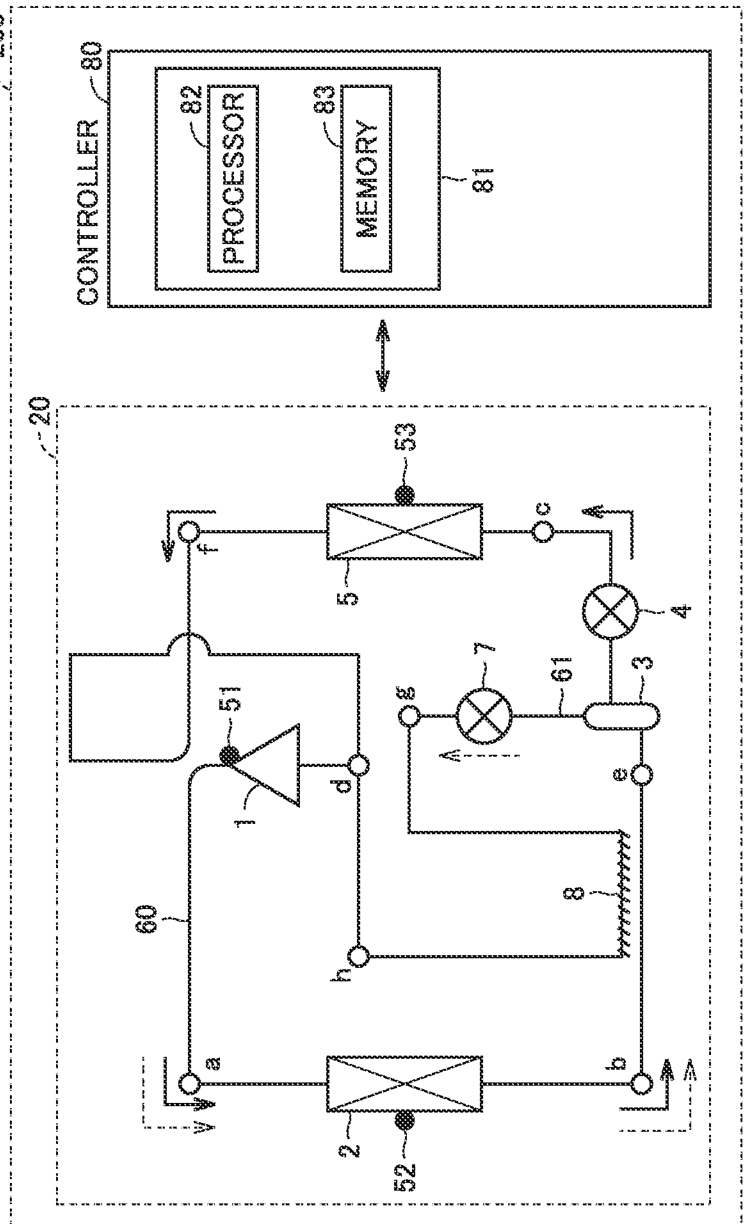

200
CONTROLLER
80
82
PROCESSOR
83
MEMORY
81
20
53
f
c
5
4
7
61
3
g
51
1
d
e
60
8
h
a
b
2
52

FIG.10

FIG.11

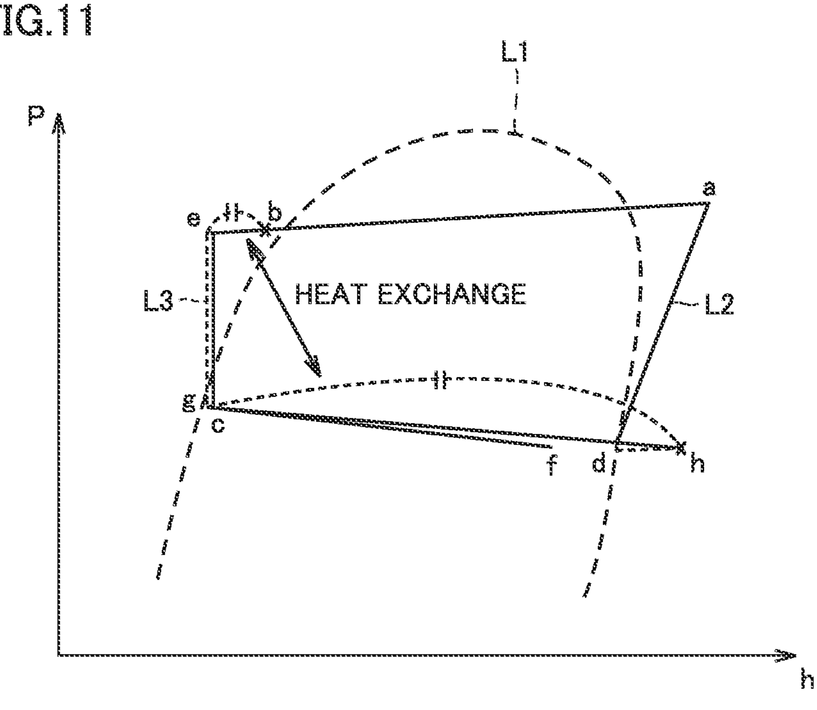


