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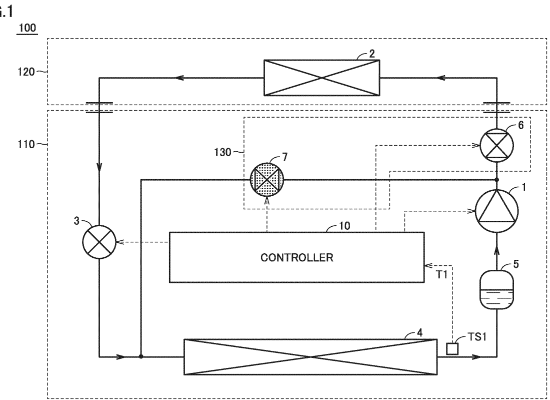
(54) **REFRIGERATION CYCLE DEVICE**

(57) A refrigeration cycle apparatus (100) includes a compressor (1), a first heat exchanger (2), a second heat exchanger (4), an expansion valve (3), a flow rate adjuster (130), and a controller (10). The flow rate adjuster (130) adjusts an amount of refrigerant flowing per unit time through at least one of the first heat exchanger (2) and the expansion valve (3). An operation mode of the refrigeration cycle apparatus (100) includes an activation mode and a normal mode. The activation mode is executed when the compressor (1) is activated. The normal mode is executed after the activation mode. In the normal mode, the refrigerant circulates in a first circulation direction in which the refrigerant flows sequentially through the compressor (1), the first heat exchanger (2), the expansion valve (3), and the second heat exchanger (4). The controller (10) controls the compressor (1) and the flow rate adjuster (130) to reduce the amount of refrigerant flowing per unit time through at least one of the first heat exchanger (2) and the expansion valve (3) in the activation mode to be less than the amount of refrigerant in the normal mode.

FIG.1



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Description

TECHNICAL FIELD

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

BACKGROUND ART

[0002] A refrigeration cycle apparatus has conventionally been known that has a function of suppressing reduction in pressure of refrigerant suctioned into a compressor at the start of the operation of the refrigeration cycle apparatus. For example, Japanese Patent Laying-Open No. 2015-94558 (PTL 1) discloses a heat pump system in which Hydro Fluoro Olefin (HFO) refrigerant is contained and a control valve is connected between a discharge port and a suction port of a compressor. When the heating operation is started in the heat pump system, the control valve is opened in the state where the pressure of the refrigerant suctioned into the compressor is equal to or less than the set pressure. Thereby, reduction in pressure of the refrigerant suctioned into the compressor is suppressed.

CITATION LIST

PATENT LITERATURE

[0003] PTL 1: Japanese Patent Laying-Open No. 2015-94558

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0004] Depending on refrigerant, pressure reduction may abruptly occur when the compressor is activated. Thus, depending on refrigerant, there is a possibility that the pressure of the refrigerant suctioned into the compressor may decrease below the atmospheric pressure (may become negative pressure) while determining whether or not the pressure of the refrigerant suctioned into the compressor is equal to or lower than the set pressure. In the heat pump system disclosed in PTL 1, however, refrigerant other than such HFO refrigerant is not taken into consideration.

[0005] The present invention has been made in order to solve the above-described problems, and an object of the present invention is to suppress reduction in pressure of refrigerant suctioned into a compressor at the start of the operation of a refrigeration cycle apparatus, irrespective of type of refrigerant.

SOLUTION TO PROBLEM

[0006] In a refrigeration cycle apparatus according to the present invention, refrigerant circulates. The refrigeration cycle apparatus includes a compressor, a first heat exchanger, a second heat exchanger, an expansion valve, a flow rate adjuster, and a controller. The flow rate adjuster is configured to adjust an amount of refrigerant flowing per unit time through at least one of the first heat exchanger and the expansion valve. The controller is configured to switch an operation mode of the refrigeration cycle apparatus. The operation mode includes an activation mode and a normal mode. The activation mode is executed when the compressor is activated. The normal mode is executed after the activation mode. In the normal mode, the refrigerant circulates in a first circulation direction in which the refrigerant flows sequentially through the compressor, the first heat exchanger, the expansion valve, and the second heat exchanger. The controller is configured to control the compressor and the flow rate adjuster to reduce the amount of refrigerant that flows per unit time through at least one of the first heat exchanger and the expansion valve in the activation mode to be less than the amount of refrigerant in the normal mode.

ADVANTAGEOUS EFFECTS OF INVENTION

[0007] According to the present invention, the amount of refrigerant flowing per unit time through at least one of the first heat exchanger and the expansion valve in the activation mode is reduced to be less than the amount of refrigerant in the normal mode, and thereby, reduction in pressure of the refrigerant suctioned into the compressor at the start of the operation of the refrigeration cycle apparatus is suppressed irrespective of the type of refrigerant.

BRIEF DESCRIPTION OF DRAWINGS

[0008]

Fig. 1 is a functional block diagram showing a configuration of a refrigeration cycle apparatus according to a first embodiment together with a flow of refrigerant in a normal mode.
Fig. 2 is a functional block diagram showing a configuration of a controller in Fig. 1.
Fig. 3 is a functional block diagram showing a configuration of a refrigeration cycle apparatus according to a comparative example.
Fig. 4 is a graph showing the relation between an elapsed time period since activation of a compressor in Fig. 3 and a saturation temperature of refrigerant suctioned into the compressor.
Fig. 5 is a functional block diagram showing a configuration of the refrigeration cycle apparatus according to the first embodiment together with the flow of refrigerant in an activation mode.
Fig. 6 is a flowchart showing a flow of an operation mode switching process performed by a controller in Figs. 1 and 5.
Fig. 7 is a flowchart showing another example of the operation mode switching process performed by the controller in Figs. 1 and 5.
Fig. 8 is a functional block diagram showing a configuration of a refrigeration cycle apparatus according to a modification of the first embodiment together with a flow of refrigerant in the activation mode.
Fig. 9 is a functional block diagram showing a configuration of a refrigeration cycle apparatus according to a second embodiment together with a flow of refrigerant in a normal mode.
Fig. 10 is a functional block diagram showing the configuration of the refrigeration cycle apparatus according to the second embodiment together with a flow of refrigerant in an activation mode.
Fig. 11 is a flowchart showing a flow of an operation mode switching process performed by a controller in Figs. 9 and 10.
Fig. 12 is a functional block diagram showing a configuration of a refrigeration cycle apparatus according to a third embodiment together with a flow of refrigerant in a normal mode.
Fig. 13 is a functional block diagram showing the configuration of the refrigeration cycle apparatus according to the third embodiment together with a flow of refrigerant in an activation mode.
Fig. 14 is a flowchart showing a flow of an operation mode switching process performed by a controller in Figs. 12 and 13.
Fig. 15 is a functional block diagram showing a configuration of a refrigeration cycle apparatus according to a fourth embodiment together with a flow of refrigerant in a cooling operation.
Fig. 16 is a functional block diagram showing the configuration of the refrigeration cycle apparatus according to the fourth embodiment together with a flow of refrigerant in a normal mode of a heating operation.
Fig. 17 is a functional block diagram showing the configuration of the refrigeration cycle apparatus according to the fourth embodiment together with a flow of refrigerant in an activation mode of the heating operation.
Fig. 18 is a flowchart showing a flow of an operation mode switching process performed by a controller in Figs. 15 to 17.
Fig. 19 is a functional block diagram showing a configuration of a refrigeration cycle apparatus according to a fifth embodiment together with a flow of refrigerant in a cooling operation.
Fig. 20 is a functional block diagram showing the configuration of the refrigeration cycle apparatus according to the fifth embodiment together with a flow of refrigerant in a normal mode of a heating operation.
Fig. 21 is a functional block diagram showing the configuration of the refrigeration cycle apparatus according to the fifth embodiment together with a flow of refrigerant in an activation mode of the heating operation.
Fig. 22 is a flowchart showing a flow of an operation mode switching process performed by a controller in Figs. 19 to 21.

DESCRIPTION OF EMBODIMENTS

[0009] The following describes embodiments of the present invention with reference to the accompanying drawings, in which the same or corresponding portions are denoted by the same reference characters, and description thereof will not basically be repeated.

First Embodiment

[0010] Fig. 1 is a functional block diagram showing a configuration of a refrigeration cycle apparatus 100 according to the first embodiment together with a flow of refrigerant in a normal mode. The closed valve in Fig. 1 is shown in dotted pattern. The same also applies to Figs. 5, 8 to 10, 12, and 13, which will be described later.
[0011] As shown in Fig. 1, a refrigeration cycle apparatus 100 includes an outdoor unit 110 and an indoor unit 120. Indoor unit 120 is disposed in an indoor space. Outdoor unit 110 is disposed outside the indoor space (outdoors).

Refrigerant including R290 is sealed in refrigeration cycle apparatus 100.

[0012] Indoor unit 120 includes a condenser 2 (the first heat exchanger). Outdoor unit 110 includes a compressor 1, an expansion valve 3, an evaporator 4 (the second heat exchanger), a gas-liquid separator 5, a flow rate adjuster 130, a temperature sensor TS1, and a controller 10. Flow rate adjuster 130 has a solenoid valve 6 (the first valve) and a solenoid valve 7 (the second valve). Controller 10 may be included in indoor unit 120 or may be provided separately from outdoor unit 110 and indoor unit 120.

[0013] The operation mode of refrigeration cycle apparatus 100 includes an activation mode and a normal mode. The activation mode is executed when compressor 1 is activated. The normal mode is executed subsequently to the activation mode. The normal mode may be executed after the activation mode, and another operation mode may be executed between the activation mode and the normal mode. In the normal mode of refrigeration cycle apparatus 100, the refrigerant circulates in a circulation direction (the first circulation direction) in which the refrigerant flows sequentially through compressor 1, condenser 2, expansion valve 3, and evaporator 4.

[0014] Solenoid valve 6 is connected between a discharge port of compressor 1 and condenser 2. Solenoid valve 7 is connected between the discharge port of compressor 1 and a flow path extending between expansion valve 3 and evaporator 4. Gas-liquid separator 5 receives refrigerant from evaporator 4, separates the received refrigerant into refrigerant in a gas state (gas refrigerant) and refrigerant in a liquid state (liquid refrigerant), stores the liquid refrigerant therein, and guides the gas refrigerant to compressor 1. Gas-liquid separator 5 prevents the liquid refrigerant from being suctioned into compressor 1. Gas-liquid separator 5 includes an accumulator or a suction muffler.

[0015] Controller 10 switches the operation mode of refrigeration cycle apparatus 100. In the normal mode, controller 10 opens solenoid valve 6 and closes solenoid valve 7. From temperature sensor TS1, controller 10 acquires a temperature T1 of the refrigerant flowing out of evaporator 4. Controller 10 controls a driving frequency F_c of compressor 1, for example, to fall within a range of 50 Hz to 60 Hz, thereby controlling the amount of refrigerant discharged per unit time by compressor 1 such that the temperature in the indoor space reaches a target temperature (for example, a temperature set by a user). Controller 10 controls the degree of opening of expansion valve 3 such that the pressure difference between the refrigerant discharged from compressor 1 but not yet depressurized and the refrigerant depressurized but not yet suctioned into compressor 1 falls within a desired range of values. Expansion valve 3 may be controlled such that the degree of superheating and the degree of supercooling of the refrigerant reach their respective target values.

[0016] Fig. 2 is a functional block diagram showing a configuration of controller 10 in Fig. 1. As shown in Fig. 2, controller 10 includes circuitry 11, a memory 12, and an input/output unit 13. Processing circuit 11 may be dedicated hardware or may be a central processing unit (CPU) that executes a program stored in memory 12. When circuitry 11 is dedicated hardware, circuitry 11 is, for example, a single circuit, a composite circuit, a programmed processor, a parallel programmed processor, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or a combination thereof. When circuitry 11 is a CPU, the function of controller 10 is implemented by software, firmware, or a combination of software and firmware. Software or firmware is described as a program and stored in memory 12. Processing circuit 11 reads and executes the program stored in the memory. Memory 12 includes a nonvolatile or volatile semiconductor memory (for example, a random access memory (RAM), a read only memory (ROM), a flash memory, an erasable programmable read only memory (EPROM) or an electrically erasable programmable read only memory (EEPROM)), a magnetic disk, a flexible disk, an optical disk, a compact disk, a mini disk, or a digital versatile disc (DVD). Note that the CPU is also referred to as a central processing unit, a processing unit, a computing unit, a microprocessor, a microcomputer, a processor, or a digital signal processor (DSP).

[0017] From the viewpoint of preventing global warming, reduction of a global warming potential (GWP) total amount value T_{gwp} of refrigerant used in a refrigeration cycle apparatus has recently been demanded. GWP total amount value T_{gwp} is represented by the following equation (1) using: a GWP value R_{gwp} as a physical property value specific to refrigerant; and a refrigerant amount M_{chg} sealed in refrigeration cycle apparatus 100.

[0018] [Equation 1]

$$T_{gwp} = R_{gwp} \times M_{chg} \qquad \cdots (1)$$

[0019] Based on the equation (1), GWP total amount value T_{gwp} can be reduced by reducing refrigerant amount M_{chg} sealed in the refrigeration cycle apparatus. In order to reduce refrigerant amount M_{chg}, refrigerant having a relatively low density needs to be used. Such refrigerant may be low-pressure refrigerant for which working pressure is relatively low. The low-pressure refrigerant includes R290 (propane) or R454a, for example.

[0020] When refrigerant having a relatively low density is used, refrigerant amount M_{chg} decreases. Thus, maintaining the performance of refrigeration cycle apparatus 100 is an issue to be solved. The heating performance of the refrigeration cycle apparatus is represented by the following equation (2) using: a refrigerant circulation amount Gr discharged per unit time by compressor 1; and an enthalpy difference Δh representing the change in latent heat of the refrigerant in a condensation process.

[0021] [Equation 2]

$$Q_{con} = Gr \times \Delta h \quad \cdots (2)$$

[0022] Refrigerant circulation amount Gr is represented by the following equation (3) using: a stroke volume Vst as the amount of refrigerant discharged per revolution by a compression mechanism of compressor 1; a density ρ_s of refrigerant suctioned into compressor 1; and driving frequency F_c of compressor 1.

