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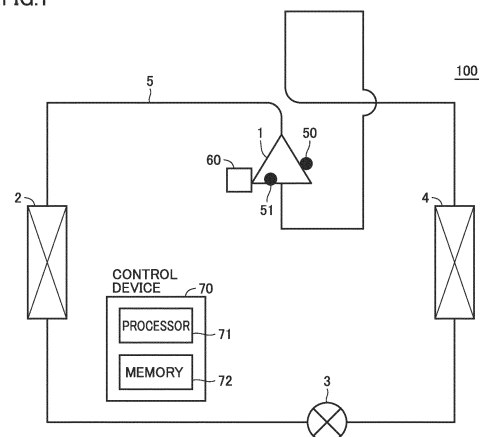
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(54) **AIR CONDITIONER**

(57) An air conditioner (100) includes a compressor (1), a first heat exchanger (2), a second heat exchanger (4), a decompression device (3), a circulation path (5), a temperature sensor (50), a concentration sensor (51), a heater (60), and a control device (70). In a case where a concentration of refrigeration oil detected by the concentration sensor (51) is less than a first threshold value, the control device (70) operates the heater (60) such that a part of a refrigerant in a liquid state in the compressor (1) is vaporized, and in a case where the concentration of the refrigeration oil detected by the concentration sensor (51) exceeds a second threshold value greater than the first threshold value and a temperature of the refrigeration oil detected by the temperature sensor (50) is less than a specified temperature, the control device (70) operates the heater (60) such that the refrigerant in the liquid state in the compressor (1) is vaporized and the temperature of the refrigeration oil in the compressor (1) is increased.

FIG.1



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to an air conditioner.

BACKGROUND ART

[0002] An air conditioner includes a compressor that discharges a high-temperature and high-pressure refrigerant to a refrigerant circuit. The compressor is filled with refrigeration oil for maintaining lubricity of a drive unit such as a motor. As a temperature of the refrigeration oil is decreased, viscosity of the refrigeration oil is increased.

[0003] When the viscosity of the refrigeration oil is increased, driving torque of the compressor is increased, and a current value of the motor may become excessive. PTL 1 discloses a technique of heating the refrigeration oil until the temperature of the refrigeration oil reaches the pour point in a case where the temperature of the refrigeration oil is lower than the pour point, for the purpose of maintaining appropriate viscosity of the refrigeration oil. Here, a temperature at which a liquid does not flow at all is referred to as solidification point, and a temperature immediately before the solidification point is referred to as pour point.

CITATION LIST

PATENT LITERATURE

[0004] PTL 1: WO 2018/138796

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0005] The refrigeration oil may be present in the compressor in a state of a mixture of the refrigeration oil and the refrigerant in a liquid state. As the amount of the refrigerant in the liquid state in the compressor is increased, a concentration of the refrigeration oil is decreased. In a constant temperature environment, the viscosity of the mixture is decreased as the concentration of the refrigeration oil is decreased. Therefore, even in a case where the temperature of the refrigeration oil is sufficiently high, in a case where the concentration of the refrigeration oil is too low, the refrigeration oil may not exhibit a function as a lubricant. In addition, even when the concentration of the refrigeration oil is not low, in a case where the temperature of the refrigeration oil is too low, the viscosity of the refrigeration oil is increased, which may abnormally increase the driving torque of the motor of the compressor.

[0006] Therefore, the necessity of heating the refrigeration oil should be determined in consideration of not

only the temperature of the refrigeration oil but also the concentration of the refrigeration oil.

[0007] The technique in the related art decides the necessity of heating the refrigeration oil by using the temperature of the refrigeration oil as an index. However, the technique in the related art does not consider the concentration of the refrigeration oil. Therefore, according to the technique in the related art, even when the concentration and temperature of the refrigeration oil are in a range in which the refrigeration oil can exhibit a lubricating function in the compressor, the refrigeration oil is unnecessarily heated in a case where the temperature of the refrigeration oil does not reach the pour point.

[0008] Moreover, in the technique in the related art, in a case where the temperature of the refrigeration oil does not reach the pour point, a heating operation is continued until the temperature of the refrigeration oil reaches the pour point. In order to increase the temperature of the refrigeration oil by heating the refrigeration oil mixed with the refrigerant in the liquid state, it is necessary to vaporize the refrigerant having a lower boiling point out of the refrigeration oil and the refrigerant first. Therefore, in the technique in the related art, power for heating is excessively consumed.

[0009] The present disclosure has been made to solve such a problem, and an object of the present disclosure is to provide an air conditioner capable of appropriately maintaining lubricating performance of refrigeration oil in a compressor in consideration of a temperature and a concentration of the refrigeration oil.

SOLUTION TO PROBLEM

[0010] The present disclosure relates to an air conditioner. The air conditioner includes a compressor; a first heat exchanger; a second heat exchanger; a decompression device; a circulation path through which a refrigerant circulates through the compressor, the first heat exchanger, the decompression device, and the second heat exchanger in this order; a temperature sensor to detect a temperature of refrigeration oil in the compressor; a concentration sensor to detect a concentration of the refrigeration oil in a mixture of the refrigerant in a liquid state and the refrigeration oil in the compressor; a heater to heat the refrigeration oil in the compressor; and a control device. In a case where a concentration of refrigeration oil detected by the concentration sensor is less than a first threshold value, the control device operates the heater such that a part of a refrigerant in a liquid state in the compressor is vaporized, and in a case where the concentration of the refrigeration oil detected by the concentration sensor exceeds a second threshold value greater than the first threshold value and a temperature of the refrigeration oil detected by the temperature sensor is less than a specified temperature, the control device operates the heater such that the refrigerant in the liquid state in the compressor is vaporized and the temperature of the refrigeration oil in the compressor is increased.

ADVANTAGEOUS EFFECTS OF INVENTION

[0011] According to an air conditioner of the present disclosure, it is possible to provide an air conditioner capable of appropriately maintaining lubricating performance of the refrigeration oil in the compressor in consideration of the temperature and the concentration of the refrigeration oil.

BRIEF DESCRIPTION OF DRAWINGS

[0012]

Fig. 1 is a refrigerant circuit diagram illustrating a configuration of an air conditioner (first embodiment).

Fig. 2 is a diagram for describing a region where a heater is operated, from the viewpoint of a temperature T_{oil} and a concentration α_{oil} of refrigeration oil (first embodiment).

Fig. 3 is a diagram for describing control of the heater, from the viewpoint of temperature T_{oil} and concentration α_{oil} of the refrigeration oil (first embodiment).

Fig. 4 is a flowchart illustrating control for setting heating conditions in accordance with temperature T_{oil} and concentration α_{oil} of the refrigeration oil (first embodiment).

Fig. 5 is a flowchart illustrating control for operating the heater according to the heating condition (first embodiment).

Fig. 6 is a diagram for describing control of a heater, from the viewpoint of a temperature T_{oil} and a concentration α_{oil} of refrigeration oil (second embodiment).

Fig. 7 is a flowchart illustrating control for setting heating conditions in accordance with temperature T_{oil} and concentration α_{oil} of the refrigeration oil (third embodiment).

Fig. 8 is a flowchart illustrating control for operating a heater according to the heating condition (third embodiment).

Fig. 9 is a diagram for describing a region where a heater is operated in a state where a refrigerant in a liquid state and refrigeration oil are separated into two layers in a compressor, from the viewpoint of a temperature T_{oil} and a concentration α_{oil} of the refrigeration oil (fourth embodiment).

Fig. 10 is a diagram for describing control of the heater, from the viewpoint of temperature T_{oil} and concentration α_{oil} of the refrigeration oil (fourth embodiment).

Fig. 11 is a flowchart illustrating control for setting heating conditions in accordance with temperature T_{oil} and concentration α_{oil} of the refrigeration oil (fourth embodiment).

Fig. 12 is a flowchart illustrating control for operating the heater according to the heating condition (fourth

embodiment).

Fig. 13 is a diagram illustrating an example in which a temperature sensor and a concentration sensor are provided in a vicinity portion of a shaft of a compressor (fifth embodiment).

Fig. 14 is a diagram illustrating an example in which a temperature sensor and a concentration sensor are provided at an end portion of a shaft of a compressor (sixth embodiment).

DESCRIPTION OF EMBODIMENTS

[0013] Hereinafter, embodiments of the present disclosure will be described in detail with reference to the drawings. Hereinafter, a plurality of embodiments will be described, but it is planned from the beginning of the application to appropriately combine the configurations described in each embodiment. In the drawings, the same or corresponding parts are denoted by the same reference numerals, and the description thereof will not be repeated.

First Embodiment

[0014] Fig. 1 is a refrigerant circuit diagram illustrating a configuration of an air conditioner 100 according to a first embodiment (first embodiment). Referring to Fig. 1, air conditioner 100 includes a compressor 1, a first heat exchanger 2, a decompression device 3, a second heat exchanger 4, and a control device 70. Compressor 1, first heat exchanger 2, decompression device 3, and second heat exchanger 4 constitute a refrigerant circuit that circulates a refrigerant. The refrigerant circuit includes a circulation path 5 through which the refrigerant circulates through compressor 1, first heat exchanger 2, decompression device 3, and second heat exchanger 4 in this order.

[0015] First heat exchanger 2 is located on a high pressure side in the refrigerant circuit. Therefore, first heat exchanger 2 functions as a condenser. Second heat exchanger 4 is located on a low pressure side in the refrigerant circuit. Therefore, second heat exchanger 4 functions as an evaporator. For example, by disposing first heat exchanger 2 indoors and disposing second heat exchanger 4 outdoors, air conditioner 100 functions as a heating unit that warms an indoor space. Air conditioner 100 may be provided with a switching valve that switches a discharge destination of the refrigerant from compressor 1 between first heat exchanger 2 and second heat exchanger 4.

[0016] The refrigeration oil is sealed in compressor 1. The refrigeration oil functions as a lubricant for a drive unit such as a motor in compressor 1. Compressor 1 is provided with a temperature sensor 50, a concentration sensor 51, and a heater 60. Temperature sensor 50 detects the temperature of the refrigeration oil in compressor 1, and transmits a detection value to control device 70. Concentration sensor 51 detects the concentration

of the refrigeration oil in compressor 1, and transmits a detection value to control device 70. Heater 60 heats the refrigeration oil in compressor 1.

[0017] Temperature sensor 50 may be provided at any position in compressor 1 as long as the temperature of the refrigeration oil in compressor 1 can be detected at the position. Similarly, concentration sensor 51 may be provided at any position in compressor 1 as long as the concentration of the refrigeration oil in compressor 1 can be detected at the position.

[0018] Control device 70 includes a processor 71 and a memory 72. Memory 72 includes a read only memory (ROM) and a random access memory (RAM). Processor 71 develops a program stored in the ROM in the RAM or the like, and executes the program. The program stored in the ROM is a program in which a processing procedure of control device 70 is described.

[0019] Control device 70 controls each device of air conditioner 100 according to the program stored in memory 72. For example, control device 70 controls compressor 1, decompression device 3, and heater 60. As a result, the frequency at which compressor 1 is operated, the opening degree of a valve of decompression device 3, the timing of the operation of heater 60, and the like are adjusted.