FIG.12

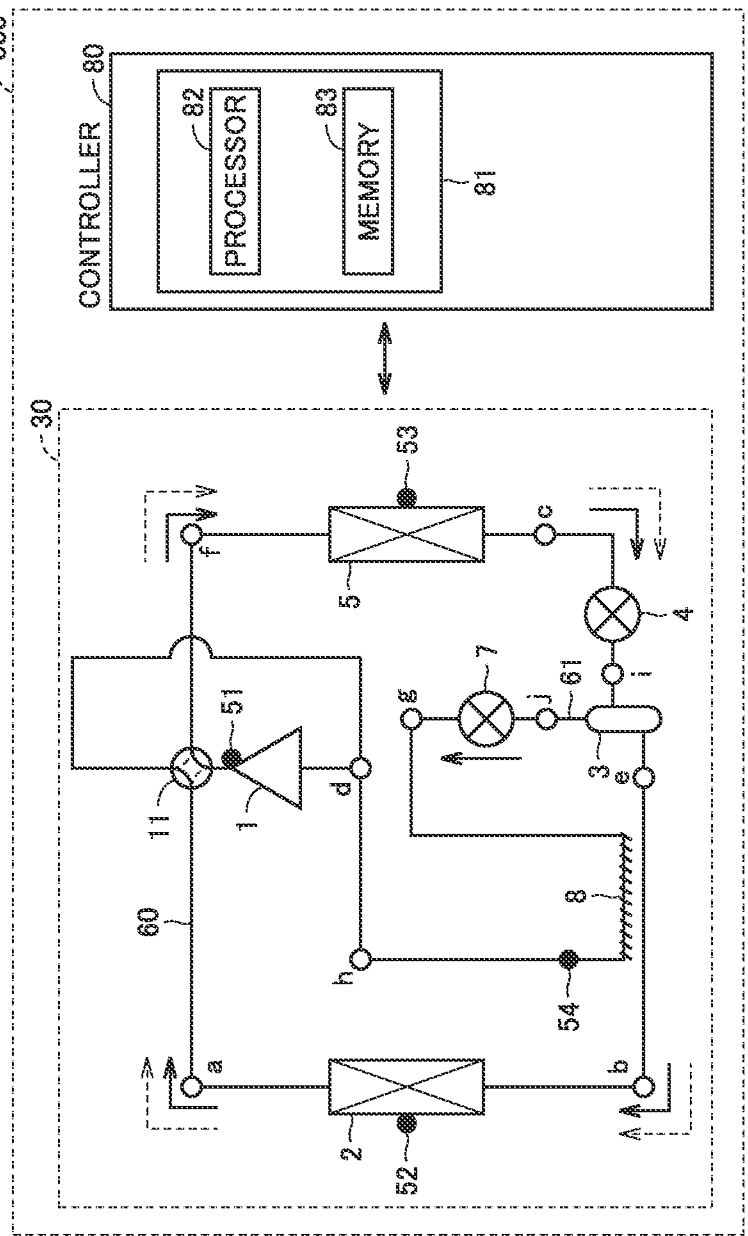

300
80
CONTROLLER
82
PROCESSOR
83
MEMORY
81
30
53
5
c
4
i
61
j
7
g
3
e
51
11
1
d
f
60
8
h
54
a
b
2
52