[0023] [Equation 3]

$$Gr = V_{st} \times \rho_s \times F_c \cdots (3)$$

[0024] Enthalpy difference Δh in the equation (2) differs for each refrigerant. Thus, refrigerant circulation amount Gr needs to be changed in order to change the refrigerant to low-pressure refrigerant for maintaining the heating performance of the refrigeration cycle apparatus. In the equation (3), density ρ_s of refrigerant is a physical property value specific to the refrigerant. When driving frequency Fc of compressor 1 is controlled to fall within a prescribed range irrespective of the type of refrigerant, stroke volume Vst needs to be changed in order to change refrigerant circulation amount Gr.

[0025] Fig. 3 is a functional block diagram showing a configuration of a refrigeration cycle apparatus 900 according to a comparative example. Refrigeration cycle apparatus 900 has the same configuration as that of refrigeration cycle apparatus 100 in Fig. 1 except that refrigeration cycle apparatus 900 does not include solenoid valves 6 and 7 and includes a controller 90 in place of controller 10. The following describes problems occurring when the refrigerant circulating through refrigeration cycle apparatus 900 is changed from R32 to R290 while maintaining the heating performance of refrigeration cycle apparatus 900.

[0026] The following Table 1 shows simulation results about the ratio of the value obtained when R290 is used to the value obtained when R32 is used, which is required for maintaining the heating performance when the refrigerant circulating through refrigeration cycle apparatus 900 in Fig. 3 is changed from R32 to R290. In this case, the above-mentioned values include values of the refrigerant amount, the refrigerant circulation amount, and the stroke volume. Note that R32 is an example of refrigerant that has conventionally been used in refrigeration cycle apparatuses.

[Table 1]

Values	Ratio of Value Obtained When R290 is Used to Value Obtained When R32 is Used (%)
Refrigerant Amount	52
Refrigerant Circulation Amount	88
Stroke Volume	210

[0027] As shown in Table 1, the ratio of the refrigerant amount of R290 to the refrigerant amount of R32 is 52 % since R290 is lower in density than R32. The refrigerant circulation amount required for R290 is 88 % of the refrigerant circulation amount of R32. The stroke volume required when R290 is used is 210 % of the stroke volume required when R32 is used.

[0028] When the stroke volume of compressor 1 is increased in order to maintain the performance of refrigeration cycle apparatus 900, the amount of refrigerant distributed in evaporator 4 at activation of compressor 1 may abruptly decrease. It takes a certain amount of time for the refrigerant discharged from compressor 1 to flow through condenser 2 and expansion valve 3 and reach evaporator 4. Thus, when compressor 1 is activated, there may be a time zone in which the pressure of the refrigerant flowing between evaporator 4 and compressor 1 abruptly decreases.

[0029] Fig. 4 is a graph showing the relation between an elapsed time period since activation of the compressor in Fig. 3 and a saturation temperature of the refrigerant suctioned into compressor 1. Fig. 4 shows graphs C10 and C11 obtained when R32 and R290, respectively, are used as refrigerant. As the saturation temperature is lower, the pressure of the refrigerant suctioned into compressor 1 is lower. As shown in Fig. 4, when comparing the saturation temperature of graph C10 and the saturation temperature of graph C11 in the time zone from activation of compressor 1 to an elapsed time period Tm10, a lowest temperature Ts11 of R290 is lower than a lowest temperature Ts10 of R32. In this time zone, the pressure of R290 suctioned into compressor 1 abruptly decreases. When the refrigerant including R290 is used in refrigeration cycle apparatus 900, the pressure of the refrigerant suctioned into compressor 1 at activation of compressor 1 becomes negative pressure, which may lead to a failure in refrigeration cycle apparatus 900.

[0030] Therefore, in refrigeration cycle apparatus 100, the operation mode of refrigeration cycle apparatus 100 is set in the activation mode when compressor 1 is activated. In the activation mode, the circulation flow path of the refrigerant is changed so as to suppress a decrease in amount of the refrigerant distributed in evaporator 4. When the operation of refrigeration cycle apparatus 100 is started, the operation mode is switched in the order of the activation mode and the normal mode. Thereby, reduction in pressure of the refrigerant suctioned into compressor 1 at the start of the operation of refrigeration cycle apparatus 100 can be suppressed irrespective of the type of refrigerant.

[0031] Fig. 5 is a functional block diagram showing the configuration of refrigeration cycle apparatus 100 according to the first embodiment together with the flow of refrigerant in the activation mode. As shown in Fig. 5, controller 10 activates compressor 1 in the activation mode. In the activation mode, controller 10 closes solenoid valve 6, opens solenoid valve 7, and fully opens expansion valve 3. Controller 10 forms a circulation flow path such that the refrigerant discharged from compressor 1 bypasses condenser 2. When solenoid valve 6 is closed and solenoid valve 7 is opened, the refrigerant discharged from compressor 1 is guided to evaporator 4 without flowing through condenser 2.

[0032] Controller 10 controls compressor 1 and flow rate adjuster 130 to reduce the amount of refrigerant flowing per unit time through condenser 2 in the activation mode to be less than the amount of refrigerant in the normal mode. By fully opening expansion valve 3, controller 10 facilitates movement of the refrigerant stored in condenser 2 toward evaporator 4. In the activation mode, the refrigerant is distributed more in evaporator 4 than in condenser 2, thereby preventing an abrupt decrease in amount of the refrigerant distributed in evaporator 4 at activation of compressor 1. As a result, the refrigerant suctioned into compressor 1 at activation of compressor 1 is prevented from becoming negative pressure.

[0033] Fig. 6 is a flowchart showing the flow of an operation mode switching process performed by controller 10 in Figs. 1 and 5. The process shown in Fig. 6 is invoked at the start of the operation of refrigeration cycle apparatus 100 by the main routine that integrally controls refrigeration cycle apparatus 100. In the following description, each step will be simply referred to as S.

[0034] As shown in Fig. 6, controller 10 starts the activation mode in S101. In S101, controller 10 closes solenoid valve 6, and then advances the process to S102. In S102, controller 10 opens solenoid valve 7, and then advances the process to S103. In S103, controller 10 fully opens expansion valve 3, and then advances the process to S104. In S104, controller 10 activates compressor 1, and then advances the process to S105.

[0035] In S105, controller 10 determines whether a reference time period Tm1 has elapsed or not since activation of compressor 1. Reference time period Tm1 is determined as appropriate by experiments by real machines or simulations. When reference time period Tm1 has not elapsed since the activation of compressor 1 (NO in S105), controller 10 waits for a prescribed time period in S106, and then returns the process to S105. When reference time period Tm1 has elapsed since the activation of compressor 1 (YES in S105), controller 10 determines in S107 whether or not temperature T1 is higher than a reference temperature Trf1. Reference temperature Trf1 is determined as appropriate by experiments by real machines or simulations.

[0036] When temperature T1 is equal to or lower than reference temperature Trf1 (NO in S107), controller 10 waits for a prescribed time period in S108, and then returns the process to S107. When temperature T1 is higher than reference temperature Trf1 (YES in S107), controller 10 advances the process to S109 and switches the operation mode from the activation mode to the normal mode. When the condition shown in S107 is satisfied, the activation mode is ended and the normal mode is started. In S109, controller 10 opens solenoid valve 6, and then advances the process to S110. In S110, controller 10 closes solenoid valve 7, and then returns the process to the main routine.

[0037] In Fig. 6, after a lapse of the reference time period since activation of compressor 1, it is determined based on temperature T1 whether or not to end the activation mode. In this case, the determination about whether or not to end the activation mode may be made based on the elapsed time period since the activation of compressor 1. In the case where the determination about whether or not to end the activation mode is made based on the elapsed time period since the activation of compressor 1, a temperature sensor for measuring the temperature of the refrigerant flowing out of evaporator 4 is not required, so that the manufacturing cost of the refrigeration cycle apparatus can be reduced.

[0038] Fig. 7 is a flowchart showing another example of the operation mode switching process performed by controller 10 in Figs. 1 and 5. The process shown in Fig. 7 is the same as the process in Fig. 6 except that the process in Fig. 7 includes S115 in place of S105 in Fig. 6 and does not include S107 and S108 in Fig. 6.

[0039] As shown in Fig. 7, after performing S101 to S104, controller 10 determines in S115 whether a reference time period Tm11 (> Tm1) has elapsed or not since the activation of compressor 1. Reference time period Tm11 is determined as appropriate by experiments by real machines or simulations. When reference time period Tm11 has not elapsed since the activation of compressor 1 (NO in S115), controller 10 waits for a prescribed time period in S106, and then returns the process to S115. When reference time period Tm11 has elapsed since the activation of compressor 1 (YES in S115), controller 10 performs S109 and S110, and then returns the process to the main routine. When the condition shown in S115 is satisfied, the activation mode is ended and the normal mode is started.

[0040] In the above description about the configuration in the first embodiment, the refrigerant discharged from compressor 1 in the activation mode is guided to the flow path between expansion valve 3 and evaporator 4. The refrigerant discharged from compressor 1 in the activation mode may be guided to the flow path between condenser 2 and expansion valve 3 as in a refrigeration cycle apparatus 100A according to the modification of the first embodiment shown in Fig. 8.

[0041] As described above, according to the refrigeration cycle apparatus in the first embodiment and the modification thereof, reduction in pressure of the refrigerant suctioned into the compressor at the start of the operation of the refrigeration cycle apparatus can be suppressed irrespective of the type of refrigerant.

Second Embodiment

[0042] In the above description about the configuration in the first embodiment, the circulation flow path is formed such that the refrigerant discharged from the compressor bypasses the condenser. In the following description about the configuration in the second embodiment, a circulation flow path is formed such that refrigerant discharged from a compressor in the activation mode bypasses a condenser, and also, the refrigerant flowing out of an evaporator is heated by the refrigerant discharged from the compressor to thereby lower the density of the refrigerant suctioned into the compressor.

[0043] Fig. 9 is a functional block diagram showing a configuration of a refrigeration cycle apparatus 200 according to the second embodiment together with a flow of refrigerant in a normal mode. As shown in Fig. 9, refrigeration cycle apparatus 200 includes an outdoor unit 210 and an indoor unit 220. Indoor unit 220 is disposed in an indoor space. Outdoor unit 210 is disposed outdoors. Refrigerant including R290 is sealed in refrigeration cycle apparatus 200.

[0044] Indoor unit 220 includes a condenser 22 (the first heat exchanger). Outdoor unit 210 includes a compressor 21, an expansion valve 23, an evaporator 24 (the second heat exchanger), a gas-liquid separator 25, a check valve 28, an internal heat exchanger 29 (the third heat exchanger), a flow rate adjuster 230, a temperature sensor TS2, and a controller 20. Flow rate adjuster 230 has a solenoid valve 26 (the first valve) and a solenoid valve 27 (the second valve). Controller 20 may be included in indoor unit 220 or may be provided separately from outdoor unit 210 and indoor unit 220.

[0045] The operation mode of refrigeration cycle apparatus 200 includes an activation mode and a normal mode. The activation mode is executed when compressor 21 is activated. The normal mode is executed subsequently to the activation mode. In the normal mode of refrigeration cycle apparatus 200, the refrigerant circulates in a circulation direction (the first circulation direction) in which the refrigerant flows sequentially through compressor 21, condenser 22, expansion valve 23, and evaporator 24.

[0046] Gas-liquid separator 25 receives refrigerant from evaporator 24, separates the received refrigerant into gas refrigerant and liquid refrigerant, stores the liquid refrigerant therein, and guides the gas refrigerant to compressor 21. Gas-liquid separator 25 prevents the liquid refrigerant from being suctioned into compressor 21. Gas-liquid separator 25 includes an accumulator or a suction muffler.

[0047] In internal heat exchanger 29, a heat exchange is performed between the refrigerant from condenser 22 and the refrigerant from evaporator 24. Check valve 28 is connected between condenser 22 and internal heat exchanger 29. The forward direction of check valve 28 corresponds to the direction from condenser 22 toward internal heat exchanger 29.

[0048] Solenoid valve 26 is connected between a discharge port of compressor 21 and condenser 22. Solenoid valve 27 is connected between the discharge port of compressor 21 and a flow path extending between check valve 28 and internal heat exchanger 29.

[0049] Controller 20 switches the operation mode of refrigeration cycle apparatus 200. In the normal mode, controller 20 opens solenoid valve 26 and closes solenoid valve 27. From temperature sensor TS2, controller 20 acquires a temperature T2 of the refrigerant flowing between internal heat exchanger 29 and gas-liquid separator 25. Controller 20 controls compressor 21 and expansion valve 23 as in the first embodiment.

[0050] Fig. 10 is a functional block diagram showing the configuration of refrigeration cycle apparatus 200 according to the second embodiment together with a flow of refrigerant in the activation mode. As shown in Fig. 10, controller 20 activates compressor 21 in the activation mode. In the activation mode, controller 20 closes solenoid valve 26, opens solenoid valve 27, and fully opens expansion valve 23. Controller 20 forms a circulation flow path such that the refrigerant discharged from compressor 21 bypasses condenser 22. When solenoid valve 26 is closed and solenoid valve 27 is opened, the refrigerant discharged from compressor 21 is guided to the flow path between check valve 28 and internal heat exchanger 29 without flowing through condenser 22. Check valve 28 prevents the refrigerant from flowing from this flow path into condenser 22. The refrigerant having flowed through internal heat exchanger 29 passes through expansion valve 23 and reaches evaporator 24. The refrigerant flowing out of evaporator 24 is heated in internal heat exchanger 29 by the refrigerant discharged from compressor 21, and then suctioned into compressor 21.

[0051] Controller 20 controls compressor 21 and flow rate adjuster 230 to reduce the amount of refrigerant flowing per unit time through condenser 22 in the activation mode to be less than the amount of refrigerant in the normal mode. By fully opening expansion valve 23, controller 20 facilitates movement of the refrigerant stored in condenser 22 to evaporator 24. In the activation mode, the refrigerant is distributed more in evaporator 24 than in condenser 22. Thus, an abrupt decrease in amount of the refrigerant distributed in evaporator 24 at activation of compressor 21 is prevented. Further, in refrigeration cycle apparatus 200, the refrigerant flowing out of evaporator 24 is heated in internal heat exchanger 29 by the refrigerant discharged from compressor 21, so that the refrigerant suctioned into compressor 21 is reduced in density. Since the amount of refrigerant suctioned into compressor 21 per unit time decreases, the amount of refrigerant remaining in evaporator 24 increases. As a result, the refrigerant suctioned into compressor 21 at activation of compressor 21 is prevented from becoming negative pressure.