[0020] In some cases, a refrigerant in a liquid state is present in compressor 1. For example, in a case where a part of the refrigerant returning from second heat exchanger 4 to compressor 1 is sucked into compressor 1 in a liquid state without being vaporized, or in a case where the temperature of the refrigerant in compressor 1 is decreased while the operation of air conditioner 100 is stopped, the refrigerant in the liquid state is generated in compressor 1.

[0021] The refrigerant in the liquid state and the refrigeration oil are mixed in compressor 1 according to the condition such as a temperature. At this time, a target of which the temperature is detected by temperature sensor 50 is more strictly a mixture of the refrigerant in the liquid state and the refrigeration oil. The target heated by heater 60 is more strictly a mixture thereof. The concentration detected by concentration sensor 51 corresponds to a proportion of the refrigeration oil included in the mixture.

[0022] That is, concentration sensor 51 detects a component ratio between the refrigeration oil and the refrigerant in the liquid state in compressor 1. In other words, the detection value of concentration sensor 51 is an index indicating how much the refrigeration oil is diluted by the refrigerant. Concentration sensor 51 is, for example, a capacitive sensor that detects the relative permittivity of the refrigeration oil to obtain the component ratio. Heater 60 is, for example, a heating winding.

[0023] The amount of the refrigerant in the liquid state in compressor 1 is changed depending on the operation status of air conditioner 100. A part of the refrigeration oil in compressor 1 is discharged to the refrigerant circuit together with the refrigerant discharged from compressor 1. Therefore, the concentration of the refrigeration oil in

compressor 1 is not constant. The viscosity of the refrigeration oil in compressor 1 is changed depending on the temperature of the refrigeration oil.

[0024] In a case where the viscosity of the refrigeration oil is too high, the driving torque of the motor in compressor 1 is abnormally increased, and the current value of the motor is excessively increased. As a result, an over-current may flow in the motor. Further, the supply of the refrigeration oil to bearings and the like of compressor 1 becomes insufficient. In addition, in a case where the concentration of the refrigeration oil is too low, the refrigeration oil cannot exhibit a function as a lubricant, and lubrication failure occurs in compressor 1. Therefore, in order to cause the refrigeration oil to exhibit a function as a lubricant, it is important to control the concentration and the temperature of the refrigeration oil.

[0025] For example, when the temperature of the refrigeration oil in compressor 1 continues to be decreased, the temperature eventually reaches the solidification point at which the refrigeration oil does not flow. In the present specification, the temperature higher than the solidification point of the refrigeration oil and immediately before the solidification point is referred to as pour point.

[0026] In a case where the temperature of the refrigeration oil detected by temperature sensor 50 is lower than the pour point, it is conceivable to operate heater 60 until the temperature of the refrigeration oil becomes greater than or equal to the pour point. As a result, the fluidity of the refrigeration oil can be enhanced. However, the refrigeration oil may be present in compressor 1 in a state of being diluted to an appropriate concentration by the refrigerant in the liquid state.

[0027] Even in a case where the temperature detected by temperature sensor 50 is lower than the pour point, the refrigeration oil diffused in the mixture may function as a lubricant depending on the concentration of the refrigeration oil. Of course, in a case where the concentration of the refrigeration oil is too low, it is necessary to operate heater 60 in order to cause the refrigeration oil to exhibit a function as a lubricant.

[0028] However, in this case, it is sufficient to increase the concentration of the refrigeration oil until the refrigeration oil diluted by the refrigerant in the liquid state functions as a lubricant. In other words, it is not necessary to operate heater 60 until all of the refrigerant in the liquid state in the mixture is vaporized and further the temperature of the refrigeration oil is increased.

[0029] On the other hand, in a case where the temperature detected by temperature sensor 50 is less than the pour point of the refrigeration oil in a state where the concentration of the refrigeration oil is too high, it is necessary to increase the fluidity of the refrigeration oil by increasing the temperature of the refrigeration oil. In this case, it is necessary to operate heater 60 until all of the refrigerant in the liquid state included in the mixture is vaporized and further the temperature of the refrigeration oil is increased.

[0030] Control device 70 determines a state of the re-

frigeration oil in compressor 1 on the basis of the detection values of temperature sensor 50 and concentration sensor 51, and operates heater 60 appropriately.

[0031] Fig. 2 is a diagram for describing a region where heater 60 is operated, from the viewpoint of temperature T_{oil} and concentration α_{oil} of the refrigeration oil (first embodiment). In Fig. 2, the horizontal axis represents temperature T_{oil} of the refrigeration oil in compressor 1, and the vertical axis represents concentration α_{oil} of the refrigeration oil in compressor 1. Temperature T_{oil} is a value detected by temperature sensor 50. Concentration α_{oil} is a value detected by concentration sensor 51. Therefore, in a case where the refrigerant in the liquid state is present in compressor 1, temperature T_{oil} illustrated in Fig. 2 is the temperature of the mixture of the refrigerant in the liquid state and the refrigeration oil.

[0032] In Fig. 2, T_p is the pour point of the refrigeration oil. In Fig. 2, X_1 is a threshold value for determining whether or not the concentration of the refrigeration oil is a concentration that causes lubrication failure. In Fig. 2, X_2 is a threshold value for determining whether or not the concentration of the refrigeration oil is a concentration that causes the overcurrent in the motor of compressor 1. In particular, X_2 is a value designed assuming that the overcurrent flows in the motor of compressor 1 when the temperature of the refrigeration oil in compressor 1 corresponds to pour point T_p and the concentration of the refrigeration oil in compressor 1 is X_2 .

[0033] Appropriate values of T_p , X_1 , and X_2 are selected by the designer in consideration of the types of the refrigeration oil and the refrigerant, the structure of compressor 1, and the like. These values are stored in memory 72 of control device 70. Note that "1" on the vertical axis means that the concentration of the refrigeration oil is 100%, that is, there is no refrigerant in the liquid state diluting the refrigeration oil in compressor 1.

[0034] As illustrated in Fig. 2, the graph with temperature T_{oil} on the horizontal axis and concentration α_{oil} on the vertical axis is divided into regions (1) to (6). Coordinates (T_{oil} , α_{oil}) specified by temperature T_{oil} and concentration α_{oil} belong to any of these regions.

[0035] Fig. 3 is a diagram for describing control of heater 60, from the viewpoint of temperature T_{oil} and concentration α_{oil} of the refrigeration oil (first embodiment). (1) to (6) illustrated in Fig. 3 correspond to regions (1) to (6) illustrated in Fig. 2. Hereinafter, the contents of the control corresponding to each region will be described with reference to Figs. 2 and 3.

[0036] (1) of Fig. 3 illustrates a region where temperature T_{oil} is less than pour point T_p and concentration α_{oil} is less than or equal to threshold value X_1 . (2) of Fig. 3 illustrates a region where temperature T_{oil} is greater than or equal to pour point T_p and concentration α_{oil} is less than or equal to threshold value X_1 . Since concentration α_{oil} is less than or equal to threshold value X_1 in both region (1) and region (2), lubrication failure may occur in compressor 1.

[0037] In a case where the position of coordinates (T_{oil} ,

α_{oil}) specified by temperature T_{oil} and concentration α_{oil} belongs to region (1) or region (2), control device 70 operates heater 60 such that a part of the refrigerant in the liquid state in compressor 1 is vaporized. As a result, concentration α_{oil} exceeds threshold value X_1 . In this case, control device 70 stops heater 60, for example, when concentration α_{oil} detected by concentration sensor 51 exceeds threshold value X_1 .

[0038] As a result, (T_{oil} , α_{oil}) is moved from region (1) to region (3) or from region (2) to region (4).

[0039] An upward arrow extending from region (1) to region (3) in Fig. 2 indicates that the position of coordinates (T_{oil} , α_{oil}) specified by temperature T_{oil} and concentration α_{oil} transitions from region (1) to region (3) by the heating operation. An upward arrow extending from region (2) to region (4) in Fig. 2 indicates that the position of coordinates (T_{oil} , α_{oil}) specified by temperature T_{oil} and concentration α_{oil} transitions from region (2) to region (4) by the heating operation.

[0040] As illustrated in Fig. 3, heating condition 1 corresponding to region (1) and region (2) is to operate heater 60 until concentration $\alpha_{oil} > X_1$ is satisfied (heating condition 1).

[0041] (3) of Fig. 2 illustrates a region where temperature T_{oil} is less than pour point T_p and concentration α_{oil} exceeds threshold value X_1 and is less than threshold value X_2 . In region (3), temperature T_{oil} is less than the pour point, but since concentration α_{oil} is less than threshold value X_2 , there is no possibility that an overcurrent flows in the motor in compressor 1. In addition, in region (3), since concentration α_{oil} exceeds threshold value X_1 , lubrication failure does not occur in compressor 1.

[0042] (4) of Fig. 2 illustrates a region where temperature T_{oil} is greater than or equal to pour point T_p and concentration α_{oil} exceeds threshold value X_1 and is less than threshold value X_2 . In region (4), since temperature T_{oil} is greater than or equal to the pour point, there is no possibility that an overcurrent flows in the motor in compressor 1. In addition, in region (4), since concentration α_{oil} exceeds threshold value X_1 , lubrication failure does not occur in compressor 1.

[0043] Therefore, in a case where temperature T_{oil} detected by temperature sensor 50 and concentration α_{oil} detected by concentration sensor 51 belong to region (3) or region (4), control device 70 does not operate heater 60 (refer to Fig. 3).

[0044] Here, the description has been given assuming that, in a case where the (T_{oil} , α_{oil}) belongs to region (1) or region (2), the operation of heater 60 is stopped when concentration α_{oil} detected by concentration sensor 51 exceeds threshold value X_1 . However, the timing of stopping the operation of heater 60 is not limited thereto.

[0045] For example, in a case where (T_{oil} , α_{oil}) belongs to region (1) or region (2), control device 70 may stop heater 60 when concentration α_{oil} detected by concentration sensor 51 reaches any value from threshold value X_1 to threshold value X_2 . However, from the view-

point of reducing power consumption, it is desirable to stop heater 60 when concentration α_{oil} detected by concentration sensor 51 exceeds threshold value X1.

[0046] (5) of Fig. 2 illustrates a region where temperature T_{oil} is less than pour point T_p and concentration α_{oil} is greater than or equal to threshold value X2. In region (5), there is a possibility that an overcurrent flows in the motor in compressor 1. In a case where (T_{oil} , α_{oil}) belongs to region (5), control device 70 operates heater 60 so that the refrigerant in the liquid state in compressor 1 is vaporized and the temperature of the refrigeration oil in compressor 1 is increased. As the heating by heater 60 is continued, the refrigerant in the liquid state is vaporized, and concentration α_{oil} of the refrigeration oil eventually reaches "1". Thereafter, temperature T_{oil} of the refrigeration oil is increased, and eventually temperature T_{oil} reaches pour point T_p . Control device 70 stops the operation of heater 60 when temperature T_{oil} detected by temperature sensor 50 reaches pour point T_p .

[0047] As a result, (T_{oil} , α_{oil}) is moved from region (5) to region (6).

[0048] An arrow extending from region (5) to region (6) in Fig. 2 indicates that the position of coordinates (T_{oil} , α_{oil}) specified by temperature T_{oil} and concentration α_{oil} transitions to region (6) in a state of concentration $\alpha_{oil} = 1$, by the heating operation.

[0049] As illustrated in Fig. 3, the heating condition corresponding to region (5) is to operate heater 60 until temperature $T_{oil} \geq$ pour point T_p by vaporizing the refrigerant in the liquid state so that concentration $\alpha_{oil} = 1$ (heating condition 2).