FIG.13

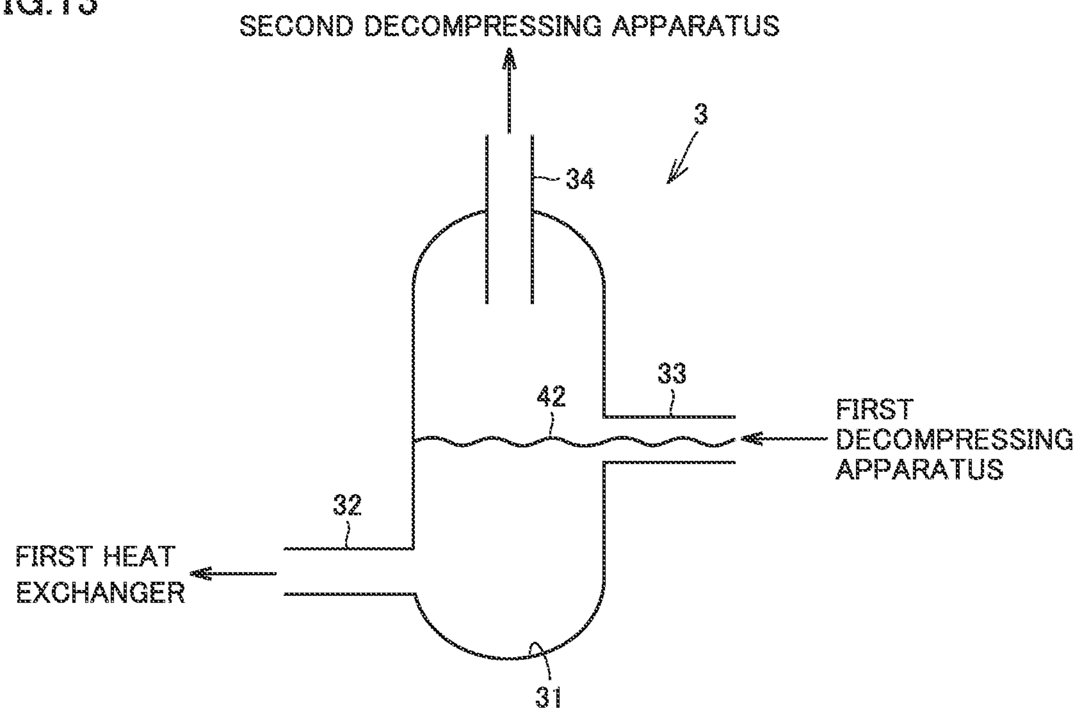
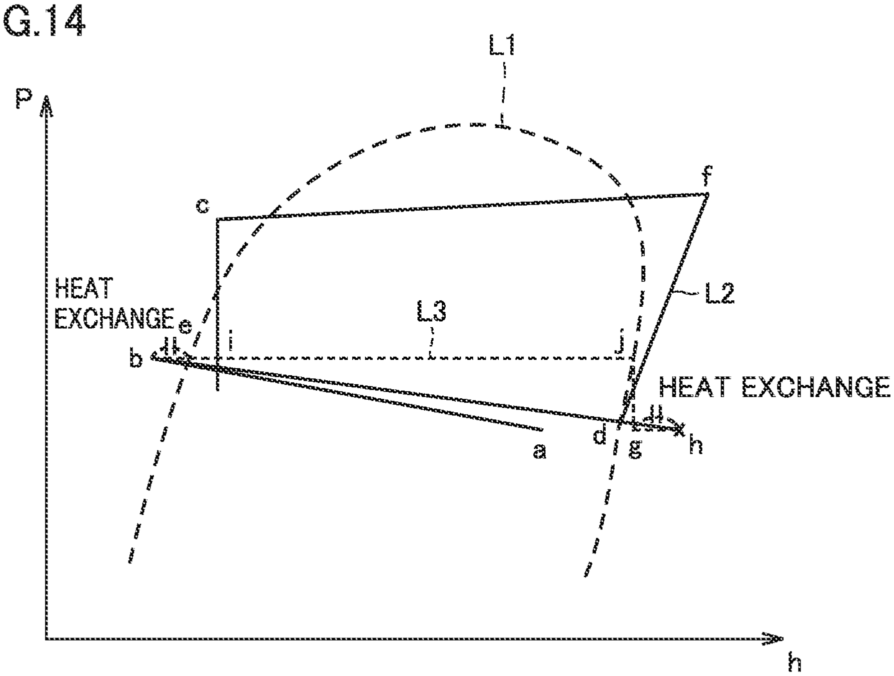