[0052] Fig. 11 is a flowchart showing a flow of an operation mode switching process performed by controller 20 in Figs. 9 and 10. The process shown in Fig. 11 is invoked at the start of the operation of refrigeration cycle apparatus 200 by the main routine that integrally controls refrigeration cycle apparatus 200.

[0053] As shown in Fig. 11, controller 20 starts the activation mode in S201. In S201, controller 20 closes solenoid valve 26, and then advances the process to S202. In S202, controller 20 opens solenoid valve 27, and then advances the process to S203. In S203, controller 20 fully opens expansion valve 23, and then advances the process to S204. In S204, controller 20 activates compressor 21, and then advances the process to S205.

[0054] In S205, controller 20 determines whether a reference time period Tm2 has elapsed or not since the activation of compressor 21. Reference time period Tm2 is determined as appropriate by experiments by real machines or simulations. When reference time period Tm2 has not elapsed since the activation of compressor 21 (NO in S205), controller 20 waits for a prescribed time period in S206, and then returns the process to S205. When reference time period Tm2 has elapsed since the activation of compressor 21 (YES in S205), controller 20 determines in S207 whether or not temperature T2 is higher than a reference temperature Trf2. Reference temperature Trf2 is determined as appropriate by experiments by real machines or simulations.

[0055] When temperature T2 is equal to or lower than reference temperature Trf2 (NO in S207), controller 20 waits for a prescribed time period in S208, and then returns the process to S207. When temperature T2 is higher than reference temperature Trf2 (YES in S207), controller 20 advances the process to S209 and then switches the operation mode from the activation mode to the normal mode. When the condition shown in S207 is satisfied, the activation mode is ended and the normal mode is started. In S209, controller 20 opens solenoid valve 26, and then advances the process to S210. In S210, controller 20 closes solenoid valve 27, and then returns the process to the main routine.

[0056] As described above, according to the refrigeration cycle apparatus in the second embodiment, reduction in pressure of the refrigerant suctioned into the compressor at the start of the operation of the refrigeration cycle apparatus can be suppressed irrespective of the type of refrigerant.

Third Embodiment

[0057] In the above description about the configuration in each of the first and second embodiments, the circulation flow path is formed such that the refrigerant discharged from the compressor bypasses the condenser. In the following description about the configuration in the third embodiment, a circulation flow path is formed such that refrigerant discharged from the compressor in the activation mode bypasses a part of the evaporator.

[0058] Fig. 12 is a functional block diagram showing a configuration of a refrigeration cycle apparatus 300 according to the third embodiment together with a flow of refrigerant in a normal mode. As shown in Fig. 12, refrigeration cycle apparatus 300 includes an outdoor unit 310 and an indoor unit 320. Indoor unit 320 is disposed in an indoor space. Outdoor unit 310 is disposed outdoors. Refrigerant including R290 is sealed in refrigeration cycle apparatus 300.

[0059] Indoor unit 320 includes a condenser 32 (the first heat exchanger). Outdoor unit 310 includes a compressor 31, an expansion valve 33, an evaporator 34 (the second heat exchanger), a gas-liquid separator 35, a flow rate adjuster 330, a temperature sensor TS3, and a controller 30. Evaporator 34 includes a heat exchange unit 341 (the first heat exchange unit) and a heat exchange unit 342 (the second heat exchange unit). Flow rate adjuster 330 has a solenoid valve 36. Controller 30 may be included in indoor unit 320 or may be provided separately from outdoor unit 310 and indoor unit 320.

[0060] The operation mode of refrigeration cycle apparatus 300 includes an activation mode and a normal mode. The activation mode is executed when compressor 31 is activated. The normal mode is executed subsequently to the activation mode. In the normal mode of refrigeration cycle apparatus 300, the refrigerant circulates in a circulation direction (the first circulation direction) in which the refrigerant flows sequentially through compressor 31, condenser 32, expansion valve 33, heat exchange unit 341, and heat exchange unit 342.

[0061] Solenoid valve 36 is connected between: a flow path between condenser 32 and expansion valve 33; and a flow path between heat exchange unit 341 and heat exchange unit 342. Gas-liquid separator 35 receives refrigerant from evaporator 34, separates the received refrigerant into gas refrigerant and liquid refrigerant, stores the liquid refrigerant therein, and guides the gas refrigerant to compressor 31. Gas-liquid separator 35 prevents the liquid refrigerant from being suctioned into compressor 31. Gas-liquid separator 35 includes an accumulator or a suction muffler.

[0062] Controller 30 switches the operation mode of refrigeration cycle apparatus 300. In the normal mode, controller 30 opens expansion valve 33 and closes solenoid valve 36. From temperature sensor TS3, controller 30 acquires a temperature T3 of the refrigerant flowing out of evaporator 34. Controller 30 controls compressor 31 and expansion valve 33 as in the first embodiment.

[0063] Fig. 13 is a functional block diagram showing the configuration of refrigeration cycle apparatus 300 according to the third embodiment together with a flow of refrigerant in the activation mode. As shown in Fig. 13, controller 30 activates compressor 31 in the activation mode. In the activation mode, controller 30 closes expansion valve 33 and opens solenoid valve 36. Controller 30 forms a circulation flow path such that the refrigerant discharged from compressor 31 bypasses heat exchange unit 341. When expansion valve 33 is closed and solenoid valve 36 is opened, the refrigerant discharged from compressor 31 is guided to heat exchange unit 341 without flowing through heat exchange unit 342.

[0064] Controller 30 controls compressor 31 and flow rate adjuster 330 to reduce the amount of refrigerant flowing per unit time through expansion valve 33 in the activation mode to be less than the amount of refrigerant in the normal mode. In the activation mode, the refrigerant stored in heat exchange unit 341 moves to heat exchange unit 342. The refrigerant is distributed more in heat exchange unit 342 than in heat exchange unit 341. Thus, an abrupt decrease in amount of the refrigerant flowing between evaporator 34 and compressor 31 at activation of compressor 31 is prevented. As a result, the refrigerant suctioned into compressor 31 at activation of compressor 31 is prevented from becoming negative pressure.

[0065] Fig. 14 is a flowchart showing a flow of an operation mode switching process performed by controller 30 in Figs. 12 and 13. The process shown in Fig. 14 is invoked at the start of the operation of refrigeration cycle apparatus 300 by the main routine that integrally controls refrigeration cycle apparatus 300.

[0066] As shown in Fig. 14, controller 30 starts the activation mode in S301. In S301, controller 30 closes expansion valve 33, and then advances the process to S302. In S302, controller 30 opens solenoid valve 36, and then advances the process to S304. In S304, controller 30 activates compressor 31, and then advances the process to S305.

[0067] In S305, controller 30 determines whether a reference time period Tm3 has elapsed or not since the activation of compressor 31. Reference time period Tm3 is determined as appropriate by experiments by real machines or simulations. When reference time period Tm3 has not elapsed since the activation of compressor 31 (NO in S305), controller 30 waits for a prescribed time period in S306, and then returns the process to S305. When reference time period Tm3 has elapsed since the activation of compressor 31 (YES in S305), controller 30 determines in S307 whether or not temperature T3 is higher than a reference temperature Trf3. Reference temperature Trf3 is determined as appropriate by experiments by real machines or simulations.

[0068] When temperature T3 is equal to or lower than reference temperature Trf3 (NO in S307), controller 30 waits for a prescribed time period in S308, and then returns the process to S307. When temperature T3 is higher than reference temperature Trf3 (YES in S307), controller 30 advances the process to S309 and then switches the operation mode from the activation mode to the normal mode. When the condition shown in S307 is satisfied, the activation mode is ended and the normal mode is started. In S309, controller 30 opens expansion valve 33, and then advances the process to S310. In S310, controller 30 closes solenoid valve 36, and then returns the process to the main routine.

[0069] As described above, according to the refrigeration cycle apparatus in the third embodiment, reduction in pressure of the refrigerant suctioned into the compressor at the start of the operation of the refrigeration cycle apparatus can be suppressed irrespective of the type of refrigerant.

Fourth Embodiment

[0070] In the above description about the configuration in each of the first to third embodiments, the compressor has one suction port. In the following description about the configuration in the fourth embodiment, a compressor includes two compression mechanisms and also has two suction ports corresponding to the two respective compression mechanisms.

[0071] Fig. 15 is a functional block diagram showing a configuration of a refrigeration cycle apparatus 400 according to the fourth embodiment together with a flow of refrigerant in a cooling operation. As shown in Fig. 15, refrigeration cycle apparatus 400 includes an outdoor unit 410 and an indoor unit 420. Indoor unit 420 is disposed in an indoor space. Outdoor unit 410 is disposed outdoors. Refrigerant including R290 is sealed in refrigeration cycle apparatus 400.

[0072] Indoor unit 420 includes a heat exchanger 42 (the first heat exchanger). Outdoor unit 410 includes a compressor 41, an expansion valve 43, a heat exchanger 44 (the second heat exchanger), a gas-liquid separator 45, a four-way valve 46, a flow rate adjuster 430, a temperature sensor TS4, and a controller 40. Flow rate adjuster 430 has a three-way valve 47. Controller 40 may be included in indoor unit 420 or may be provided separately from outdoor unit 410 and indoor unit 420.

[0073] Compressor 41 includes a suction port Ps1 (the first suction port), a suction port Ps2 (the second suction port), a discharge port Pd, a compression mechanism 411 (the first compression mechanism), and a compression mechanism 412 (the second compression mechanism). Compression mechanism 411, which is connected between suction port Ps1 and discharge port Pd, compresses the refrigerant received through suction port Ps1 and then discharges the refrigerant through discharge port Pd. Compression mechanism 412, which is connected between suction port Ps2 and discharge port Pd, compresses the refrigerant received through suction port Ps2 and then discharges the refrigerant through discharge port Pd. Compressor 41 is a twin rotary compressor.

[0074] Three-way valve 47 includes a port P1 (the first port), a port P2 (the second port), and a port P3 (the third port). Port P1 is connected to suction port Ps2. Port P2 is in communication with suction port Ps1 through gas-liquid separator 45. Port P3 is connected to discharge port Pd. Three-way valve 47 selectively switches the state of communication among ports P1 to P3 between the state where port P1 is in communication with port P2 and the state where port P1 is in communication with port P3. In Fig. 15 and Figs. 16 and 17 described later, each port not in communication with other ports are shown in dotted pattern.

[0075] Controller 40 controls the driving frequency of each of compression mechanisms 411 and 412, for example, to fall within a range of 50 Hz to 60 Hz to thereby control the amount of refrigerant discharged per unit time by compressor 41 such that the temperature in the indoor space reaches a target temperature (for example, a temperature set by a user). Controller 40 controls expansion valve 43 as in the first embodiment.

[0076] Controller 40 controls four-way valve 46 to switch the direction in which the refrigerant circulates. In the cooling operation, controller 40 allows discharge port Pd of compressor 41 to communicate with heat exchanger 44, and allows suction ports Ps1 and Ps2 of compressor 41 to communicate with heat exchanger 42. In the cooling operation, controller 40 allows ports P1 and P2 to communicate with each other. In the cooling operation, the refrigerant circulates in the circulation direction (the second circulation direction) in which the refrigerant flows sequentially through compressor 41, heat exchanger 44, expansion valve 43, and heat exchanger 42. In the cooling operation, heat exchangers 42 and 44 function as an evaporator and a condenser, respectively.

[0077] Gas-liquid separator 45 receives the refrigerant from heat exchanger 42, separates the received refrigerant into gas refrigerant and liquid refrigerant, stores the liquid refrigerant therein, and guides the gas refrigerant to compressor 41. Gas-liquid separator 45 prevents the liquid refrigerant from being suctioned into compressor 41. Gas-liquid separator 45 includes an accumulator or a suction muffler.

[0078] Fig. 16 is a functional block diagram showing the configuration of refrigeration cycle apparatus 400 according to the fourth embodiment together with a flow of refrigerant in a normal mode of a heating operation. The operation modes of refrigeration cycle apparatus 400 in the heating operation include an activation mode and a normal mode. The activation mode is executed when compressor 41 is activated. The normal mode is executed subsequently to the activation mode.

[0079] As shown in Fig. 16, in the heating operation, controller 40 allows discharge port Pd of compressor 41 to communicate with heat exchanger 42, and allows suction ports Ps1 and Ps2 of compressor 41 to communicate with heat exchanger 44. In the normal mode of the heating operation, controller 40 allows ports P1 and P2 to communicate with each other. In the normal mode of the heating operation, controller 40 operates compression mechanisms 411 and 412. From temperature sensor TS4, controller 40 acquires a temperature T4 of the refrigerant flowing out of heat exchanger 44 in the heating operation.

[0080] In the heating operation, the refrigerant circulates in the circulation direction (the first circulation direction) in which the refrigerant flows sequentially through compressor 41, heat exchanger 42, expansion valve 43, and heat exchanger 44. In the heating operation, heat exchangers 42 and 44 function as a condenser and an evaporator, respectively.

[0081] Fig. 17 is a functional block diagram showing the configuration of refrigeration cycle apparatus 400 according to the fourth embodiment together with a flow of refrigerant in the activation mode of the heating operation. As shown in Fig. 17, in the activation mode, controller 40 allows ports P1 and P3 to communicate with each other, and activates compression mechanism 411 but does not activate compression mechanism 412. In Fig. 17, compression mechanism 412 that is not operated is shown in dotted pattern. Since compression mechanism 412 is not operated in the activation mode, the amount of refrigerant suctioned per unit time into compressor 41 is smaller than the amount of refrigerant suctioned into compressor 41 in the normal mode.

[0082] Controller 40 controls compressor 41 and flow rate adjuster 430 to reduce the amount of refrigerant flowing per unit time through heat exchanger 42 and expansion valve 43 in the activation mode to be less than the amount of refrigerant in the normal mode. In the activation mode, the amount of refrigerant suctioned per unit time into compressor 41 is smaller than that in the normal mode. Thereby, an abrupt decrease in amount of the refrigerant flowing between heat exchanger 44 and compressor 41 at activation of compressor 41 is prevented. As a result, the refrigerant suctioned into compressor 41 at activation of compressor 41 is prevented from becoming negative pressure.

[0083] Fig. 18 is a flowchart showing a flow of an operation mode switching process performed by controller 40 in Figs. 15 to 17. The process shown in Fig. 14 is invoked at the start of the operation of refrigeration cycle apparatus 400 by the main routine that integrally controls refrigeration cycle apparatus 400.