[0050] (6) of Fig. 2 illustrates a region where temperature T_{oil} is greater than or equal to pour point T_p and concentration α_{oil} is greater than or equal to threshold value X2. In region (6), concentration α_{oil} is greater than or equal to threshold value X2. However, in region (6), since temperature T_{oil} is greater than or equal to pour point T_p , there is no possibility that an overcurrent flows in the motor in compressor 1. In addition, in region (6), since concentration α_{oil} exceeds threshold value X1, lubrication failure does not occur in compressor 1. Therefore, in a case where temperature T_{oil} detected by temperature sensor 50 and concentration α_{oil} detected by concentration sensor 51 belong to region (6), control device 70 does not operate heater 60 (refer to Fig. 3).

[0051] As described above, among regions (1) to (6), the regions as the targets where control device 70 operates heater 60 are (1), (2), and (5). Control device 70 operates heater 60 in a case where (T_{oil} , α_{oil}) belongs to either region (1) or region (2). Moreover, control device 70 stops the operation of heater 60 in a stage where concentration α_{oil} of the refrigeration oil exceeds threshold value X1.

[0052] In other words, control device 70 does not operate heater 60 until all of the refrigerant in the liquid state for diluting the refrigeration oil is vaporized. Therefore, according to the present embodiment, it is possible to reduce the power consumption associated with the op-

eration of heater 60 while increasing the concentration of the refrigeration oil until the refrigeration oil diluted by the refrigerant in the liquid state functions as a lubricant.

[0053] Further, in a case where (T_{oil} , α_{oil}) belongs to region (5), control device 70 operates heater 60. At this time, control device 70 operates heater 60 until the refrigerant in the liquid state is vaporized so that $\alpha_{oil} = 1$ and further temperature $T_{oil} \geq$ pour point T_p is satisfied. As a result, the fluidity of the refrigeration oil can be enhanced. As a result, according to the present embodiment, it is possible to prevent the driving torque of the motor in compressor 1 from being abnormally increased and an overcurrent from flowing in the motor.

[0054] As described above, according to the present embodiment, it is possible to provide the air conditioner capable of appropriately maintaining lubricating performance of the refrigeration oil in compressor 1 in consideration of the temperature and the concentration of the refrigeration oil.

[0055] Fig. 4 is a flowchart illustrating control for setting the heating conditions in accordance with temperature T_{oil} and concentration α_{oil} of the refrigeration oil (first embodiment). The processing based on this flowchart is executed by control device 70. A program corresponding to this flowchart is stored in memory 72 of control device 70.

[0056] First, control device 70 determines whether or not the power supply of compressor 1 is on (step S1). In a case where the power supply of compressor 1 is not on (NO in step S1), control device 70 ends the processing based on the present flowchart.

[0057] In a case where the power supply of compressor 1 is on (YES in step S1), control device 70 acquires temperature T_{oil} and concentration α_{oil} of the refrigeration oil in compressor 1 (step S2). Control device 70 acquires temperature T_{oil} from temperature sensor 50. Control device 70 acquires concentration α_{oil} from concentration sensor 51.

[0058] Next, control device 70 determines whether or not "concentration $\alpha_{oil} \leq$ threshold value X1" is satisfied (step S3). In a case where "concentration $\alpha_{oil} \leq$ threshold value X1" is satisfied, control device 70 sets heating condition 1 (step S4), and ends the processing. As a result, heating condition 1 is set corresponding to region (1) and region (2) illustrated in Fig. 2.

[0059] In a case where "concentration $\alpha_{oil} \leq$ threshold value X1" is not satisfied, control device 70 determines whether or not "temperature $T_{oil} <$ pour point T_p " and "concentration $\alpha_{oil} \geq$ threshold value X2" are satisfied (step S5). In a case where "temperature $T_{oil} <$ pour point T_p " and "concentration $\alpha_{oil} \geq$ threshold value X2" are satisfied, control device 70 sets heating condition 2 (step S6), and ends the processing. As a result, heating condition 2 is set corresponding to region (5) illustrated in Fig. 2.

[0060] In a case where "temperature $T_{oil} <$ pour point T_p " and "concentration $\alpha_{oil} \geq$ threshold value X2" are not satisfied, control device 70 decides not to perform heat-

ing (step S7), and ends the processing. As a result, the heating is not performed corresponding to region (3), region (4), and region (6) illustrated in Fig. 2.

[0061] Fig. 5 is a flowchart illustrating control for operating heater 60 according to the heating condition (first embodiment). The processing based on this flowchart is executed by control device 70. A program corresponding to this flowchart is stored in memory 72 of control device 70.

[0062] First, control device 70 determines whether or not heating condition 1 is set (step S11). In a case where heating condition 1 is set, control device 70 operates heater 60 (step S12). Control device 70 operates heater 60 until "concentration $\alpha_{oil} > X1$ " corresponding to heating condition 1 is satisfied. When "concentration $\alpha_{oil} > X1$ " is satisfied (YES in step S13), control device 70 stops the operation of heater 60 (step S14), and ends the processing based on the present flowchart.

[0063] In a case of determining NO in step S11, control device 70 determines whether or not heating condition 2 is set (step S15). In a case where heating condition 2 is set, control device 70 operates heater 60 (step S16). Control device 70 operates heater 60 until "concentration $\alpha_{oil} = 1$ " and "temperature $Toil \geq$ pour point Tp " corresponding to heating condition 2 are satisfied. When heating condition 2 is satisfied (YES in step S17), control device 70 stops the operation of heater 60 (step S14), and ends the processing based on the present flowchart.

Second Embodiment

[0064] Next, a second embodiment will be described. Fig. 6 is a diagram for describing control of heater 60, from the viewpoint of temperature $Toil$ and concentration α_{oil} of the refrigeration oil (second embodiment). As illustrated in Fig. 6, the second embodiment is different from the first embodiment in that threshold value $X1$ is varied according to temperature $Toil$ of the refrigeration oil. In other respects, the second embodiment is similar to the first embodiment.

[0065] When temperature $Toil$ of the refrigeration oil is decreased, the viscosity of the refrigeration oil is increased. In a case where the viscosity of the refrigeration oil is appropriately high, the lubricating performance of the refrigeration oil can be secured even when concentration α_{oil} of the refrigeration oil is small. Therefore, in the second embodiment, in consideration of the fact that the viscosity of the refrigeration oil is increased when temperature $Toil$ of the refrigeration oil is decreased, threshold value $X1$ is made smaller as temperature $Toil$ is decreased.

[0066] For example, Fig. 6 illustrates threshold value $X11$ corresponding to temperature $T1$ of the refrigeration oil and threshold value $X12$ corresponding to temperature $T2$ of the refrigeration oil. Control device 70 of air conditioner 100 according to the second embodiment stores a plurality of threshold values $X1$ including threshold value $X11$ and threshold value $X12$ in memory 72.

[0067] As is clear from the comparison between Figs. 2 and 6, in the second embodiment, region (1) and region (2) are narrower than those in the first embodiment by an area $A1$ illustrated in Fig. 6. This means that there is less need to operate heater 60 in the second embodiment than in the first embodiment. As a result, according to the second embodiment, the power consumption associated with the operation of heater 60 can be further reduced as compared with the first embodiment.

Third Embodiment

[0068] Next, a third embodiment will be described. Fig. 7 is a flowchart illustrating control for setting the heating conditions in accordance with temperature $Toil$ and concentration α_{oil} of the refrigeration oil (third embodiment). Fig. 8 is a flowchart illustrating control for operating heater 60 according to the heating condition (third embodiment). The processing based on these flowcharts of Figs. 7 and 8 is executed by control device 70. A program corresponding to these flowcharts is stored in memory 72 of control device 70.

[0069] As illustrated in step S1A of Fig. 7, control device 70 starts the control for setting the heating condition by detecting an activation signal. The activation signal is a signal for an instruction to start the operation of air conditioner 100. The activation signal is output from, for example, a remote controller of air conditioner 100.

[0070] As illustrated in step S18 of Fig. 8, control device 70 turns on the power supply of compressor 1 after operating heater 60 according to the set heating condition.

[0071] That is, in the third embodiment, control device 70 sets the heating condition before turning on the power supply of compressor 1, and operates heater 60 according to the set heating condition. According to the third embodiment, compressor 1 is activated after temperature $Toil$ and concentration α_{oil} of the refrigeration oil are adjusted to appropriate values. Therefore, compressor 1 can be operated in an appropriate environment from an activation start time point. As a result, it is possible to more reliably prevent occurrence of a failure such as an overcurrent flowing in the motor of compressor 1.

[0072] The third embodiment is similar to the first embodiment except for the timing of turning on the power supply of compressor 1. For example, the processing in steps S2 to S7 in Fig. 7 is similar to the processing in steps S2 to S7 in Fig. 4 described as the first embodiment. In addition, the processing in steps S11 to S17 in Fig. 8 is similar to the processing in steps S11 to S17 in Fig. 5 described as the first embodiment. Therefore, the description of points common to the first embodiment including the flowchart will not be repeated here.

Fourth Embodiment

[0073] Next, a fourth embodiment will be described. The fourth embodiment realizes control in consideration of a case where the refrigerant in the liquid state and the

refrigeration oil are separated into two layers in compressor 1. Fig. 9 is a diagram for describing a region where heater 60 is operated in a state where the refrigerant in the liquid state and the refrigeration oil are separated into two layers in compressor 1, from the viewpoint of temperature T_{oil} and concentration α_{oil} of the refrigeration oil (fourth embodiment).

[0074] As illustrated in Fig. 9, the graph with temperature T_{oil} on the horizontal axis and concentration α_{oil} on the vertical axis is divided into regions (7) to (9). Coordinates (T_{oil} , α_{oil}) specified by temperature T_{oil} and concentration α_{oil} belong to any of these regions.

[0075] Fig. 10 is a diagram for describing control of heater 60, from the viewpoint of temperature T_{oil} and concentration α_{oil} of the refrigeration oil (fourth embodiment). (1) to (6) illustrated in Fig. 10 are similar to (1) to (6) of Fig. 3 described as the first embodiment. These indicate heating conditions when the refrigerant in the liquid state and the refrigeration oil are not separated into two layers in compressor 1. (7) to (9) illustrated in Fig. 10 illustrate heating conditions when the refrigerant in the liquid state and the refrigeration oil are separated into two layers in compressor 1. (7) to (9) correspond to regions (7) to (9) illustrated in Fig. 9.

[0076] Hereinafter, the contents of the control corresponding to regions (7) to (9) will be described with reference to Figs. 9 and 10. Note that the contents of the control corresponding to regions (1) to (6) are similar to those in the first embodiment, and thus, the description thereof will not be repeated here.

[0077] (7) of Fig. 9 illustrates a region where temperature T_{oil} is less than pour point T_p . In a case where the refrigerant in the liquid state and the refrigeration oil are separated into two layers in compressor 1, the refrigeration oil and the refrigerant are not mixed with each other and are present in a single state.