SECOND DECOMPRESSING APPARATUS
3
34
33
42
FIRST
DECOMPRESSING
APPARATUS
32
FIRST HEAT
EXCHANGER
31

FIG.14



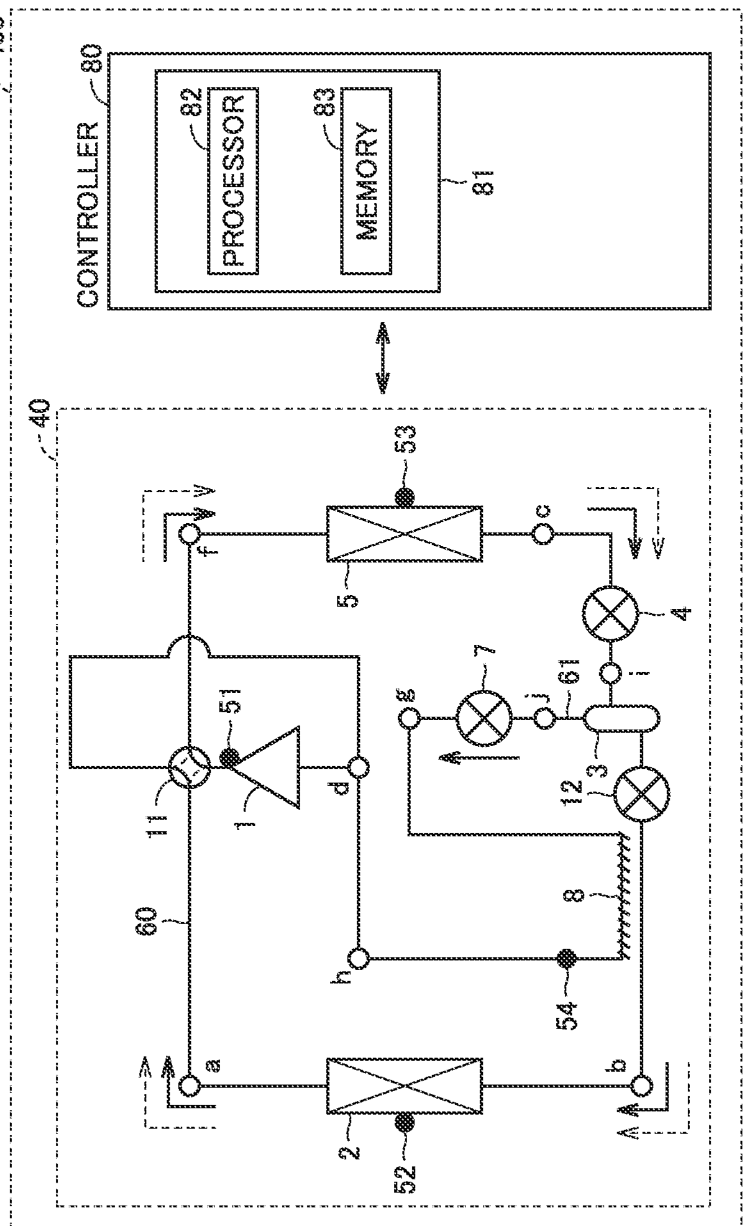

400
80
CONTROLLER
82
PROCESSOR
83
MEMORY
81
40
53
f
c
5
4
7
61
g
j
i
51
11
1
d
3
12
60
8
h
54
a
b
2
52