[0084] As shown in Fig. 18, controller 40 starts the activation mode in S401. In S401, controller 40 allows ports P1 and P3 to communicate with each other and then advances the process to S403. In S403, controller 40 fully opens expansion valve 43 and then advances the process to S404. In S404, controller 40 activates compression mechanism 411, and then advances the process to S405.

[0085] In S405, controller 40 determines whether a reference time period Tm4 has elapsed or not since activation of compression mechanism 411. Reference time period Tm4 is determined as appropriate by experiments by real machines or simulations. When reference time period Tm4 has not elapsed since activation of compression mechanism 411 (NO in S405), controller 40 waits for a prescribed time period in S406, and then returns the process to S405. When reference time period Tm4 has elapsed since activation of compression mechanism 411 (YES in S405), controller 40 determines in S407 whether or not temperature T4 is higher than reference temperature Trf4. Reference temperature Trf4 is determined as appropriate by experiments by real machines or simulations.

[0086] When temperature T4 is equal to or lower than reference temperature Trf4 (NO in S407), controller 40 waits for a prescribed time period in S408, and then returns the process to S407. When temperature T4 is higher than reference temperature Trf4 (YES in S407), controller 40 advances the process to S409 and then switches the operation mode from the activation mode to the normal mode. When the condition shown in S407 is satisfied, the activation mode is ended and the normal mode is started. In S409, controller 40 allows ports P1 and P2 to communicate with each other, and then advances the process to S410. In S410, controller 40 activates compression mechanism 412, and then returns the process to the main routine.

[0087] As described above, according to the refrigeration cycle apparatus in the fourth embodiment, reduction in pressure of the refrigerant suctioned into the compressor at the start of the operation of the refrigeration cycle apparatus can be suppressed irrespective of the type of refrigerant.

Fifth Embodiment

[0088] In the above description about the configuration in the second embodiment, the refrigerant flowing out of the evaporator is heated by the refrigerant discharged from the compressor, thereby lowering the density of the refrigerant suctioned into the compressor. In the following description about a configuration in the fifth embodiment, the refrigerant suctioned into a compressor is heated by a heater.

[0089] Fig. 19 is a functional block diagram showing a configuration of a refrigeration cycle apparatus 500 according to the fifth embodiment together with a flow of refrigerant in a cooling operation. As shown in Fig. 19, refrigeration cycle apparatus 500 includes an outdoor unit 510 and an indoor unit 520. Indoor unit 520 is disposed in an indoor space. Outdoor unit 510 is disposed outdoors. Refrigerant including R290 is sealed in refrigeration cycle apparatus 500.

[0090] Indoor unit 520 includes a heat exchanger 52 (the first heat exchanger). Outdoor unit 510 includes a compressor 51, an expansion valve 53, a heat exchanger 54 (the second heat exchanger), a gas-liquid separator 55, a four-way valve 56, a flow rate adjuster 530, a temperature sensor TS5, and a controller 50. Flow rate adjuster 530 includes a heater 57. Controller 50 may be included in indoor unit 520 or may be provided separately from outdoor unit 510 and indoor unit 520.

[0091] Controller 50 controls compressor 51 and expansion valve 53 as in the first embodiment. Controller 50 controls four-way valve 56 to switch the direction in which the refrigerant circulates. In the cooling operation, controller 50 allows a discharge port of compressor 51 to communicate with heat exchanger 54, and also allows a suction port of compressor 51 to communicate with heat exchanger 52. In the cooling operation, the refrigerant circulates in the circulation direction (the second circulation direction) in which the refrigerant flows sequentially through compressor 51, heat exchanger 54, expansion valve 53, and heat exchanger 52. In the cooling operation, heat exchangers 52 and 54 function as an evaporator and a condenser, respectively.

[0092] Gas-liquid separator 55 receives the refrigerant from heat exchanger 52, separates the received refrigerant into gas refrigerant and liquid refrigerant, stores the liquid refrigerant therein, and guides the gas refrigerant to compressor 51. Gas-liquid separator 55 prevents the liquid refrigerant from being suctioned into compressor 51. Gas-liquid separator 55 includes an accumulator or a suction muffler.

[0093] Heater 57 is disposed to heat the refrigerant flowing into gas-liquid separator 55. In the cooling operation, heater 57 is not operating.

[0094] Fig. 20 is a functional block diagram showing the configuration of refrigeration cycle apparatus 500 according to the fifth embodiment together with a flow of refrigerant in the normal mode of the heating operation. Operation modes of refrigeration cycle apparatus 500 in the heating operation include an activation mode and a normal mode. The activation mode is executed when compressor 51 is activated. The normal mode is executed subsequently to the activation mode.

[0095] As shown in Fig. 20, in the heating operation, controller 50 allows a discharge port of compressor 51 to communicate with heat exchanger 52, and allows a suction port of compressor 51 to communicate with heat exchanger 54. Controller 50 does not activate heater 57 in the normal mode of the heating operation. From temperature sensor TS5, controller 50 acquires a temperature T5 of the refrigerant having flowed through a heating portion of heater 57 in the heating operation. This heating portion is included in a flow path through which the refrigerant flowing between heat exchanger 54 and compressor 51 in the heating operation passes.

[0096] In the heating operation, the refrigerant circulates in the circulation direction (the first circulation direction) in which the refrigerant flows sequentially through compressor 51, heat exchanger 52, expansion valve 53, and heat exchanger 54. In the heating operation, heat exchangers 52 and 54 function as a condenser and an evaporator, respectively.

[0097] Fig. 21 is a functional block diagram showing the configuration of refrigeration cycle apparatus 500 according to the fifth embodiment together with a flow of refrigerant in an activation mode of the heating operation. As shown in Fig. 21, controller 50 activates heater 57 in the activation mode. Due to heating by heater 57, the density of the refrigerant suctioned into compressor 51 in the activation mode is lower than the density of the refrigerant suctioned into compressor 51 in the normal mode.

[0098] Controller 50 controls compressor 51 and flow rate adjuster 530 to reduce the amount of refrigerant flowing per unit time through heat exchanger 52 and expansion valve 53 in the activation mode to be less than the amount of refrigerant in the normal mode. In the activation mode, the amount of refrigerant suctioned per unit time into compressor 51 decreases, thereby preventing an abrupt decrease in amount of the refrigerant flowing between heat exchanger 54 and compressor 51 at activation of compressor 51. As a result, the refrigerant suctioned into compressor 51 at activation of compressor 51 is prevented from becoming negative pressure.

[0099] Fig. 22 is a flowchart showing a flow of an operation mode switching process performed by controller 50 in Figs. 19 to 21. The process shown in Fig. 22 is invoked at the start of the operation of refrigeration cycle apparatus 500 by the main routine that integrally controls refrigeration cycle apparatus 500.

[0100] As shown in Fig. 22, controller 50 starts the activation mode in S501. In S501, controller 50 activates heater 57, and then advances the process to S503. In S503, controller 50 fully opens expansion valve 53, and then advances the process to S504. In S504, controller 50 activates compressor 51, and then advances the process to S505.

[0101] In S505, controller 50 determines whether a reference time period Tm5 has elapsed or not since activation of compressor 51. Reference time period Tm5 is determined as appropriate by experiments by real machines or simulations. When reference time period Tm5 has not elapsed since activation of compressor 51 (NO in S505), controller 50 waits for a prescribed time period in S506 and then returns the process to S505. When reference time period Tm5 has elapsed since activation of compressor 51 (YES in S505), then in S507, controller 50 determines whether or not temperature T5 is higher than a reference temperature Trf5. Reference temperature Trf5 is determined as appropriate by experiments by real machines or simulations.

[0102] When temperature T5 is equal to or lower than reference temperature Trf5 (NO in S507), controller 50 waits for a prescribed time period in S508, and then returns the process to S507. When temperature T5 is higher than reference temperature Trf5 (YES in S507), controller 50 advances the process to S509 and then switches the operation mode from the activation mode to the normal mode. When the condition shown in S507 is satisfied, the activation mode is ended and the normal mode is started. In S509, controller 50 deactivates heater 57 and then returns the process to the main routine.

[0103] As described above, according to the refrigeration cycle apparatus in the fifth embodiment, reduction in pressure of the refrigerant suctioned into the compressor at the start of the operation of the refrigeration cycle apparatus can be suppressed irrespective of the type of refrigerant.

[0104] The embodiments disclosed herein are also intended to be implemented in combination as appropriate within a consistent scope. It should be understood that the embodiments disclosed herein are illustrative and non-restrictive in every respect. The scope of the present invention is defined by the terms of the claims, rather than the description above, and is intended to include any modifications within the meaning and scope equivalent to the terms of the claims.

REFERENCE SIGNS LIST

[0105] 1, 21, 31, 41, 51 compressor, 2, 22, 32 condenser, 3, 23, 33, 43, 53 expansion valve, 4, 24, 34 evaporator, 5, 25, 35, 45, 55 gas-liquid separator, 6, 7, 26, 27, 36 solenoid valve, 10, 20, 30, 40, 50, 90 controller, 11 circuitry, 12 memory, 13 input/output unit, 28 check valve, 29 internal heat exchanger, 42, 44, 52, 54 heat exchanger, 46, 56 four-way valve, 47 three-way valve, 57 heater, 100, 100A, 200, 300, 400, 500, 900 refrigeration cycle apparatus, 110, 210, 310, 410, 510 outdoor unit, 120, 220, 320, 420, 520 indoor unit, 130, 230, 330, 430, 530 flow rate adjuster, 341, 342 heat exchange unit, 411, 412 compression mechanism, P1 to P3 port, Pd discharge port, Ps1, Ps2 suction port, TS1 to TS5 temperature sensor.

Claims

1. A refrigeration cycle apparatus in which refrigerant circulates, the refrigeration cycle apparatus comprising:

a compressor;
a first heat exchanger;
a second heat exchanger;
an expansion valve;
a flow rate adjuster configured to adjust an amount of refrigerant flowing per unit time through at least one of

the first heat exchanger and the expansion valve; and
a controller configured to switch an operation mode of the refrigeration cycle apparatus, wherein
the operation mode includes

an activation mode that is executed when the compressor is activated,
and
a normal mode that is executed after the activation mode,

in the normal mode, the refrigerant circulates in a first circulation direction in which the refrigerant flows sequentially through the compressor, the first heat exchanger, the expansion valve, and the second heat exchanger, and
the controller is configured to control the compressor and the flow rate adjuster to reduce the amount of refrigerant in the activation mode to be less than the amount of refrigerant in the normal mode.

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

the flow rate adjuster has

a first valve connected between a discharge port of the compressor and the first heat exchanger, and
a second valve connected between the discharge port and a flow path extending between the expansion valve and the second heat exchanger, and

the controller is configured to

close the first valve and open the second valve in the activation mode,
and
open the first valve and close the second valve in the normal mode.

3. The refrigeration cycle apparatus according to claim 1 or 2, wherein the controller is configured to fully open the expansion valve in the activation mode.

4. The refrigeration cycle apparatus according to claim 1, further comprising:

a third heat exchanger configured to perform heat exchange between the refrigerant from the first heat exchanger and the refrigerant from the second heat exchanger, and
a check valve connected between the first heat exchanger and the third heat exchanger and configured to set a direction from the first heat exchanger toward the third heat exchanger as a forward direction, wherein
the flow rate adjuster has

a first valve connected between a discharge port of the compressor and the first heat exchanger, and
a second valve connected to the discharge port and a flow path extending between the check valve and the third heat exchanger, and

the controller is configured to

close the first valve and open the second valve in the activation mode,
and
open the first valve and close the second valve in the normal mode.

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

the second heat exchanger comprises a first heat exchange unit and a second heat exchange unit,
the refrigerant flows through the second heat exchanger in an order of the first heat exchange unit and the second heat exchange unit,
the flow rate adjuster has a valve connected between

a flow path extending between the first heat exchanger and the expansion valve and
a flow path extending between the first heat exchange unit and the second heat exchange unit, and

the controller is configured to
close the expansion valve and open the valve in the activation mode, and open the expansion valve and close the valve in the normal mode.

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

the compressor comprises

a first suction port,
a second suction port,
a discharge port,
a first compression mechanism connected between the first suction port and the discharge port and configured to compress the refrigerant from the first suction port and discharge the refrigerant through the discharge port, and
a second compression mechanism connected between the second suction port and the discharge port and configured to compress the refrigerant from the second suction port and discharge the refrigerant through the discharge port,

the flow rate adjuster further has a three-way valve connected between the discharge port and the second suction port,
the three-way valve has a first port, a second port, and a third port,
the first port is connected to the second suction port,
the second port is in communication with the first suction port,
the third port is connected to the discharge port, and
the controller is configured to

in the activation mode, allow the first port and the third port to communicate with each other, activate the first compression mechanism, and deactivate the second compression mechanism, and
in the normal mode, allow the first port and the second port to communicate with each other, and activate the first compression mechanism and the second compression mechanism.

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

the flow rate adjuster comprises a heater configured to heat the refrigerant flowing out of the second heat exchanger when the refrigerant circulates in the first circulation direction, and
the controller is configured to activate the heater in the activation mode and deactivate the heater in the normal mode.

8. The refrigeration cycle apparatus according to any one of claims 1 to 7, wherein the controller is configured to switch the operation mode from the activation mode to the normal mode after a lapse of a reference time period since the activation mode is started, and when a temperature of the refrigerant flowing out of the second heat exchanger is higher than a reference temperature.

9. The refrigeration cycle apparatus according to any one of claims 1 to 8, further comprising a gas-liquid separator configured to

receive the refrigerant from one of the first heat exchanger and the second heat exchanger, the one of the first heat exchanger and the second heat exchanger being configured to function as an evaporator,
separate the refrigerant into the refrigerant in a gas state and the refrigerant in a liquid state, and
store the refrigerant in a liquid state and guide the refrigerant in a gas state to the compressor.

10. The refrigeration cycle apparatus according to any one of claims 1 to 9, further comprising a flow path switching valve configured to switch a circulation direction of the refrigerant between the first circulation direction and a second circulation direction opposite to the first circulation direction.