[0078] Therefore, even in a case where the concentration of the refrigeration oil satisfies $\alpha_{oil} > X1$, when temperature T_{oil} is less than pour point T_p , the refrigeration oil maintains a high viscosity state. In general, the density of the refrigerant in the liquid state is higher than the density of the refrigeration oil. Therefore, in a case where the refrigerant in the liquid state and the refrigeration oil are separated into two layers in compressor 1, a state is obtained in which the refrigeration oil collects in an upper portion of compressor 1, and the refrigeration oil is not present at the end portion of the shaft in a lower portion of compressor 1. In this state, lubrication failure may occur in compressor 1.

[0079] Therefore, at this time, regardless of concentration α_{oil} of the refrigeration oil, control device 70 operates heater 60 until the refrigerant in the liquid state is present at the end portion of the shaft of compressor 1 is gasified (concentration $\alpha_{oil} = 1$) and further temperature $T_{oil} \geq$ pour point T_p is satisfied (heating condition 2). As a result, the refrigerant in the liquid state pushing the refrigeration oil upward is gasified.

[0080] As a result, (T_{oil} , α_{oil}) is moved from region (7)

to region (9). At this time, the end portion of the shaft in the lower portion of compressor 1 is thus moistened by the refrigeration oil.

[0081] An arrow extending from region (7) to region (9) in Fig. 9 indicates that the position of coordinates (T_{oil} , α_{oil}) specified by temperature T_{oil} and concentration α_{oil} transitions from region (7) to region (9) by the heating operation. As indicated by the tip of the arrow, the transition destination is the position of concentration $\alpha_{oil} = 1$.

[0082] (8) of Fig. 9 illustrates a region where temperature T_{oil} is greater than or equal to pour point T_p and concentration α_{oil} is less than or equal to threshold value $X1$. Since concentration α_{oil} is less than or equal to threshold value $X1$ in region (8), lubrication failure may occur in compressor 1. In particular, in a case where the refrigerant in the liquid state and the refrigeration oil are separated into two layers in compressor 1, a state is obtained in which the refrigeration oil collects in an upper portion of compressor 1, and the refrigeration oil is not present at the end portion of the shaft in a lower portion of compressor 1. In order to prevent lubrication failure in compressor 1 in this state, it is necessary to gasify all of the refrigerant in the liquid state in compressor 1. Therefore, at this time, control device 70 operates heater 60 until $\alpha_{oil} = 1$ is satisfied to gasify the refrigerant in the liquid state (heating condition 3).

[0083] As a result, (T_{oil} , α_{oil}) is moved from region (8) to region (9). At this time, the end portion of the shaft in the lower portion of compressor 1 is thus moistened by the refrigeration oil.

[0084] An arrow extending from region (8) to region (9) in Fig. 9 indicates that the position of coordinates (T_{oil} , α_{oil}) specified by temperature T_{oil} and concentration α_{oil} transitions from region (8) to region (9) by the heating operation. As indicated by the tip of the arrow, the transition destination is the position of concentration $\alpha_{oil} = 1$.

[0085] (9) of Fig. 9 illustrates a region where temperature T_{oil} is greater than or equal to pour point T_p and concentration α_{oil} exceeds threshold value $X1$. Under this condition, there is no possibility that lubrication failure occurs in compressor 1 in region (9). Therefore, in a case where temperature T_{oil} detected by temperature sensor 50 and concentration α_{oil} detected by concentration sensor 51 belong to region (9), control device 70 does not operate heater 60 (refer to Fig. 10).

[0086] Fig. 11 is a flowchart illustrating control for setting the heating conditions in accordance with temperature T_{oil} and concentration α_{oil} of the refrigeration oil (fourth embodiment). The processing based on this flowchart is executed by control device 70. The processing based on the flowchart of Fig. 11 is executed by control device 70. A program corresponding to this flowchart is stored in memory 72 of control device 70.

[0087] The flowchart illustrated in Fig. 11 is different from the flowchart illustrated in Fig. 4 described as the first embodiment in the following two points. The first point is that step S48 of determining that the refrigeration oil and the refrigerant in the liquid state are separated into

two layers is added. The second point is that steps S49 to S53 of setting the heating conditions in a case where the refrigeration oil and the refrigerant in the liquid state are separated into two layers are added.

[0088] Hereinafter, the flowchart illustrated in Fig. 11 will be described. Among the steps of the flowchart illustrated in Fig. 11, step S41 corresponds to step S1 of the flowchart illustrated in Fig. 4, and steps S42 to S47 correspond to steps S2 to S7 of the flowchart illustrated in Fig. 4, respectively. Therefore, the description of these steps will not be repeated here.

[0089] After acquiring temperature T_{oil} and concentration α_{oil} of the refrigeration oil in compressor 1 in step S42, control device 70 determines whether or not temperature T_{oil} of the refrigeration oil is less than or equal to a separation temperature T_s (step S48). That is, control device 70 compares acquired temperature T_{oil} of the refrigeration oil with the separation temperature T_s to determine whether or not the refrigeration oil and the refrigerant in the liquid state are separated into two layers in step S48.

[0090] Separation temperature T_s used for the determination in step S48 is stored in memory 72 of control device 70. Control device 70 may vary separation temperature T_s according to the concentration detected by concentration sensor 51.

[0091] In a case where it is determined that the refrigeration oil and the refrigerant in the liquid state are not separated into two layers, control device 70 proceeds to step S43. The processing in steps S43 to S47 is similar to that in steps S3 to S7 in Fig. 4 as described above.

[0092] In a case where it is determined that the refrigeration oil and the refrigerant in the liquid state are separated into two layers, control device 70 determines whether or not "temperature $T_{oil} < \text{pour point } T_p$ " is satisfied (step S49). In a case where "temperature $T_{oil} < \text{pour point } T_p$ " is satisfied, control device 70 sets heating condition 2 (step S50), and ends the processing. As a result, heating condition 2 is set corresponding to region (7) illustrated in Fig. 9.

[0093] In a case where "temperature $T_{oil} < \text{pour point } T_p$ " is not satisfied, control device 70 determines whether or not "concentration $\alpha_{oil} \leq \text{threshold value } X1$ " is satisfied (step S51). In a case where "concentration $\alpha_{oil} \leq \text{threshold value } X1$ " is satisfied, control device 70 sets heating condition 3 (step S52), and ends the processing. As a result, heating condition 3 is set corresponding to region (8) illustrated in Fig. 9. In a case where "concentration $\alpha_{oil} \leq \text{threshold value } X1$ " is not satisfied, control device 70 decides not to perform heating (step S53), and ends the processing. Accordingly, it is decided that heating is not performed corresponding to region (9) illustrated in Fig. 9.

[0094] Fig. 12 is a flowchart illustrating control for operating heater 60 according to the heating condition (fourth embodiment). The processing based on this flowchart is executed by control device 70. A program corresponding to this flowchart is stored in memory 72 of con-

trol device 70.

[0095] Hereinafter, the flowchart illustrated in Fig. 12 will be described. The flowchart shown in Fig. 12 is different from the flowchart illustrated in Fig. 5 described as the first embodiment in that control corresponding to heating condition 3 is added. The control corresponding to heating condition 3 is illustrated in steps S58 to S60 in Fig. 12. Steps S51 to S57 in Fig. 12 are similar to steps S11 to S17 in Fig. 5. Therefore, the description of steps S51 to S57 will not be repeated here.

[0096] In a case where it is determined in step S55 that heating condition 2 is not set, control device 70 determines whether or not heating condition 3 is set (step S58). In a case where heating condition 3 is not set, control device 70 ends the processing without operating heater 60.

[0097] In a case where heating condition 3 is set, control device 70 operates heater 60 (step S59). Control device 70 operates heater 60 until "concentration $\alpha_{oil} = 1$ " corresponding to heating condition 3 is satisfied. When heating condition 3 is satisfied (YES in step S60), control device 70 stops the operation of heater 60 (step S54), and ends the processing based on the present flowchart.

[0098] According to the fourth embodiment, the state of the refrigerant and the state of the refrigeration oil can be set to appropriate states according to each of a case where the refrigerant in the liquid state and the refrigeration oil are separated into two layers in compressor 1 and a case where the refrigerant in the liquid state and the refrigeration oil are not separated.

Fifth Embodiment

[0099] Next, a fifth embodiment will be described. Fig. 13 is a diagram illustrating an example in which temperature sensor 50 and concentration sensor 51 are provided in a vicinity portion of a shaft 53 of compressor 1 (fifth embodiment). Compressor 1 includes a compression unit 52, shaft 53, an oil reservoir 54, and a motor 55. Refrigeration oil is stored in oil reservoir 54. In Fig. 13, heater 60 is not illustrated. For example, heater 60 may be disposed between compression unit 52 and motor 55. Alternatively, heater 60 may be disposed at a lower portion of motor 55 and outside a housing of compressor 1.

[0100] As illustrated in Fig. 13, temperature sensor 50 and concentration sensor 51 are disposed in the vicinity portion of shaft 53 when shaft 53 is viewed from a vertical direction. For example, temperature sensor 50 and concentration sensor 51 are disposed in the vicinity portion of shaft 53 at a position close to a lower portion of compression unit 52. In particular, temperature sensor 50 and concentration sensor 51 are disposed at a lower portion of compression unit 52.

[0101] By disposing temperature sensor 50 and concentration sensor 51 at the positions illustrated in Fig. 13, temperature sensor 50 and concentration sensor 51 can respectively detect the temperature and the concentration for the refrigeration oil supplied when compressor

1 is activated. As a result, control device 70 can determine whether or not the refrigeration oil exhibits lubricating performance when compressor 1 is activated.

Sixth Embodiment

[0102] Next, a sixth embodiment will be described. Fig. 14 is a diagram illustrating an example in which the temperature sensor and the concentration sensor are provided at the end portion of shaft 53 of compressor 1 (sixth embodiment). As illustrated in Fig. 14, temperature sensor 50 and concentration sensor 51 are disposed at the lower portion of shaft 53 when shaft 53 is viewed from the vertical direction. In particular, temperature sensor 50 and concentration sensor 51 are disposed at positions close to the end of shaft 53.

[0103] By disposing temperature sensor 50 and concentration sensor 51 at the positions illustrated in Fig. 14, temperature sensor 50 and concentration sensor 51 can respectively detect the temperature and the concentration for the refrigeration oil present in the lower portion of shaft 53 before the activation of compressor 1. As a result, control device 70 can determine whether or not the refrigeration oil is sufficiently supplied before the activation of compressor 1 and the refrigeration oil exhibits lubricating performance.

[0104] In each embodiment described above, "exceeding" may be replaced with "greater than or equal to", and "less than or equal to" may be replaced with "less than". Conversely, "greater than or equal to" may be replaced with "exceeding", and "less than" may be replaced with "less than or equal to".

(Summary)

[0105] Hereinafter, the present embodiment will be summarized.

(1) The present disclosure relates to an air conditioner (100). The air conditioner includes a compressor (1); a first heat exchanger (2); a second heat exchanger (4); a decompression device (3); a circulation path (5) through which a refrigerant circulates through the compressor, the first heat exchanger, the decompression device, and the second heat exchanger in this order; a temperature sensor (50) to detect a temperature of refrigeration oil in the compressor; a concentration sensor (51) to detect a concentration of the refrigeration oil in a mixture of the refrigerant in a liquid state and the refrigeration oil in the compressor; a heater (60) to heat the refrigeration oil in the compressor; and a control device (70). In a case where a concentration of refrigeration oil detected by the concentration sensor is less than a first threshold value, the control device operates the heater such that a part of a refrigerant in a liquid state in the compressor is vaporized (step S4 and steps S11 to S13), and in a case where the concentration

of the refrigeration oil detected by the concentration sensor exceeds a second threshold value greater than the first threshold value and a temperature of the refrigeration oil detected by the temperature sensor is less than a specified temperature, the control device operates the heater such that the refrigerant in the liquid state in the compressor is vaporized and the temperature of the refrigeration oil in the compressor is increased (step S6 and steps S15 to S17). According to the disclosure described in (1), it is possible to provide the air conditioner capable of appropriately maintaining lubricating performance of the refrigeration oil in the compressor in consideration of the temperature and the concentration of the refrigeration oil.