FIG.15

FIG.16

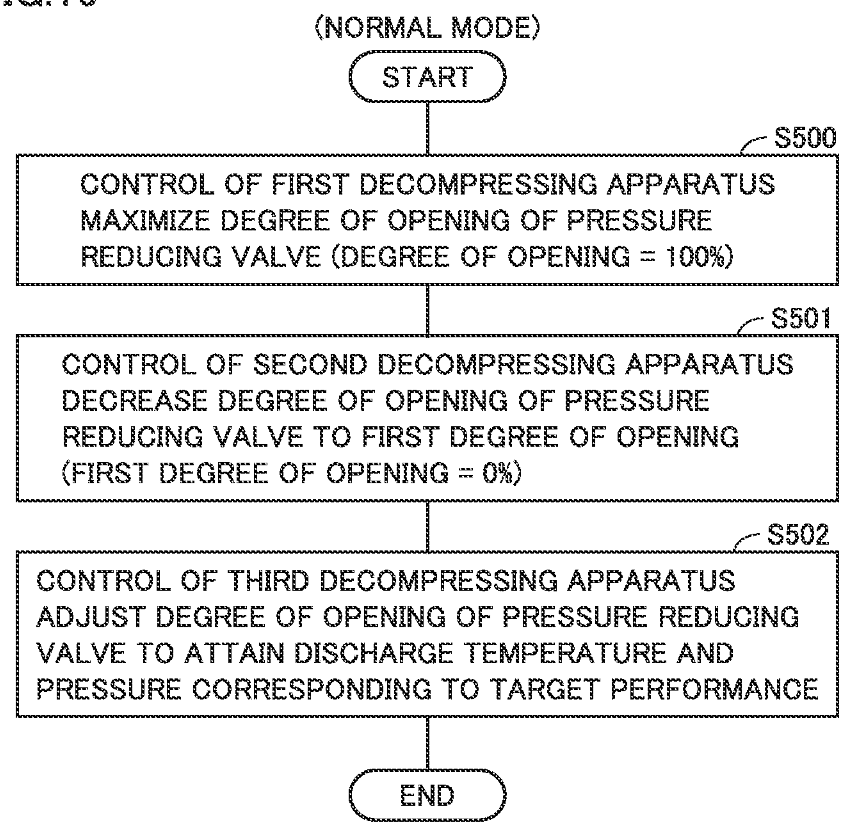
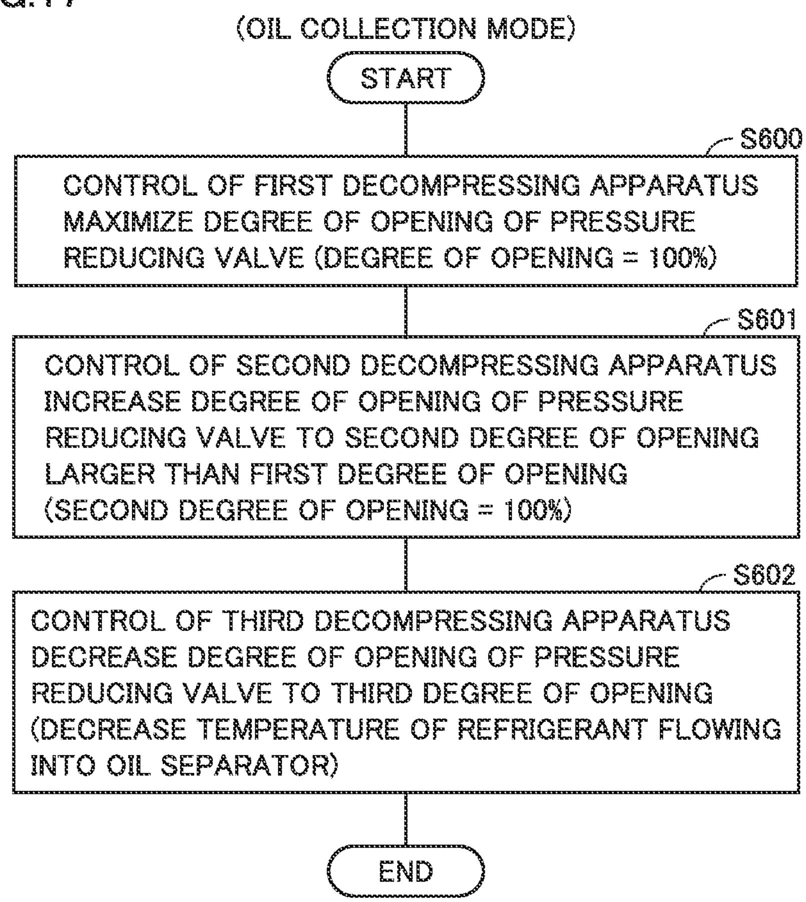

(NORMAL MODE)
START
S500
CONTROL OF FIRST DECOMPRESSING APPARATUS MAXIMIZE DEGREE OF OPENING OF PRESSURE REDUCING VALVE (DEGREE OF OPENING = 100%)
S501
CONTROL OF SECOND DECOMPRESSING APPARATUS DECREASE DEGREE OF OPENING OF PRESSURE REDUCING VALVE TO FIRST DEGREE OF OPENING (FIRST DEGREE OF OPENING = 0%)
S502
CONTROL OF THIRD DECOMPRESSING APPARATUS ADJUST DEGREE OF OPENING OF PRESSURE REDUCING VALVE TO ATTAIN DISCHARGE TEMPERATURE AND PRESSURE CORRESPONDING TO TARGET PERFORMANCE
END