11. The refrigeration cycle apparatus according to any one of claims 1 to 10, wherein the refrigerant comprises R290.

FIG.1

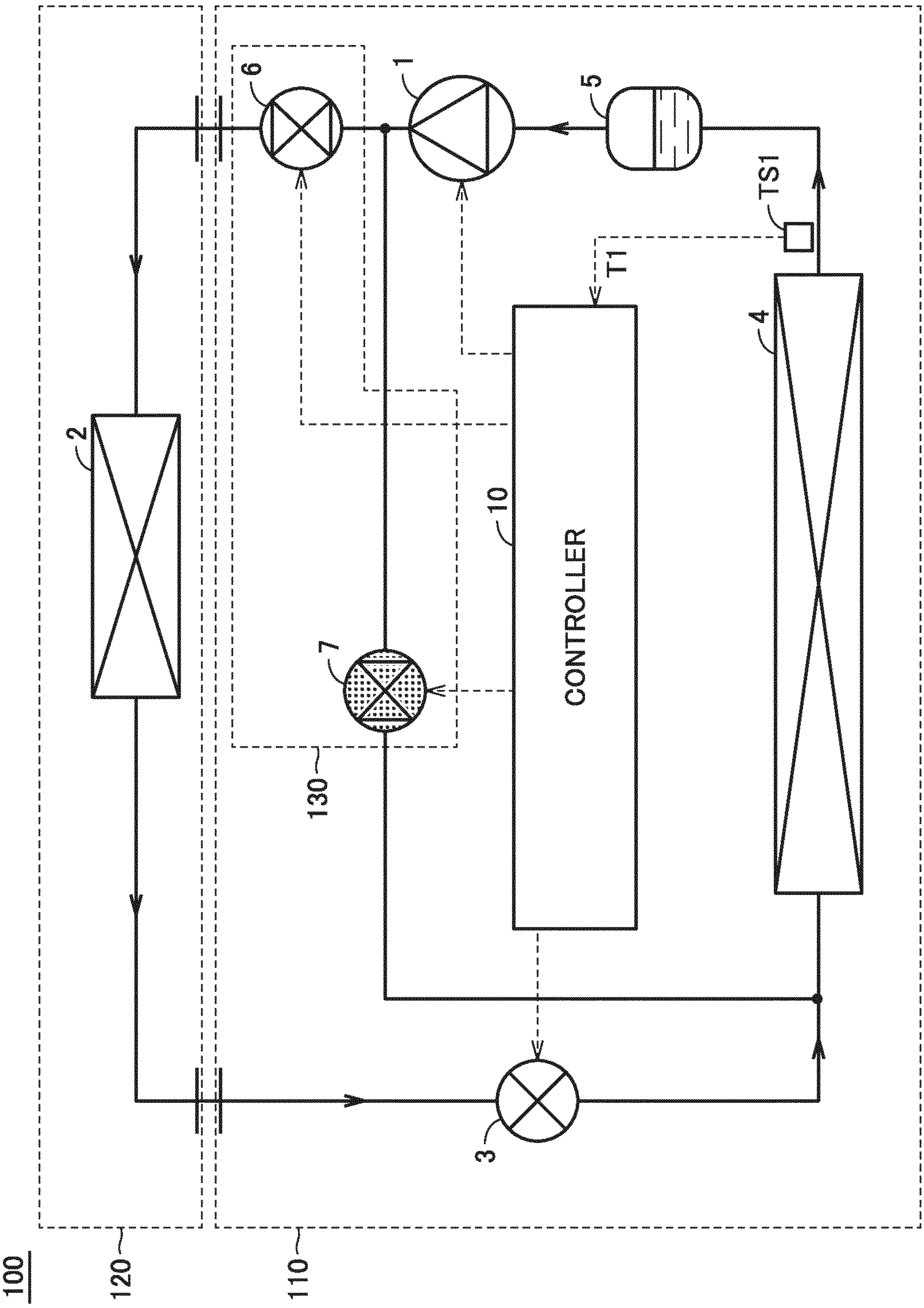


FIG.2

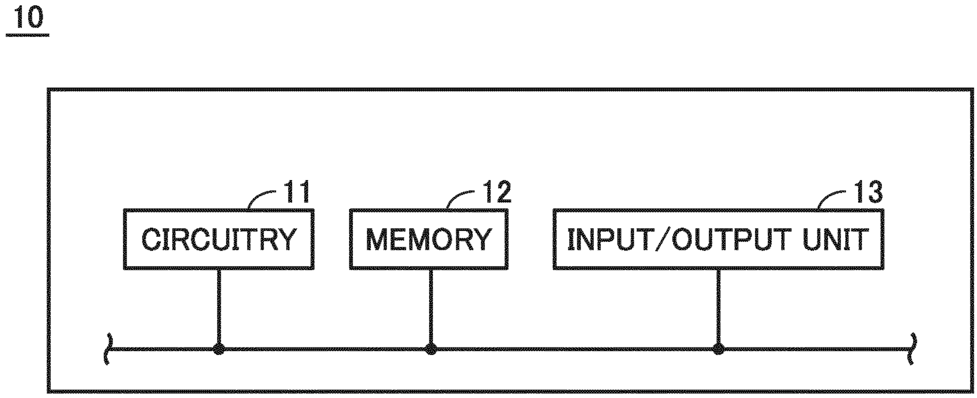


FIG.3

900

120

110

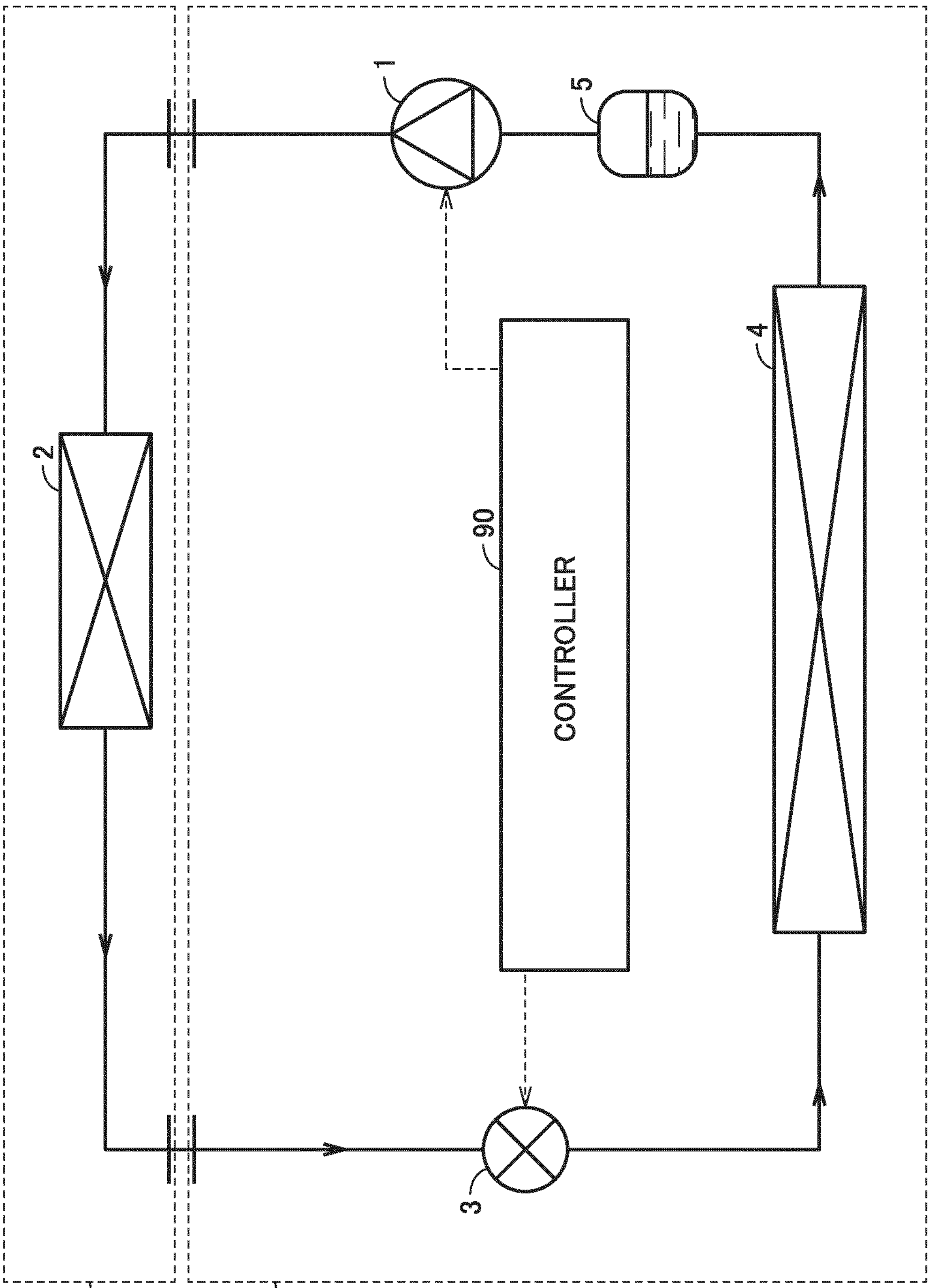


FIG.4

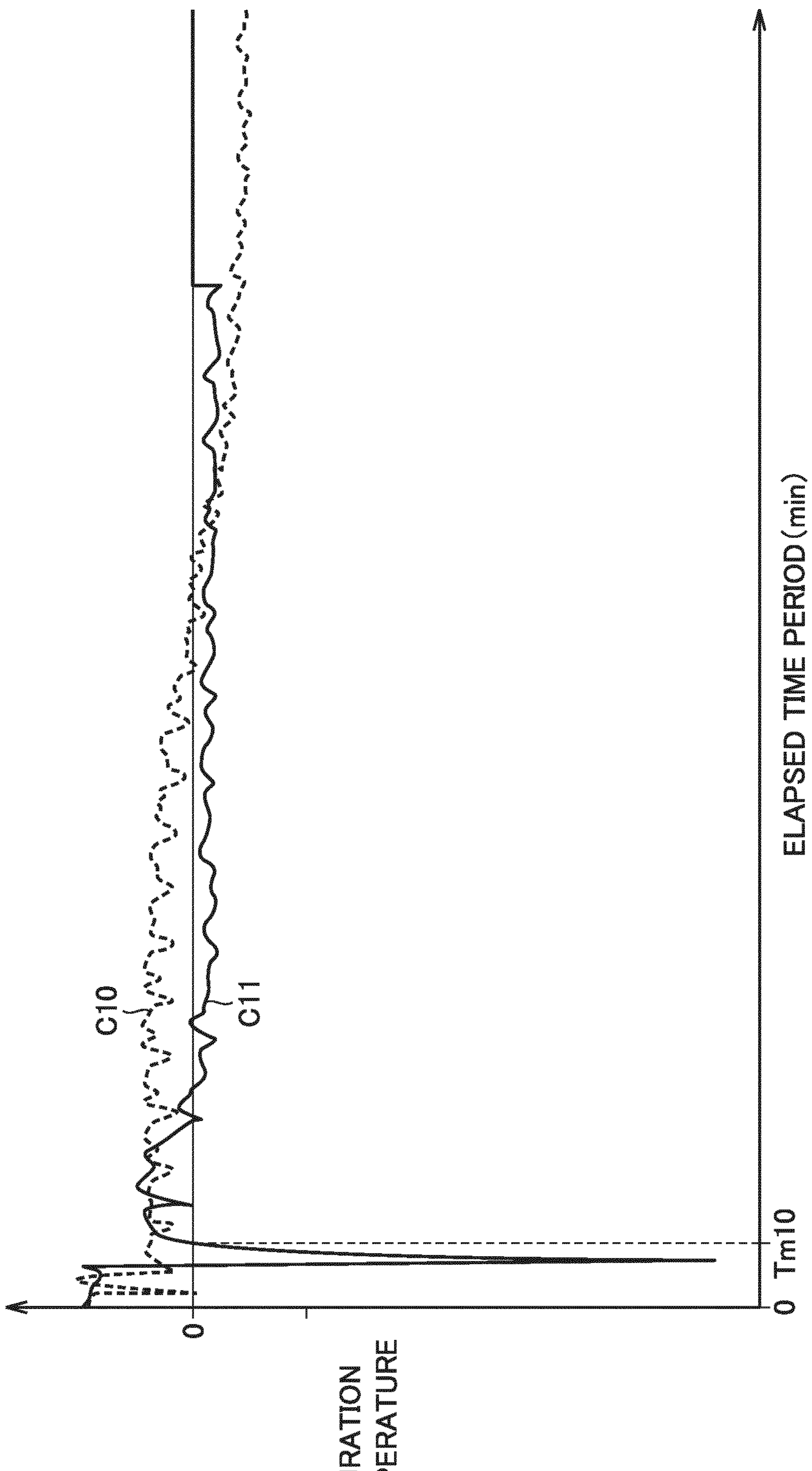

SATURATION TEMPERATURE (°C)
0
C10
C11
0
Tm10
ELAPSED TIME PERIOD (min)