(2) In a case where the concentration of the refrigeration oil detected by the concentration sensor is less than the first threshold value, the control device ends heating of the refrigeration oil via the heater when the concentration of the refrigeration oil in the compressor exceeds the first threshold value (steps S13 and S14).

According to the disclosure described in (2), the power consumption of the heater can be reduced as compared with a case where the heater is continuously operated even when the concentration of the refrigeration oil in the compressor exceeds the first threshold value.

(3) The specified temperature is a temperature (T_p) corresponding to a pour point of the refrigeration oil (Fig. 2).

According to the disclosure described in (3), it is possible to prevent occurrence of a failure in the operation of the compressor due to the refrigeration oil having high viscosity.

(4) The second threshold value is a value designed assuming that an overcurrent flows in a motor of the compressor when the temperature of the refrigeration oil in the compressor is a temperature (T_p) corresponding to the pour point and the concentration of the refrigeration oil in the compressor is the second threshold value.

According to the disclosure described in (4), it is possible to prevent an overcurrent from flowing in the motor of the compressor.

(5) The air conditioner further includes a memory (72) to store the first threshold value, in which the first threshold value (X_{11}) is a value corresponding to a first temperature (T_1) of the refrigeration oil, and the memory further stores a third threshold value (X_{12}) corresponding to a second temperature (T_2) of the refrigeration oil (Fig. 6).

According to the disclosure described in (5), the power consumption of the heater can be reduced.

(6) The control device activates the compressor (step S18) after adjusting the concentration or the temperature of the refrigeration oil in the compressor by operating the heater.

According to the disclosure described in (6), the compressor can be operated in an appropriate environment from an activation start time point. As a result, it is possible to more reliably prevent occurrence of a failure in the operation of the compressor.

(7) The control device operates the heater (steps S48 to S50) regardless of the concentration of the refrigeration oil in the compressor in a case where the refrigerant and the refrigeration oil in the compressor are separated and the temperature of the refrigeration oil detected by the temperature sensor is less than the specified temperature.

According to the disclosure described in (7), the heater operates to gasify the refrigerant in the liquid state pushing the refrigeration oil upward in the compressor. As a result, it is possible to prevent occurrence of the lubrication failure in the compressor.

(8) The control device stops the operation of the heater (steps S57 and S54) in a case where the temperature of the refrigeration oil in the compressor exceeds the specified temperature.

According to the disclosure described in (8), the refrigerant in the liquid state can be sufficiently gasified.

(9) The control device operates the heater (steps S48, S49, S51, and S52) in a case where the refrigerant and the refrigeration oil in the compressor are separated, the temperature of the refrigeration oil detected by the temperature sensor exceeds the specified temperature, and the concentration of the refrigeration oil detected by the concentration sensor is less than the first threshold value.

According to the disclosure described in (9), the heater operates to gasify the refrigerant in the liquid state pushing the refrigeration oil upward in the compressor. As a result, it is possible to prevent occurrence of the lubrication failure in the compressor.

(10) The control device stops the operation of the heater (steps S60 and S54) in a case where the refrigerant in the liquid state in the compressor is vaporized.

According to the disclosure described in (10), the power consumption of the heater can be reduced as compared with a case where the heater is continuously operated even after the refrigerant is vaporized.

(11) The temperature sensor and the concentration sensor are provided in a vicinity of a shaft of the compressor (Fig. 13).

According to the disclosure described in (11), the control device can more appropriately maintain the lubricating performance of the refrigeration oil in the compressor in consideration of the temperature and the concentration of the refrigeration oil in a state where the compressor is activated.

(12) The temperature sensor and the concentration sensor are provided at an end portion of a shaft of the compressor (Fig. 14).

[0106] According to the disclosure described in (12), the control device can more appropriately maintain the lubricating performance of the refrigeration oil in the compressor in consideration of the temperature and the concentration of the refrigeration oil before the compressor is activated.

[0107] It should be understood that the embodiments disclosed herein are illustrative in all respects and not restrictive. The scope of the present disclosure is defined not by the above description in the above embodiments but by the claims, and is intended to include meanings equivalent to the claims and all modifications within the scope.

REFERENCE SIGNS LIST

[0108] 1: compressor, 2: first heat exchanger, 3: decompression device, 4: second heat exchanger, 5: circulation path, 50: temperature sensor, 51: concentration sensor, 52: compression unit, 53: shaft, 54: oil reservoir, 55: motor, 60: heater, 70: control device, 71: processor, 72: memory, 100: air conditioner, A1: area

Claims

1. An air conditioner comprising:

a compressor;
a first heat exchanger;
a second heat exchanger;
a decompression device;
a circulation path through which a refrigerant circulates through the compressor, the first heat exchanger, the decompression device, and the second heat exchanger in this order;
a temperature sensor to detect a temperature of refrigeration oil in the compressor;
a concentration sensor to detect a concentration of the refrigeration oil in a mixture of the refrigerant in a liquid state and the refrigeration oil in the compressor;
a heater to heat the refrigeration oil in the compressor; and
a control device,
wherein

in a case where the concentration of the refrigeration oil detected by the concentration sensor is less than a first threshold value, the control device operates the heater such that a part of the refrigerant in the liquid state in the compressor is vaporized, and

in a case where the concentration of the refrigeration oil detected by the concentration sensor exceeds a second threshold value greater than the first threshold value and the temperature of the refrigeration oil detected by the temperature sensor is less than a specified temperature, the

- control device operates the heater such that the refrigerant in the liquid state in the compressor is vaporized and the temperature of the refrigeration oil in the compressor is increased.
2. The air conditioner according to claim 1, wherein in a case where the concentration of the refrigeration oil detected by the concentration sensor is less than the first threshold value, the control device ends heating of the refrigeration oil via the heater when the concentration of the refrigeration oil in the compressor exceeds the first threshold value.
 3. The air conditioner according to claim 1 or 2, wherein the specified temperature is a temperature corresponding to a pour point of the refrigeration oil.
 4. The air conditioner according to claim 3, wherein the second threshold value is a value designed assuming that an overcurrent flows in a motor of the compressor when the temperature of the refrigeration oil in the compressor is a temperature corresponding to the pour point and the concentration of the refrigeration oil in the compressor is the second threshold value.
 5. The air conditioner according to any one of claims 1 to 4, further comprising:
 - a memory to store the first threshold value, wherein the first threshold value is a value corresponding to a first temperature of the refrigeration oil, and the memory further stores a third threshold value corresponding to a second temperature of the refrigeration oil.
 6. The air conditioner according to any one of claims 1 to 5, wherein the control device activates the compressor after adjusting the concentration or the temperature of the refrigeration oil in the compressor by operating the heater.
 7. The air conditioner according to any one of claims 1 to 6, wherein the control device operates the heater regardless of the concentration of the refrigeration oil in the compressor in a case where the refrigerant and the refrigeration oil in the compressor are separated and the temperature of the refrigeration oil detected by the temperature sensor is less than the specified temperature.
 8. The air conditioner according to claim 7, wherein the control device stops the operation of the heater in a case where the temperature of the refrigeration oil in the compressor exceeds the specified temperature.
 9. The air conditioner according to any one of claims 1 to 8, wherein the control device operates the heater in a case where the refrigerant and the refrigeration oil in the compressor are separated, the temperature of the refrigeration oil detected by the temperature sensor exceeds the specified temperature, and the concentration of the refrigeration oil detected by the concentration sensor is less than the first threshold value.
 10. The air conditioner according to claim 9, wherein the control device stops the operation of the heater in a case where the refrigerant in the liquid state in the compressor is vaporized.
 11. The air conditioner according to any one of claims 1 to 10, wherein the temperature sensor and the concentration sensor are provided in a vicinity of a shaft of the compressor.
 12. The air conditioner according to any one of claims 1 to 10, wherein the temperature sensor and the concentration sensor are provided at an end portion of a shaft of the compressor.