FIG.17


(OIL COLLECTION MODE)
START
S600
CONTROL OF FIRST DECOMPRESSING APPARATUS MAXIMIZE DEGREE OF OPENING OF PRESSURE REDUCING VALVE (DEGREE OF OPENING = 100%)
S601
CONTROL OF SECOND DECOMPRESSING APPARATUS INCREASE DEGREE OF OPENING OF PRESSURE REDUCING VALVE TO SECOND DEGREE OF OPENING LARGER THAN FIRST DEGREE OF OPENING (SECOND DEGREE OF OPENING = 100%)
S602
CONTROL OF THIRD DECOMPRESSING APPARATUS DECREASE DEGREE OF OPENING OF PRESSURE REDUCING VALVE TO THIRD DEGREE OF OPENING (DECREASE TEMPERATURE OF REFRIGERANT FLOWING INTO OIL SEPARATOR)
END

REFRIGERATION CYCLE APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a U.S. national stage application of PCT/JP2020/041211 filed on Nov. 4, 2020, the contents of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure relates to a refrigeration cycle apparatus.

BACKGROUND

[0003] 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.

PATENT LITERATURE

[0004] PTL 1: Japanese Patent Laying-Open No. 08-086519

[0005] 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.

[0006] It is an object of the present disclosure to provide a refrigeration cycle apparatus to improve efficiency of collecting a refrigerating machine oil.

SUMMARY

[0007] 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.

[0008] 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

[0009] FIG. **1** is a diagram showing a configuration of a refrigeration cycle apparatus according to a first embodiment (normal mode).

[0010] FIG. **2** is a diagram showing the configuration of the refrigeration cycle apparatus according to the first embodiment (oil collection mode).

[0011] FIG. **3** is a graph showing a relation between a separation temperature and a saturation solubility ratio of the refrigerating machine oil.

[0012] FIG. **4** is a diagram showing a structure of an oil separator functioning as a liquid-liquid separator.

[0013] FIG. **5** is a p-h diagram showing a state change of a refrigerant in the refrigeration cycle apparatus according to the first embodiment.

[0014] FIG. **6** is a flowchart showing control for switching between the normal mode and the oil collection mode at the time of starting.

[0015] FIG. **7** is a flowchart showing control for switching between the normal mode and the oil collection mode during an operation.

[0016] FIG. **8** is a flowchart showing control in the normal mode.

[0017] FIG. **9** is a flowchart showing control in the oil collection mode.

[0018] FIG. **10** is a diagram showing a configuration of a refrigeration cycle apparatus according to a second embodiment (oil collection mode).

[0019] FIG. **11** is a p-h diagram showing a state change of a refrigerant in the refrigeration cycle apparatus according to the second embodiment.

[0020] FIG. **12** is a diagram showing a configuration of a refrigeration cycle apparatus according to a third embodiment.

[0021] FIG. **13** is a diagram showing a structure of an oil separator functioning as a gas-liquid separator.

[0022] FIG. **14** is a p-h diagram showing a state change of a refrigerant in the refrigeration cycle apparatus according to the third embodiment.

[0023] FIG. **15** is a diagram showing a configuration of a refrigeration cycle apparatus according to a fourth embodiment (oil collection mode).

[0024] FIG. **16** is a flowchart showing control in the normal mode according to the fourth embodiment.

[0025] FIG. **17** is a flowchart showing control in the oil collection mode according to the fourth embodiment.

DETAILED DESCRIPTION

[0026] 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

[0027] 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.

[0028] 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**.

[0029] <Configuration of Refrigerant Circuit **10**>

[0030] 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**.

[0031] 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**.

[0032] 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**.

[0033] 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** functions as a condenser. First heat exchanger **2** is provided with a second temperature sensor **52** configured to detect a condensation temperature of the refrigerant.

[0034] 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.

[0035] 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.

[0036] 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**.

[0037] <Configuration of Controller **80**>

[0038] 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**.

[0039] 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.

[0040] 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.

[0041] 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**.

[0042] <Relation Between Separation Temperature of Refrigerating Machine Oil and Saturation Solubility Ratio>

[0043] 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.

[0044] 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.

[0045] <Normal Mode>

[0046] 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**.

[0047] 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**.

[0048] 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.

[0049] <Oil Collection Mode>

[0050] 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.

[0051] 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.

[0052] 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.

[0053] 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 second decompressing apparatus **7** may be constituted of an electromagnetic valve that changes oil-returned tube **61** between an opened state and a closed state.

[0054] 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**.

[0055] <Structure of Oil Separator>

[0056] 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**.

[0057] 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**.