FIG.5

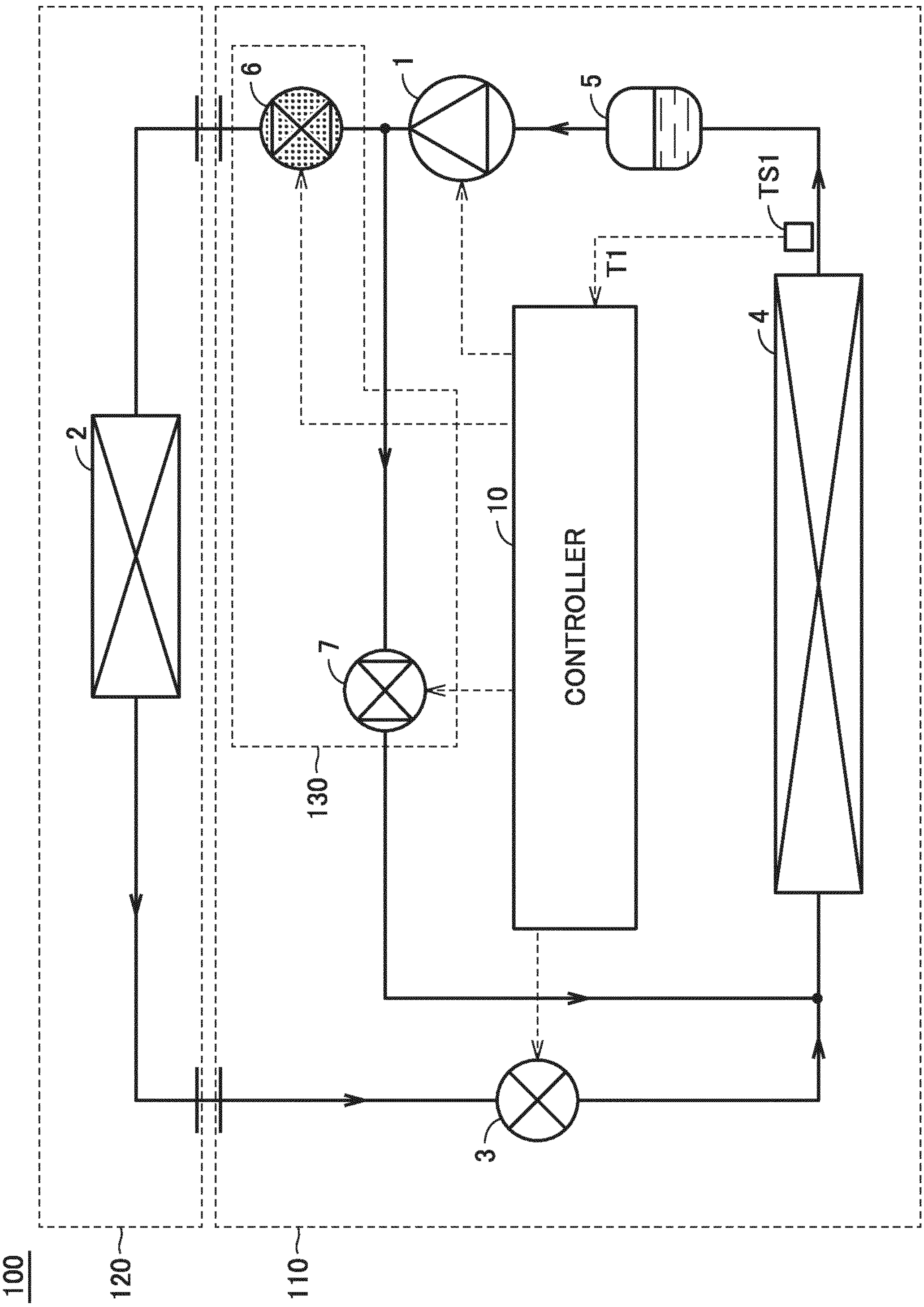


FIG.6

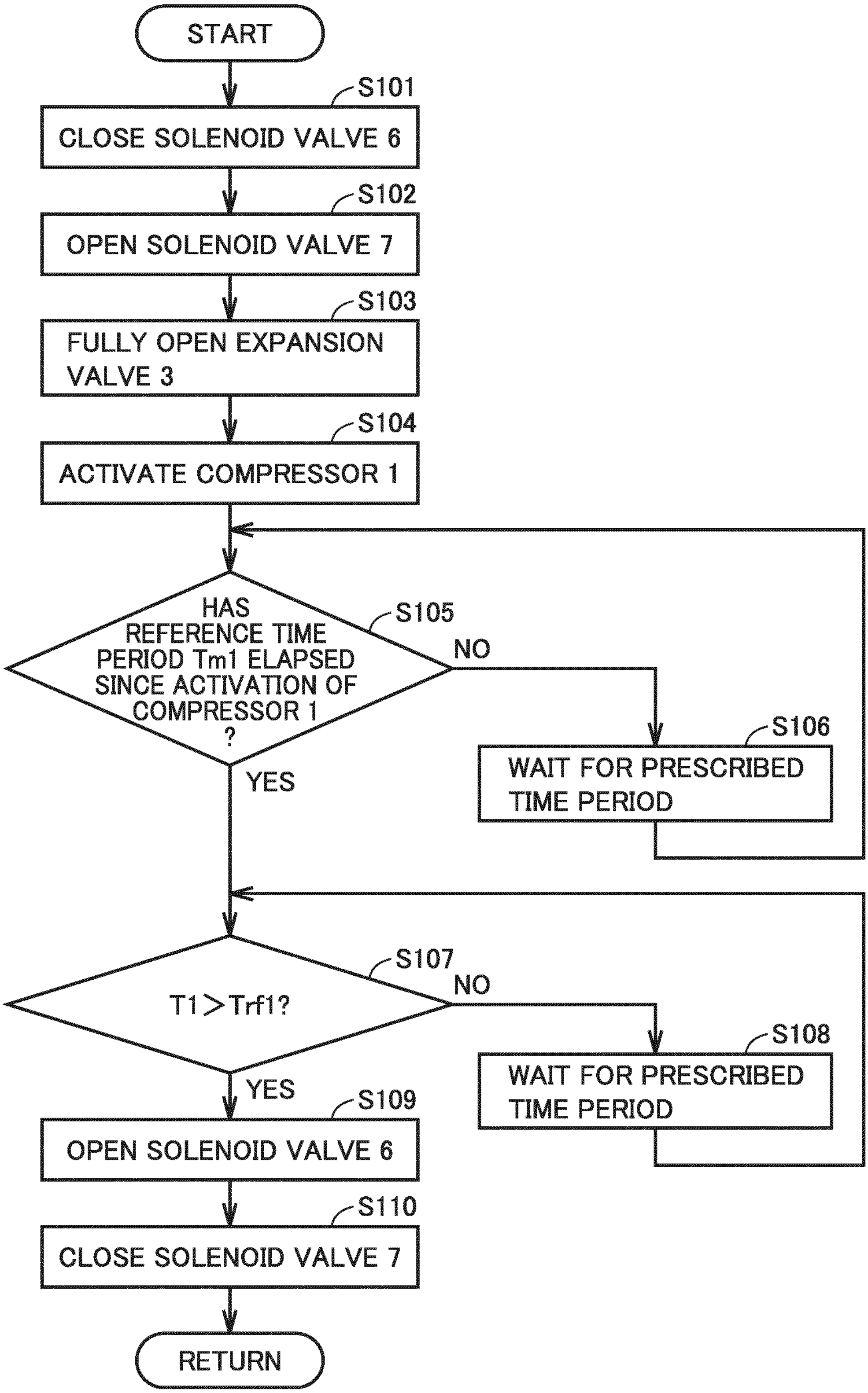

START
S101
CLOSE SOLENOID VALVE 6
S102
OPEN SOLENOID VALVE 7
S103
FULLY OPEN EXPANSION VALVE 3
S104
ACTIVATE COMPRESSOR 1
S105
HAS REFERENCE TIME PERIOD Tm1 ELAPSED SINCE ACTIVATION OF COMPRESSOR 1 ?
NO
S106
WAIT FOR PRESCRIBED TIME PERIOD
YES
S107
T1＞Trf1?
NO
S108
WAIT FOR PRESCRIBED TIME PERIOD
YES
S109
OPEN SOLENOID VALVE 6
S110
CLOSE SOLENOID VALVE 7
RETURN

FIG.7

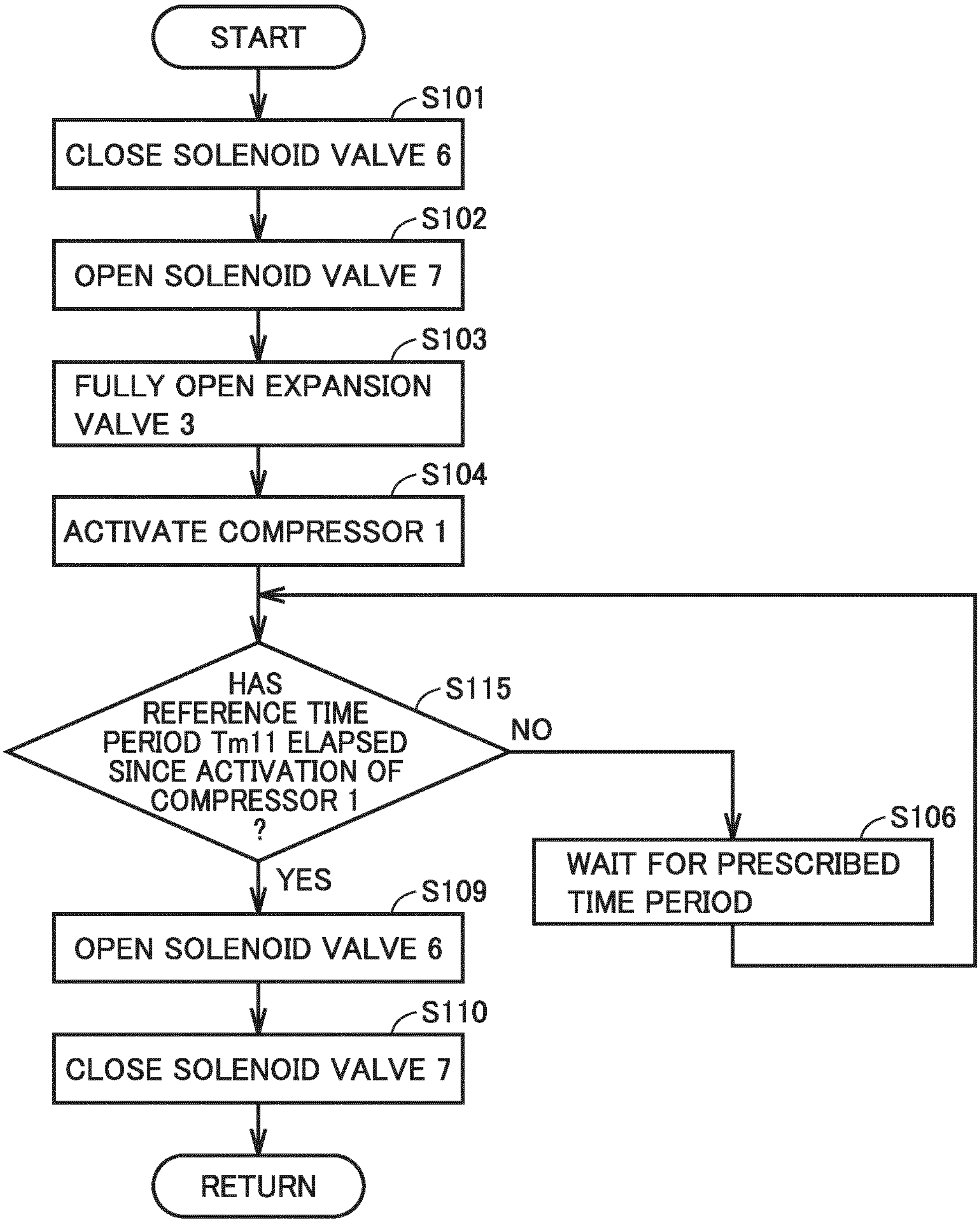

START
S101
CLOSE SOLENOID VALVE 6
S102
OPEN SOLENOID VALVE 7
S103
FULLY OPEN EXPANSION VALVE 3
S104
ACTIVATE COMPRESSOR 1
S115
HAS REFERENCE TIME PERIOD Tm11 ELAPSED SINCE ACTIVATION OF COMPRESSOR 1 ?
NO
S106
WAIT FOR PRESCRIBED TIME PERIOD
YES
S109
OPEN SOLENOID VALVE 6
S110
CLOSE SOLENOID VALVE 7
RETURN