FIG.1

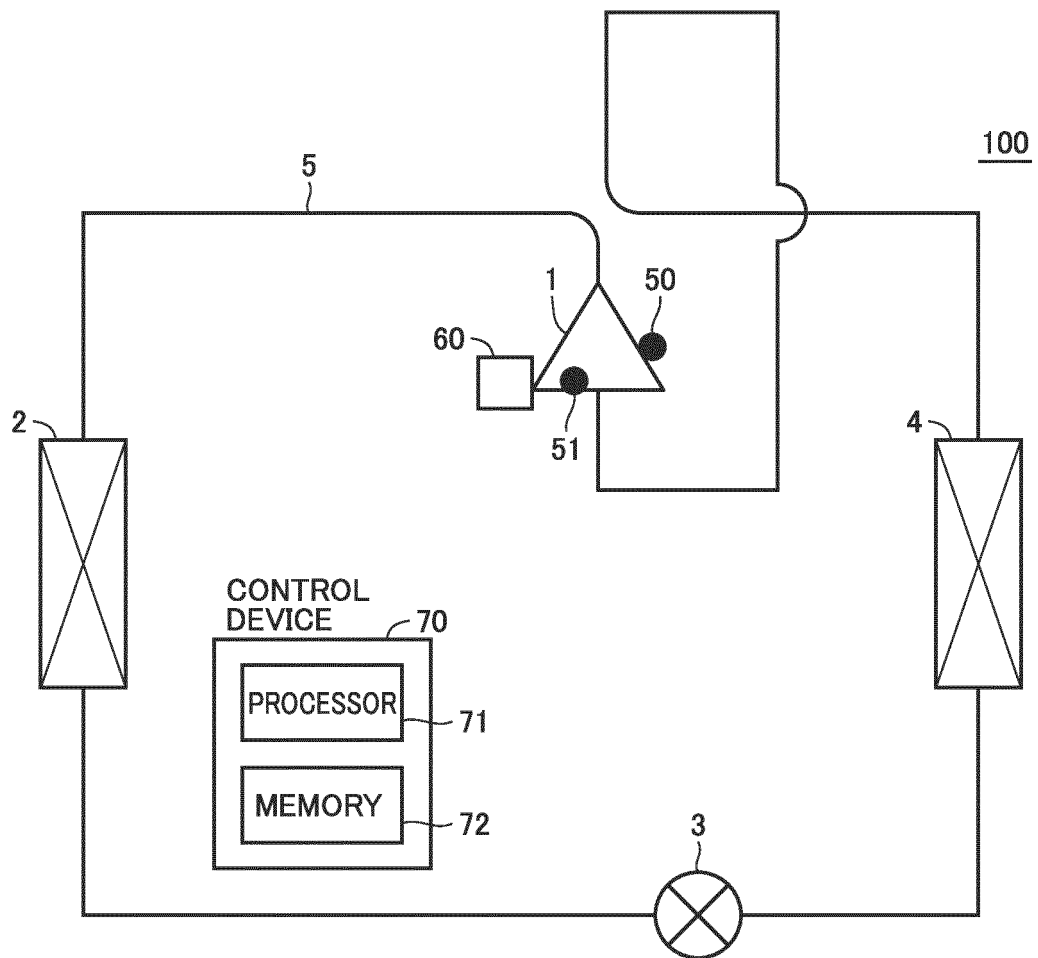


FIG.2

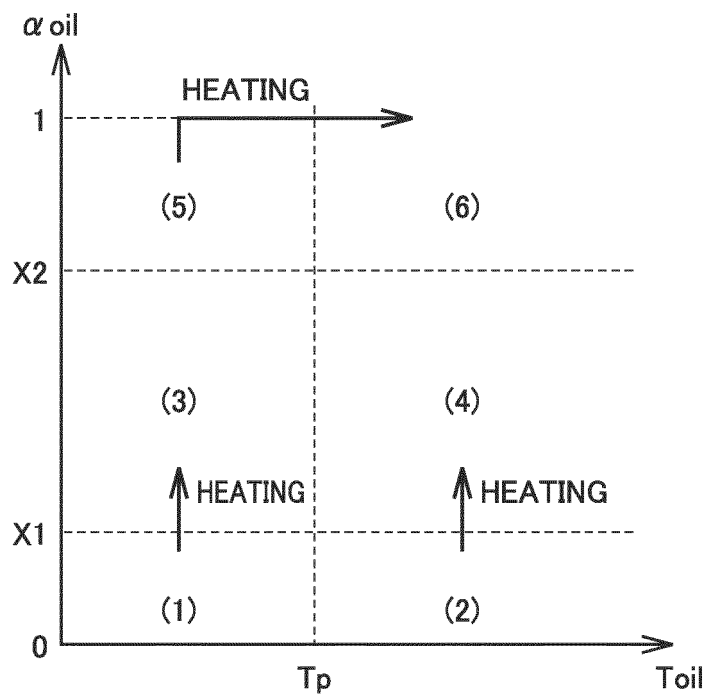


FIG.3

	STATE	CONTROL OF HEATER
(1)	$T_{oil} < T_p$ AND $\alpha_{oil} \leq X1$	WITH HEATING: OPERATE HEATER UNTIL $\alpha_{oil} > X1$ (HEATING CONDITION 1)
(2)	$T_{oil} \geq T_p$ AND $\alpha_{oil} \leq X1$	WITH HEATING: OPERATE HEATER UNTIL $\alpha_{oil} > X1$ (HEATING CONDITION 1)
(3)	$T_{oil} < T_p$ AND $X1 < \alpha_{oil} < X2$	NO HEATING
(4)	$T_{oil} \geq T_p$ AND $X1 < \alpha_{oil} < X2$	NO HEATING
(5)	$T_{oil} < T_p$ AND $\alpha_{oil} \geq X2$	WITH HEATING: OPERATE HEATER UNTIL $T_{oil} \geq T_p$ BY VAPORIZING LIQUID-STATE REFRIGERANT SO THAT $\alpha_{oil} = 1$ (HEATING CONDITION 2)
(6)	$T_{oil} \geq T_p$ AND $\alpha_{oil} \geq X2$	NO HEATING