[0058] <P-H Diagram>

[0059] 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**, L**1** represents a saturation liquid line and a saturation vapor line of the refrigerant, and L**2** and L**3** 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**.

[0060] 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→b'→c'→d→a.

[0061] <Flowchart>

[0062] 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.

[0063] When refrigeration cycle apparatus **100** is started, controller **80** obtains a discharge temperature Td of compressor **1** from first temperature sensor **51** (step S**100**). Next, controller **80** obtains a condensation temperature CT of first heat exchanger **2** from second temperature sensor **52** (step S**101**). Next, controller **80** obtains an evaporation temperature ET of second heat exchanger **5** from third temperature sensor **53** (step S**102**).

[0064] Next, controller **80** calculates a discharge SH (Super Heat) (step S**103**). 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 S**104**). 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.

[0065] When it is determined in step S**104** that discharge SH is less than the determination value, controller **80** performs the operation in the oil collection mode (step S**106**). 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**.

[0066] On the other hand, when it is determined in step S**104** 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 S**105**). 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 S**105** 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 S**106**). On the other hand, when it is determined in step S**104** that evaporation temperature ET is more than the oil separation temperature, controller **80** performs the operation in the normal mode (step S**107**). The flow of control in the normal mode will be described later with reference to FIG. **8**.

[0067] It should be noted that instead of determining whether or not discharge SH is less than the determination value in step S**104**, 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.

[0068] 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.

[0069] 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**.

[0070] First, controller **80** obtains evaporation temperature ET of second heat exchanger **5** from third temperature sensor **53** (step S**200**). Next, controller **80** determines whether or not evaporation temperature ET is equal to or less than the oil separation temperature (step S**201**). 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 S**201** 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 S**202**). 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 S**201** that evaporation temperature ET is more than the oil separation temperature, controller **80** performs the operation in the normal mode (step S**203**). Details of the control in the normal mode will be described later with reference to FIG. **8**.

[0071] <Flow of Control in Normal Mode>

[0072] 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 S**300**).

[0073] 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 S**301**). 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%.

[0074] Controller **80** controls first decompressing apparatus **4** and second decompressing apparatus **7** as in steps S**300** and S**301**, thereby implementing the normal mode. It should be noted that controller **80** may perform step S**301** prior to step S**300**.

[0075] <Flow of Control in Oil Collection Mode>

[0076] 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 S**400**). 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.

[0077] 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 S**401**). 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%.

[0078] Controller **80** controls first decompressing apparatus **4** and second decompressing apparatus **7** as in steps S**400** and S**401**, thereby implementing the oil collection mode. It should be noted that controller **80** may perform step S**401** prior to step S**400**.

[0079] 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 S**401** without performing step **400**. That is, by controlling second decompressing apparatus **7** as in step S**401**, the refrigerating machine oil can flow from oil separator **3** into oil-returned tube **61**, thereby implementing the oil collection mode.

[0080] 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**.

[0081] 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

[0082] In a second embodiment, a refrigeration cycle apparatus **200** comprising a third heat exchanger **8** will be described.

[0083] 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**.

[0084] 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**.

[0085] <P-H Diagram>

[0086] 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.

[0087] 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 exchange is performed between the section from b to e and the section from g to h.

[0088] 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**.

[0089] 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

[0090] 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.

[0091] 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**.

[0092] 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.

[0093] 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.

[0094] 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**.

[0095] 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**.

[0096] 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**.

[0097] 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.

[0098] 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.

[0099] <P-H Diagram>

[0100] 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**.

[0101] 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.

[0102] 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**.

[0103] 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**.

[0104] 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

[0105] 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.

[0106] 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**.

[0107] <Case where Second Heat Exchanger **5** is Connected to Discharge Side of Compressor **1**>

[0108] 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.

[0109] 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**.

[0110] As understood from these circuit configurations, as with refrigeration cycle apparatus **100** (see FIG. **2**) according to the first embodiment, refrigeration cycle apparatus **400** shown in FIG. **15** can implement the oil collection mode when the refrigerant flows as shown in the figure.

[0111] 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**.

[0112] 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**.

[0113] 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.

[0114] 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**.

[0115] 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**.

[0116] 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**.

[0117] 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 S**101**, and evaporation temperature ET is obtained from the detection value of second temperature sensor **52** in each of steps S**102** and S**200**.

[0118] <Flow of Control in Normal Mode (Fourth Embodiment)>

[0119] 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**.

[0120] 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 S**500**). Thus, the decompression effect of first decompressing apparatus **4** is negligible.