FIG.8

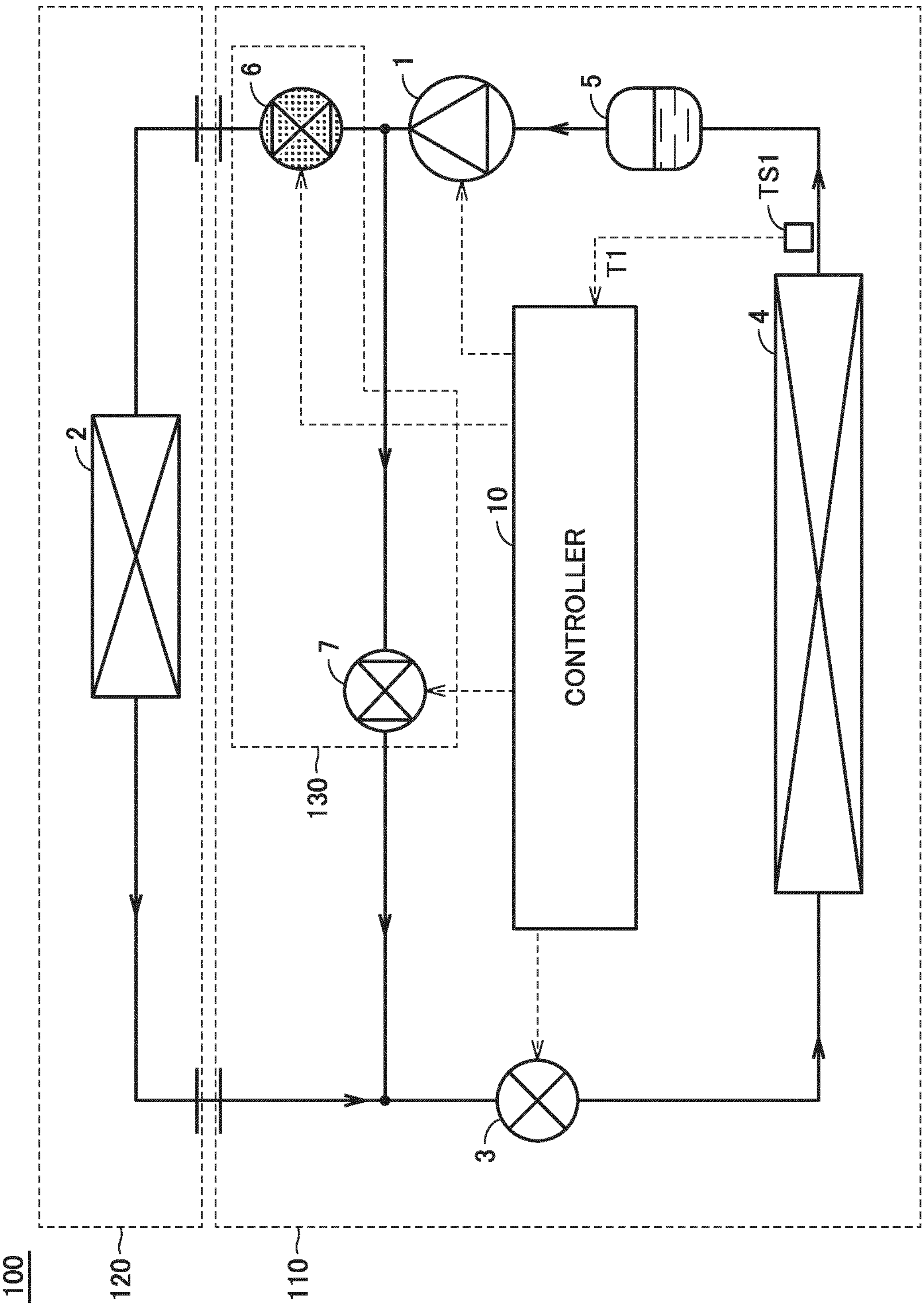


FIG.9

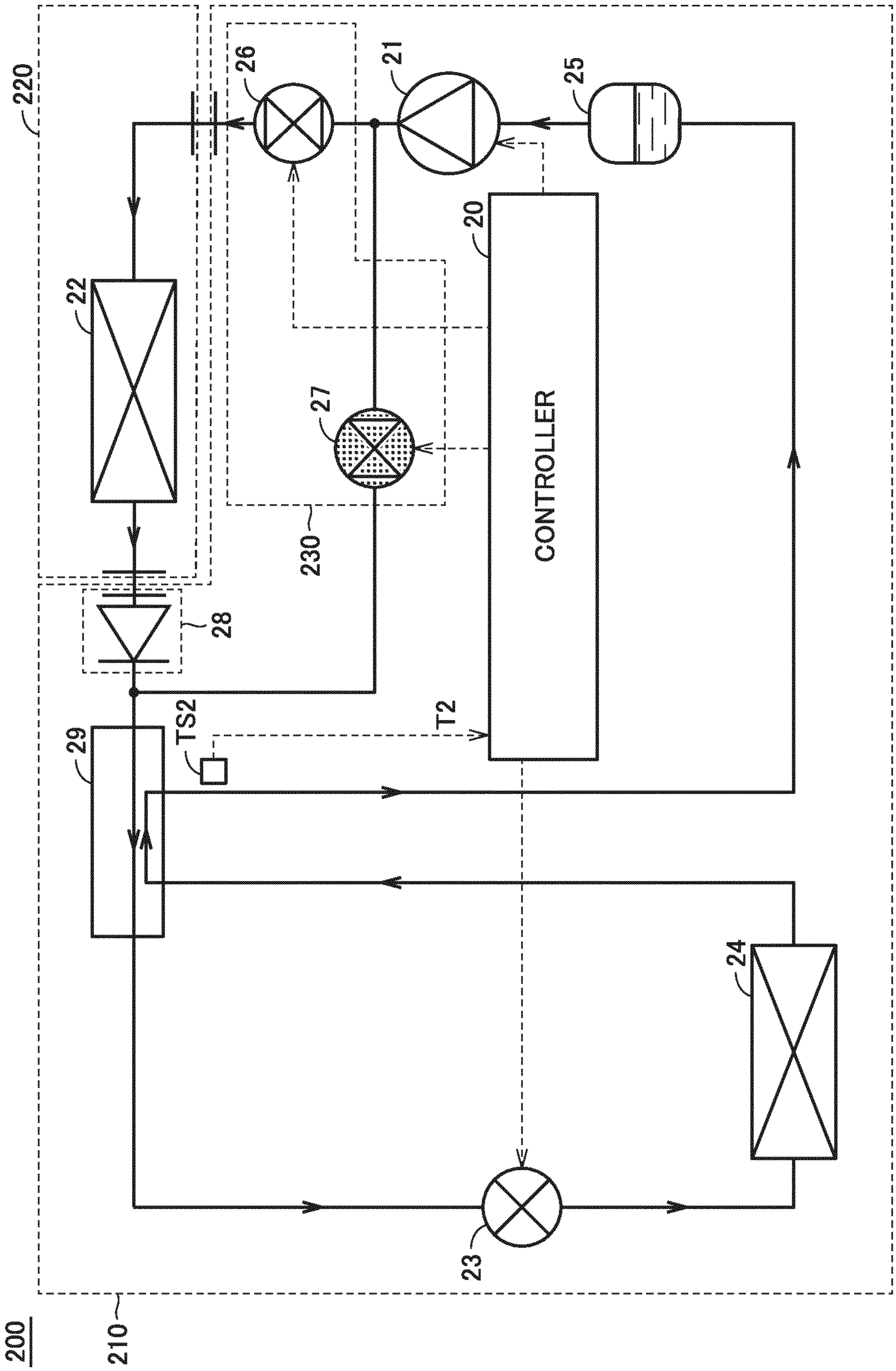


FIG.10

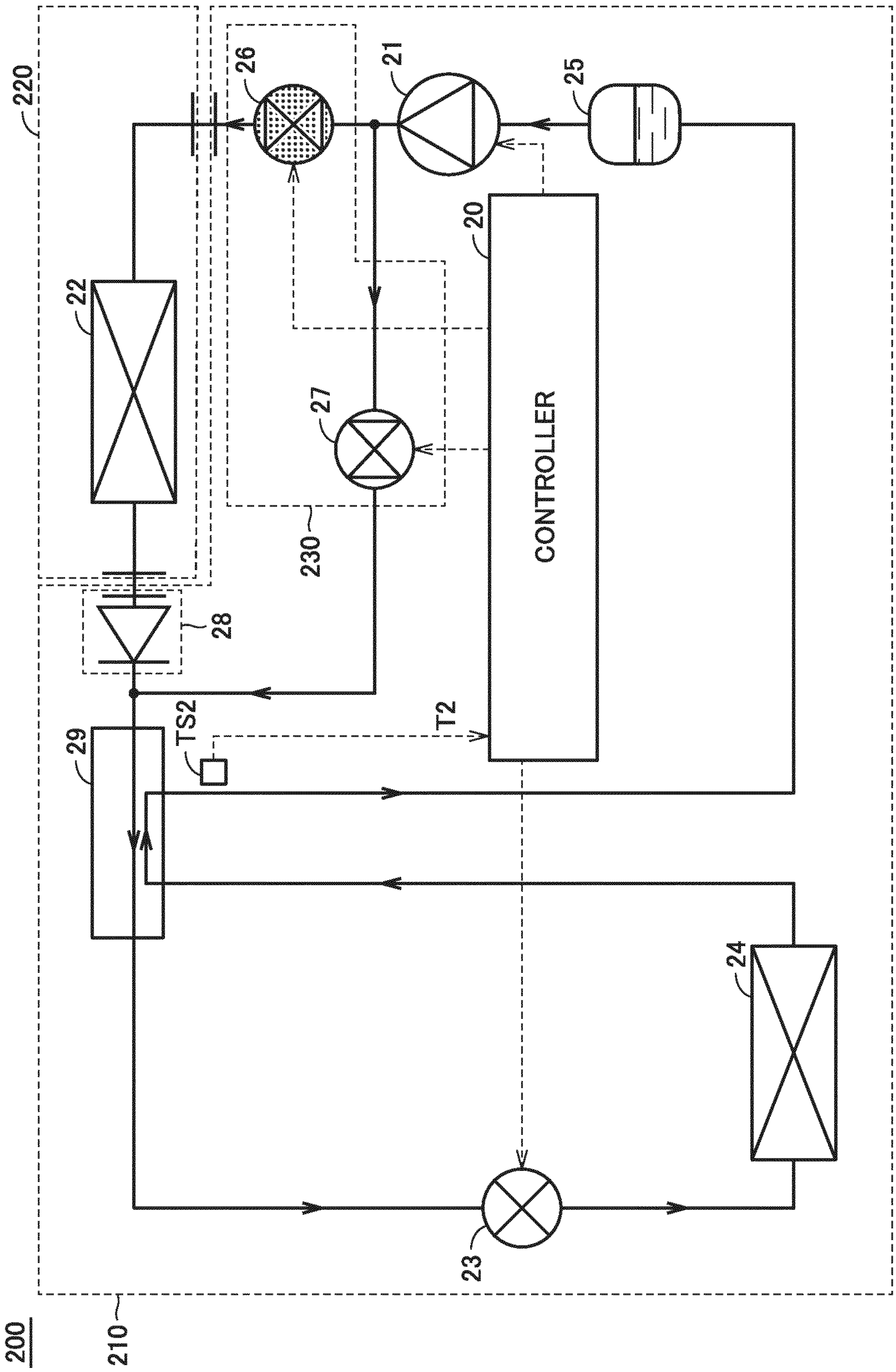


FIG.11

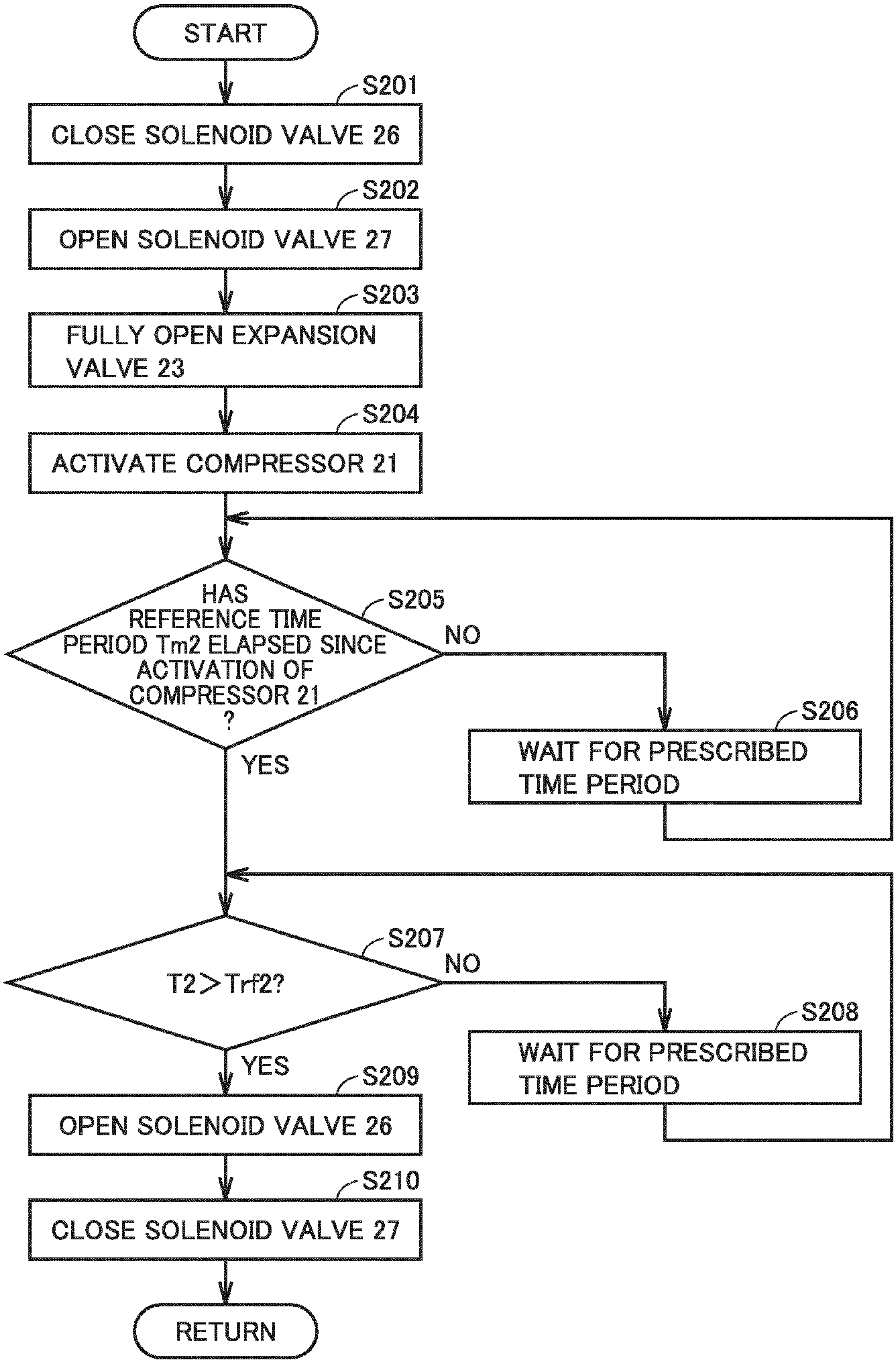

START
S201
CLOSE SOLENOID VALVE 26
S202
OPEN SOLENOID VALVE 27
S203
FULLY OPEN EXPANSION VALVE 23
S204
ACTIVATE COMPRESSOR 21
S205
HAS REFERENCE TIME PERIOD Tm2 ELAPSED SINCE ACTIVATION OF COMPRESSOR 21 ?
NO
S206
WAIT FOR PRESCRIBED TIME PERIOD
YES
S207
T2＞Trf2?
NO
S208
WAIT FOR PRESCRIBED TIME PERIOD
YES
S209
OPEN SOLENOID VALVE 26
S210
CLOSE SOLENOID VALVE 27
RETURN