FIG.4

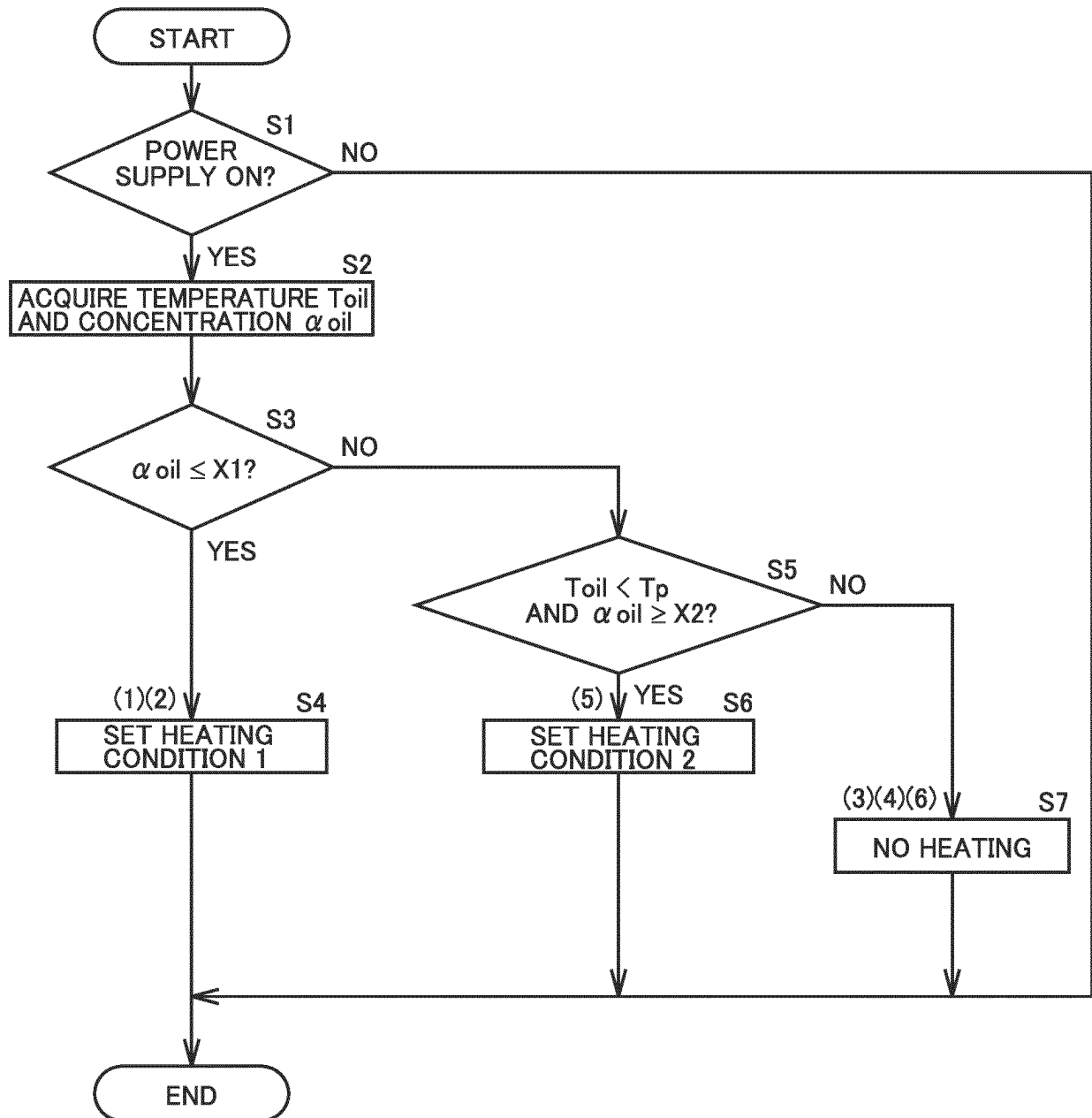


FIG.5

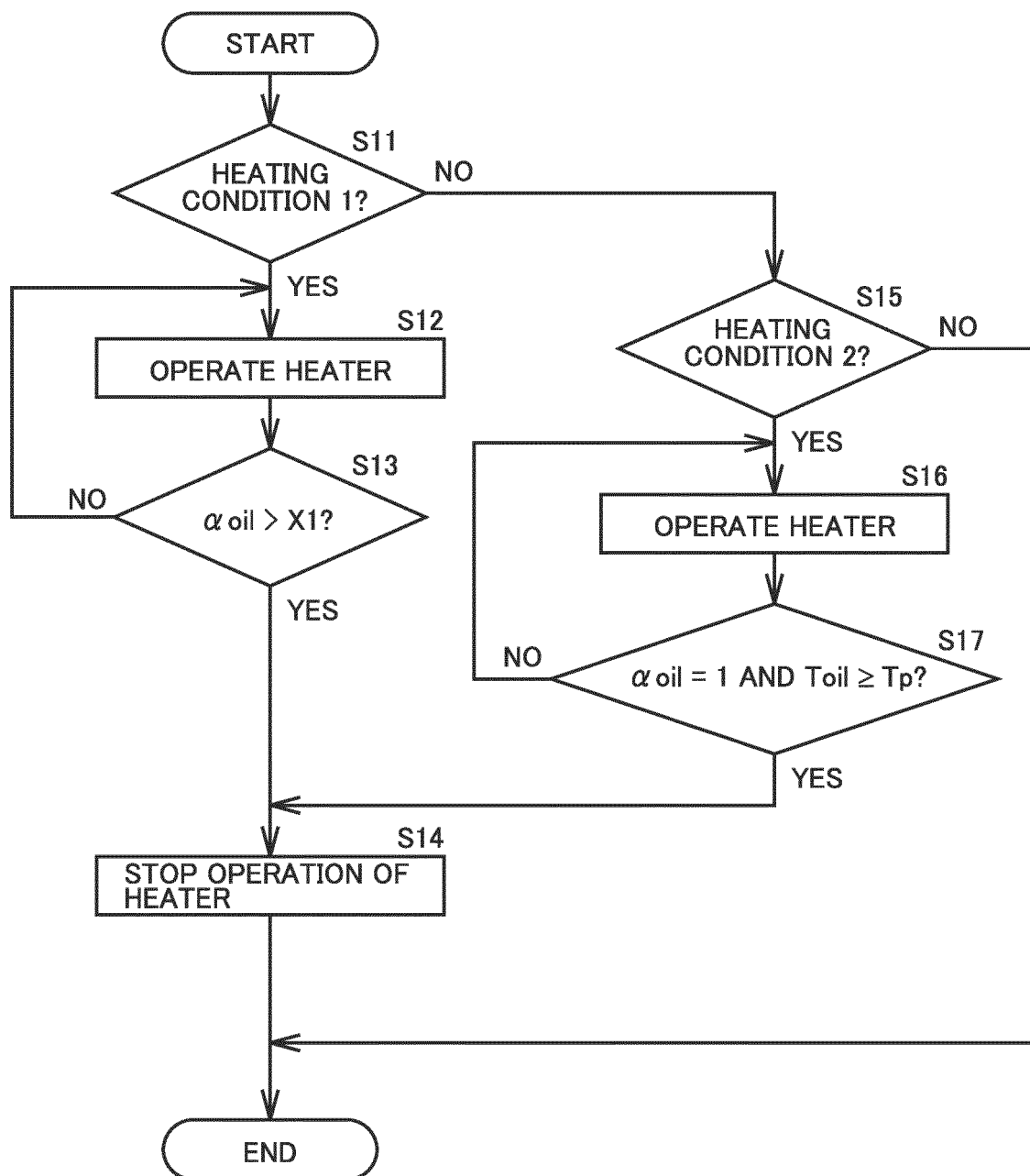


FIG.6

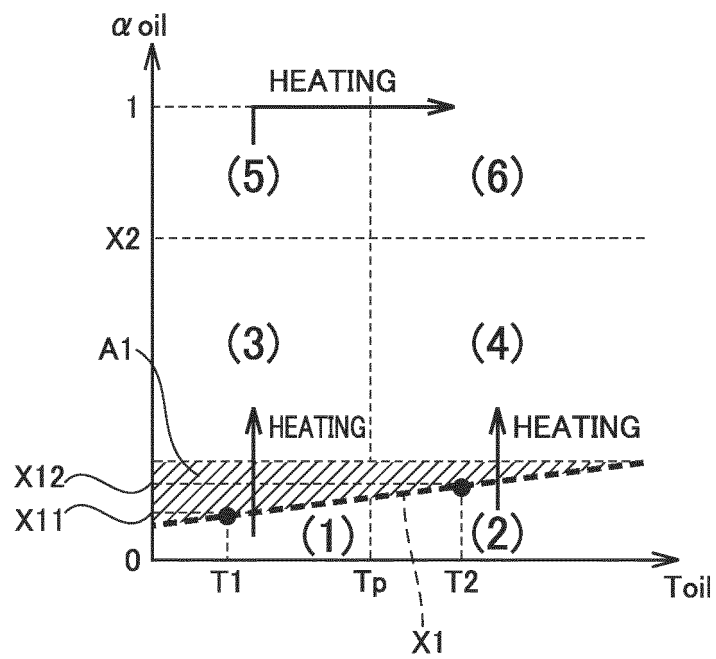


FIG.7

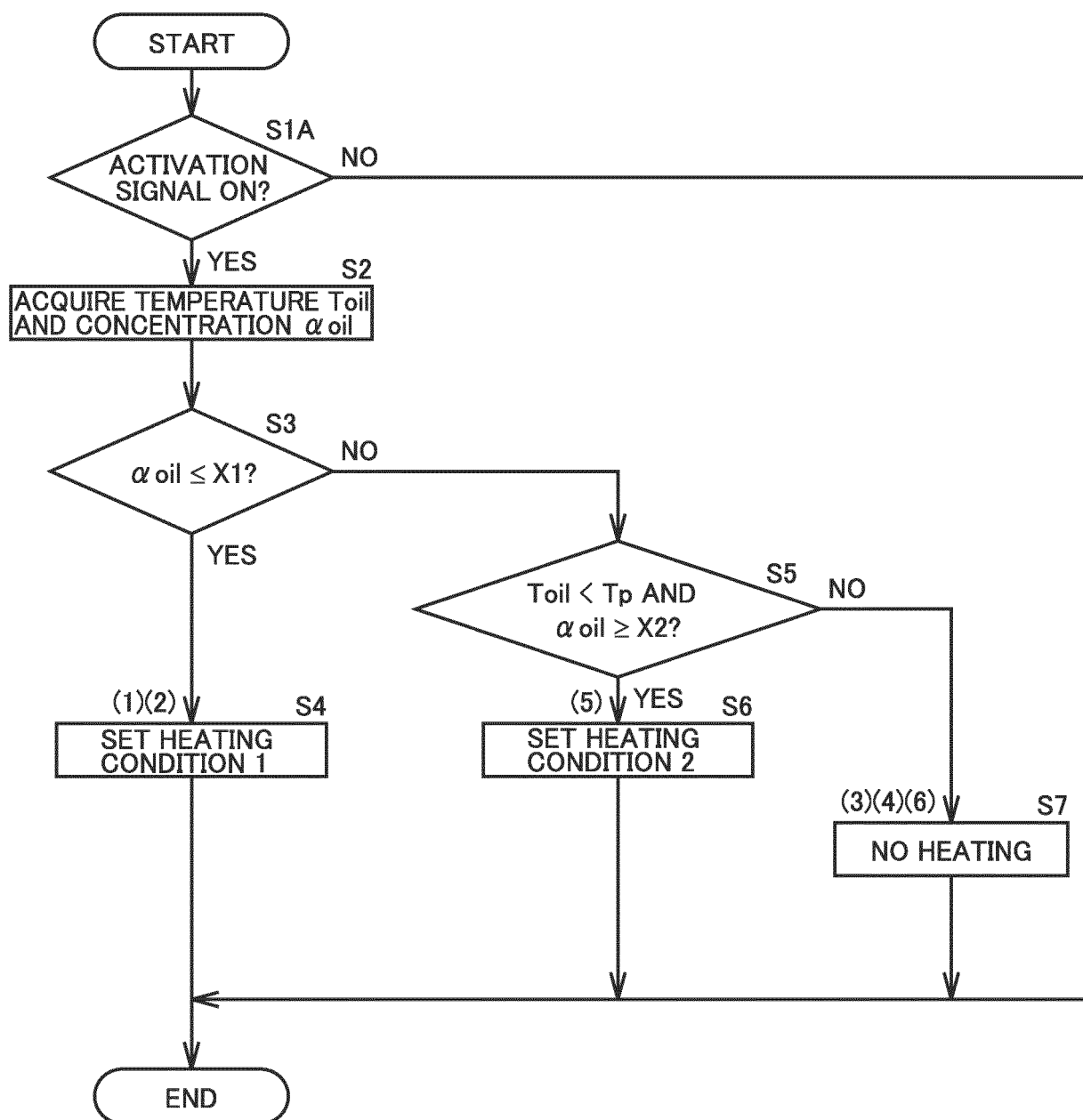


FIG.8

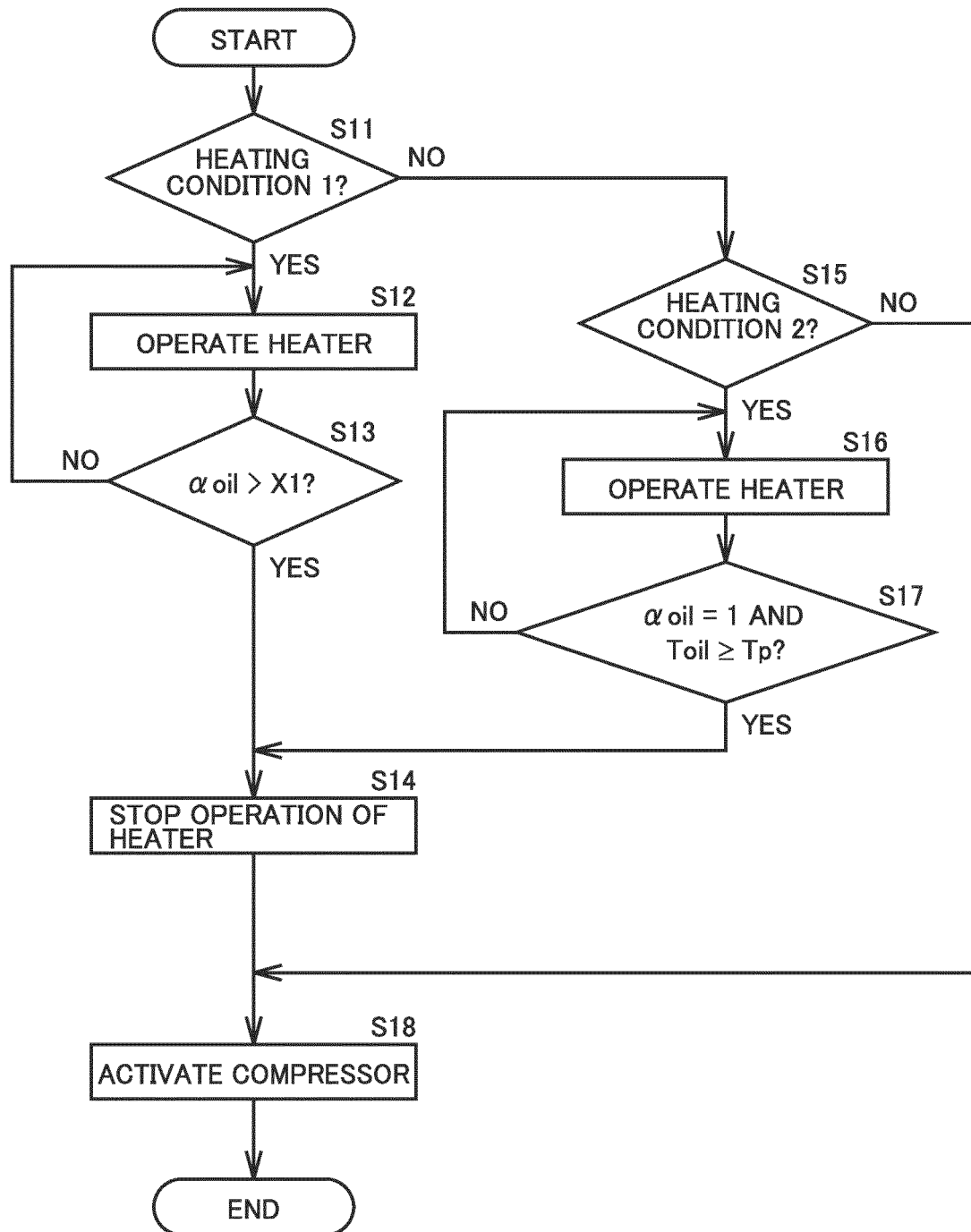


FIG.9

WHEN SEPARATED INTO TWO LAYERS ($T_{oil} \leq T_s$)

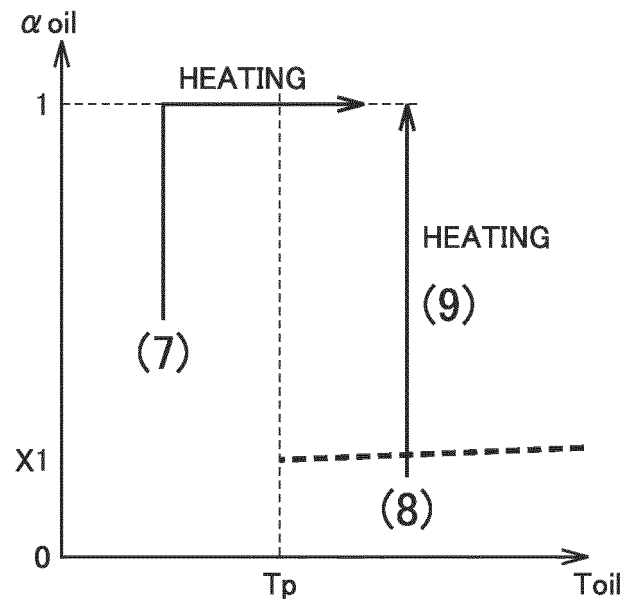


FIG.10

	STATE	CONTROL OF HEATER
(1)	$T_{oil} < T_p$ AND $\alpha_{oil} \leq X1$	WITH HEATING: OPERATE HEATER UNTIL $\alpha_{oil} > X1$ (HEATING CONDITION 1)
(2)	$T_{oil} \geq T_p$ AND $\alpha_{oil} \leq X1$	WITH HEATING: OPERATE HEATER UNTIL $\alpha_{oil} > X1$ (HEATING CONDITION 1)
(3)	$T_{oil} < T_p$ AND $X1 < \alpha_{oil} < X2$	NO HEATING
(4)	$T_{oil} \geq T_p$ AND $X1 < \alpha_{oil} < X2$	NO HEATING
(5)	$T_{oil} < T_p$ AND $\alpha_{oil} \geq X2$	WITH HEATING: OPERATE HEATER UNTIL $T_{oil} \geq T_p$ BY VAPORIZING LIQUID-STATE REFRIGERANT SO THAT $\alpha_{oil} = 1$ (HEATING CONDITION 2)
(6)	$T_{oil} \geq T_p$ AND $\alpha_{oil} \geq X2$	NO HEATING
(7)	$T_{oil} \leq T_p$	WITH HEATING: OPERATE HEATER UNTIL $T_{oil} \geq T_p$ BY VAPORIZING LIQUID-STATE REFRIGERANT SO THAT $\alpha_{oil} = 1$ (HEATING CONDITION 2)
(8)	$T_{oil} > T_p$ AND $\alpha_{oil} \leq X1$	WITH HEATING: OPERATE HEATER UNTIL $\alpha_{oil} = 1$ (HEATING CONDITION 3)
(9)	$T_{oil} > T_p$ AND $\alpha_{oil} > X1$	NO HEATING