[0121] 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 S**501**). 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%.

[0122] 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 S**502**).

[0123] Controller **80** controls first decompressing apparatus **4**, second decompressing apparatus **7**, and third decompressing apparatus **12** to implement the normal mode as in steps S**500** to S**502**. The order in which controller **80** performs steps S**500** to S**502** may be changed to any order.

[0124] <Flow of Control in Oil Collection Mode (Fourth Embodiment)>

[0125] 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**.

[0126] 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 S**600**). Thus, the decompression effect of first decompressing apparatus **4** is negligible.

[0127] 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 S**601**). 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%.

[0128] 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 S**602**). 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.

[0129] 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 S**600** to S**602**. The order in which controller **80** performs steps S**600** to S**602** 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 S**600** and S**601**, the refrigerating machine oil can be caused to flow from oil separator **3** into oil-returned tube **61**, thereby implementing the oil collection mode.

[0130] <Case where First Heat Exchanger **2** is Connected to Discharge Side of Compressor **1**>

[0131] 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**.

[0132] 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

[0133] In each of step S**102** of FIG. **6** and step S**200** of FIG. **7**, outdoor air temperature Tout may be obtained instead of or in addition to evaporation temperature ET. Here, outdoor air temperature Tout 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 Tout. For example, it is considered that outdoor air temperature Tout is detected by a temperature sensor provided at a suction port of a fan (not shown) of second heat exchanger **5**.

[0134] When outdoor air temperature Tout is obtained in each of step S**102** of FIG. **6** and step S**200** 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 Tout with a reference value in each of step S**105** of FIG. **6** and step S**201** of FIG. **7**. Normally, outdoor air temperature Tout is considered to be higher than evaporation temperature ET. For this reason, when determination is made as to "outdoor air temperature Tout≤reference value?" instead of "evaporation temperature ET≤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

[0135] In step S**104** of FIG. **6**, instead of discharge SH, discharge temperature Td 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

[0136] Condensation temperature CT may be calculated from a detection value of a pressure sensor provided on the discharge side of compressor **1**.

Modification 4

[0137] Evaporation temperature ET may be calculated from a detection value of a pressure sensor provided on the suction side of compressor **1**.

Modification 5

[0138] In the flowchart of FIG. **6**, determination may be made in only one of step S**104** and step S**105**. For example, when NO is determined in step S**104**, the process proceeds to step S**107** to perform the operation in the normal mode. Alternatively, the process proceeds from step S**103** to step S**105** directly. When YES is determined in step S**105**, the operation is performed in the oil collection mode (step S**106**), and when NO is determined in step S**105**, the operation is performed in the normal mode (step S**107**).

Conclusion

[0139] The present embodiment is concluded as follows.

[0140] 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 (S**106** in FIGS. **6** and S**202** 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**).

[0141] 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.

[0142] Preferably, the controller (**80**) is configured to set the operation mode to a normal mode (S**107** in FIGS. **6** and S**203** 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**).

[0143] 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.

[0144] Preferably, in the oil collection mode (S**106** in FIGS. **6** and S**202** 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.

[0145] With such a configuration, the separation between the refrigerant and the refrigerating machine oil can be promoted.

[0146] 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**).

[0147] 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 (S**106** in FIGS. **6** and S**202** in FIG. **7**) by using the temperature detected by the first temperature sensor (**51**) when the refrigeration cycle apparatus (**100** to **400**) is started.

[0148] 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 determines whether to set the operation mode to the oil collection mode (S**106** 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**) (S**104** in FIG. **6**).

[0149] 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 (S**202** 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**) (S**201** in FIG. **7**).

[0150] 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**).

[0151] 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.

[0152] 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**).

[0153] Preferably, the controller (**80**) is configured to set the oil collection mode (S**106** in FIGS. **6** and S**202** 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**).

[0154] 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**).

[0155] 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.

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 decom-

pression 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,

the controller being 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.

2. (canceled)

3. The refrigeration cycle apparatus according to claim **1**, 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 claim **1**, 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 temperature 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 claim **1**, 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 claim **1**, 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 claim **1**, 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 claim **1**, 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 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, the third decompressing apparatus, and the first heat exchanger, and

the controller is configured to set the operation mode to the oil collection mode by adjusting a degree of decompression of the first decompressing apparatus and the degree of decompression of the second decompressing apparatus when the refrigerant and the refrigerating machine oil flowing in the second circulation pathway are separated in the oil separator.

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