(1) TO (6): NO SEPARATION INTO TWO LAYERS ($T_{oil} >$ TWO-LAYER SEPARATION TEMPERATURE T_s)

(7) TO (9): WITH SEPARATION INTO TWO LAYERS ($T_{oil} \leq$ TWO-LAYER SEPARATION TEMPERATURE T_s)

FIG.11

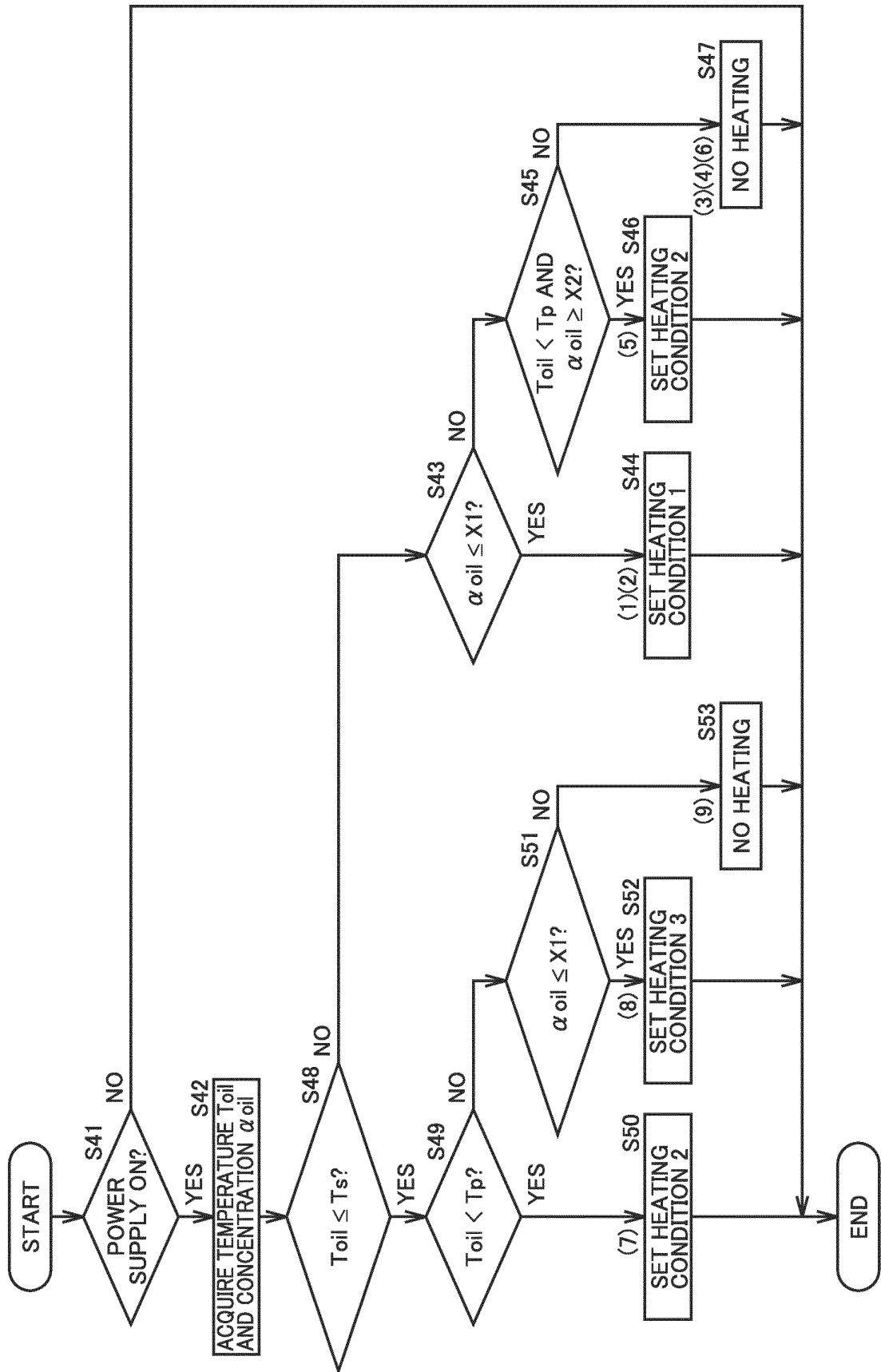


FIG.12

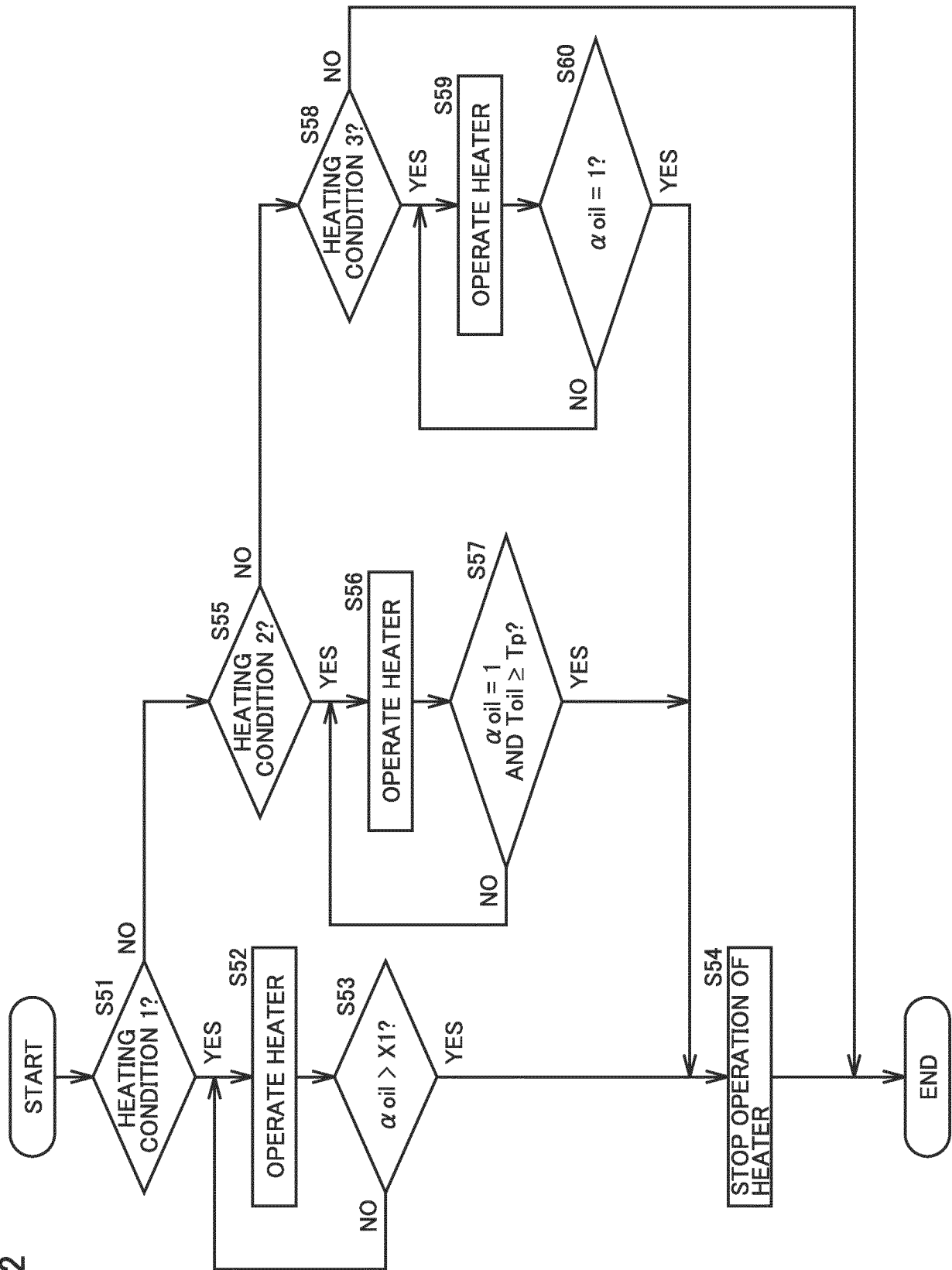


FIG.13

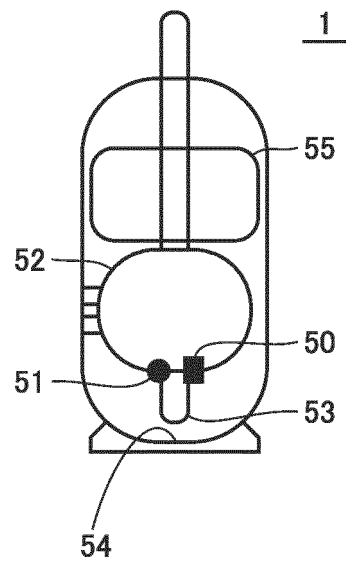
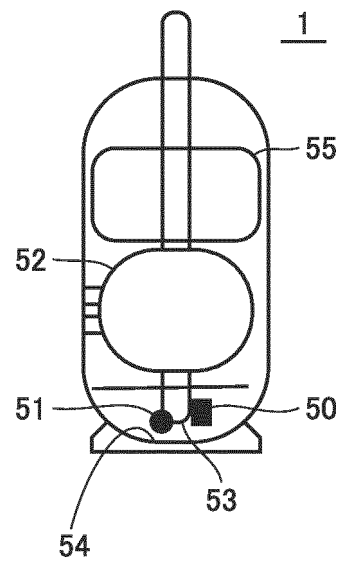


FIG.14



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2021/032974

A. CLASSIFICATION OF SUBJECT MATTER

F25B 1/00(2006.01)i

FI: F25B1/00 321J

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)

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 1971-2021

Registered utility model specifications of Japan 1996-2021

Published registered utility model applications of Japan 1994-2021

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.
Y	WO 2018/138796 A1 (MITSUBISHI ELECTRIC CORP.) 02 August 2018 (2018-08-02) paragraphs [0012]-[0071], fig. 1-15	1-12
Y	JP 2012-189240 A (MITSUBISHI ELECTRIC CORP.) 04 October 2012 (2012-10-04) paragraphs [0012]-[0025], fig. 1-3	1-12

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:	"T" 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
"A" document defining the general state of the art which is not considered to be of particular relevance	"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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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"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	

Date of the actual completion of the international search

30 September 2021

Date of mailing of the international search report

12 October 2021

Name and mailing address of the ISA/JP

Japan Patent Office (ISA/JP)
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/032974

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				paragraphs [0030]-[0089], fig. 1-15			
				EP	3575708	A1	
				CN	110192070	A	
JP	2012-189240	A	04 October 2012	US	2012/0227430	A1	
				paragraphs [0015]-[0031], fig. 1-3			
				EP	2498029	A2	
				CN	102679507	A	
				AU	2012200688	A	
				ES	2777892	T	

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2018138796 A [0004]