FIG.12

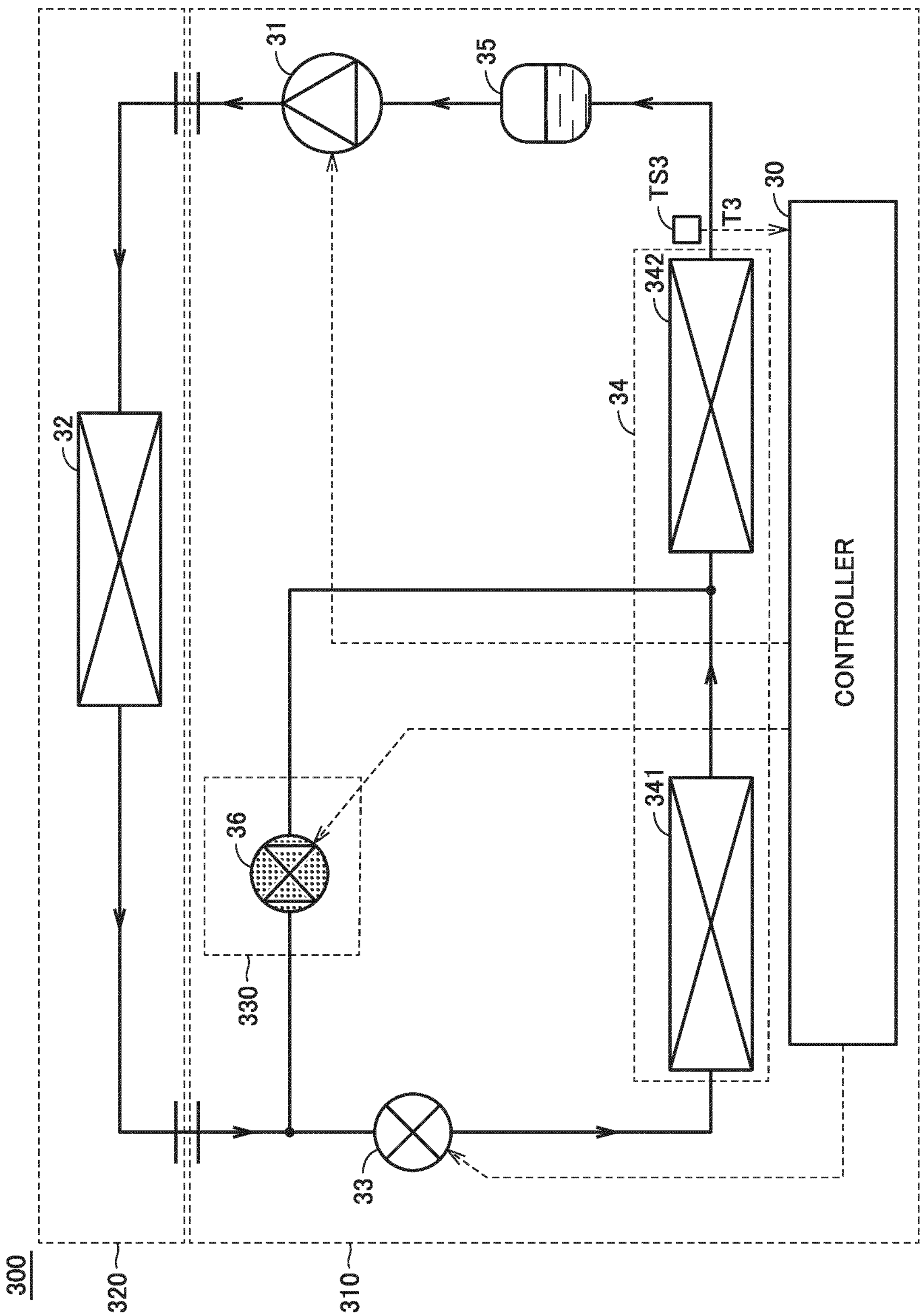


FIG.13

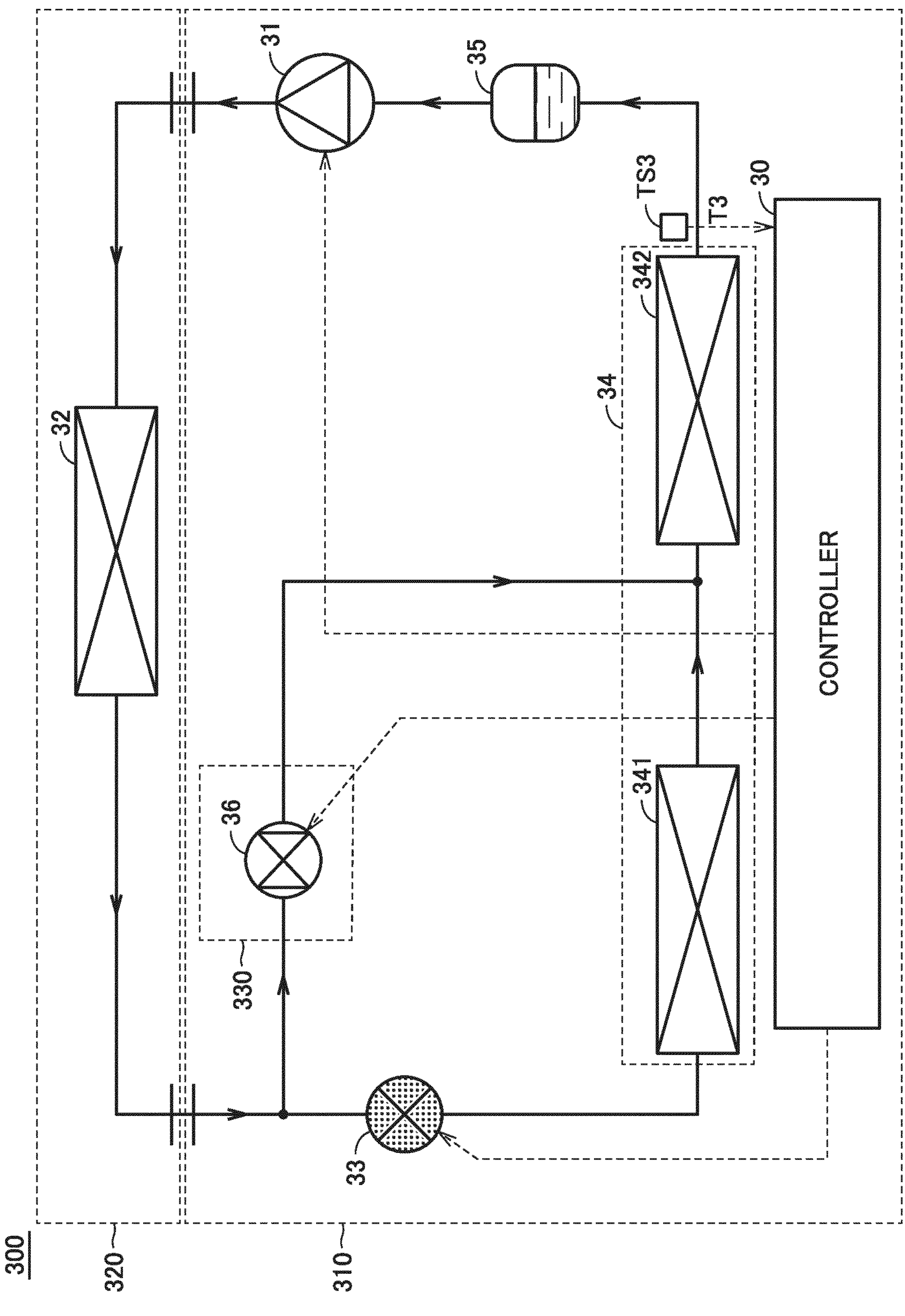


FIG.14

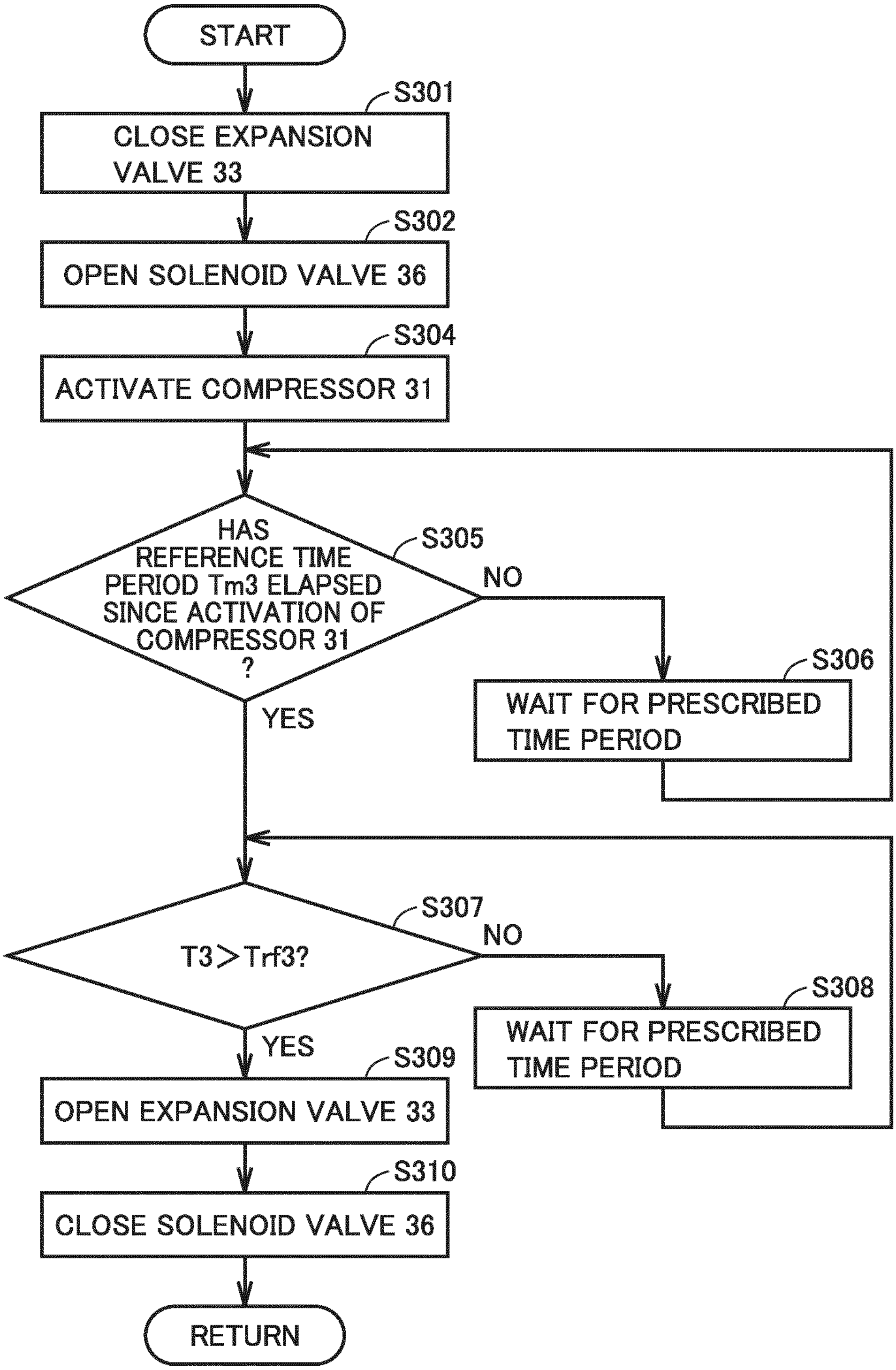

START
S301
CLOSE EXPANSION VALVE 33
S302
OPEN SOLENOID VALVE 36
S304
ACTIVATE COMPRESSOR 31
S305
HAS REFERENCE TIME PERIOD Tm3 ELAPSED SINCE ACTIVATION OF COMPRESSOR 31 ?
NO
YES
S306
WAIT FOR PRESCRIBED TIME PERIOD
S307
T3 > Trf3?
NO
YES
S308
WAIT FOR PRESCRIBED TIME PERIOD
S309
OPEN EXPANSION VALVE 33
S310
CLOSE SOLENOID VALVE 36
RETURN

FIG.15

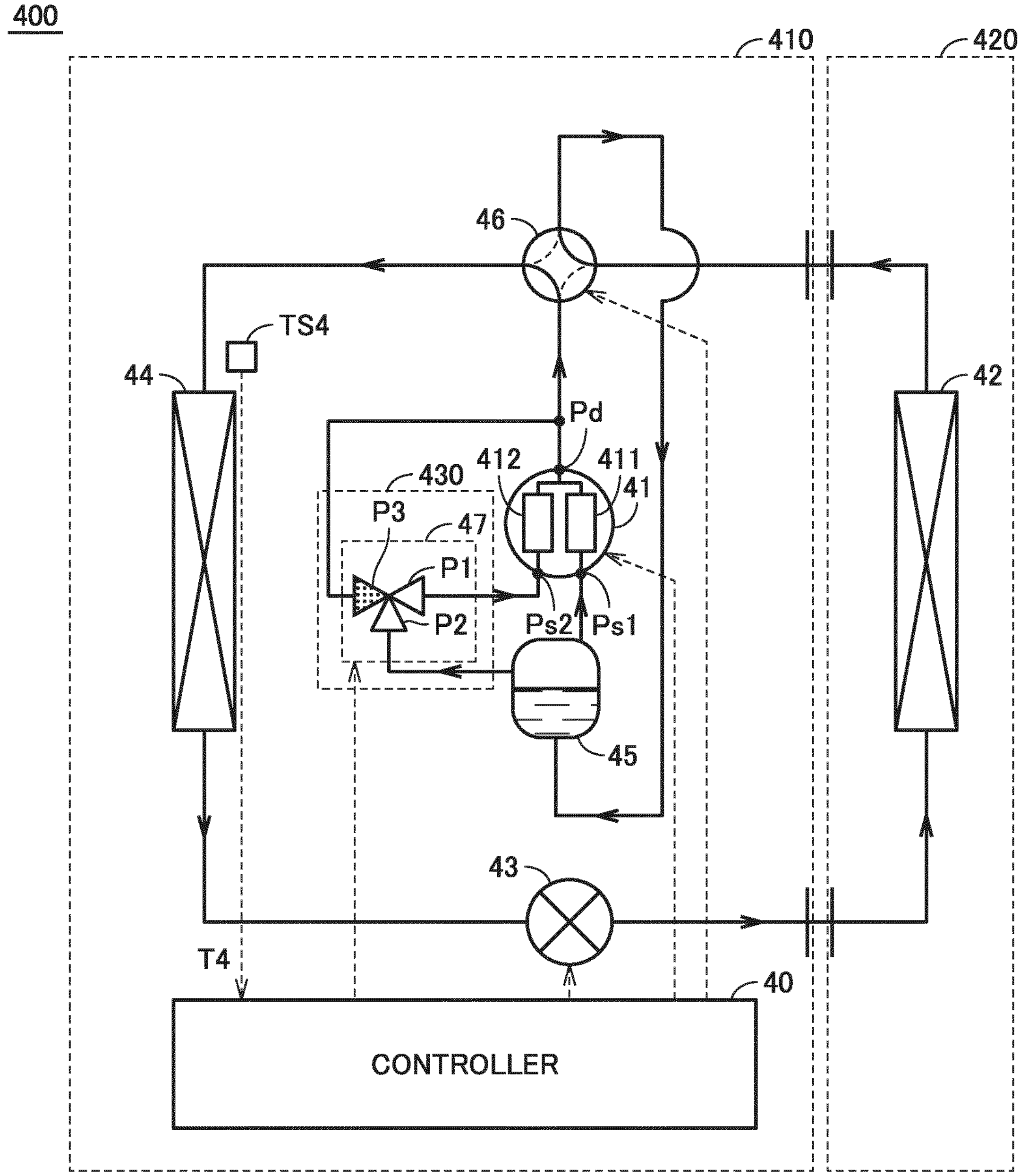
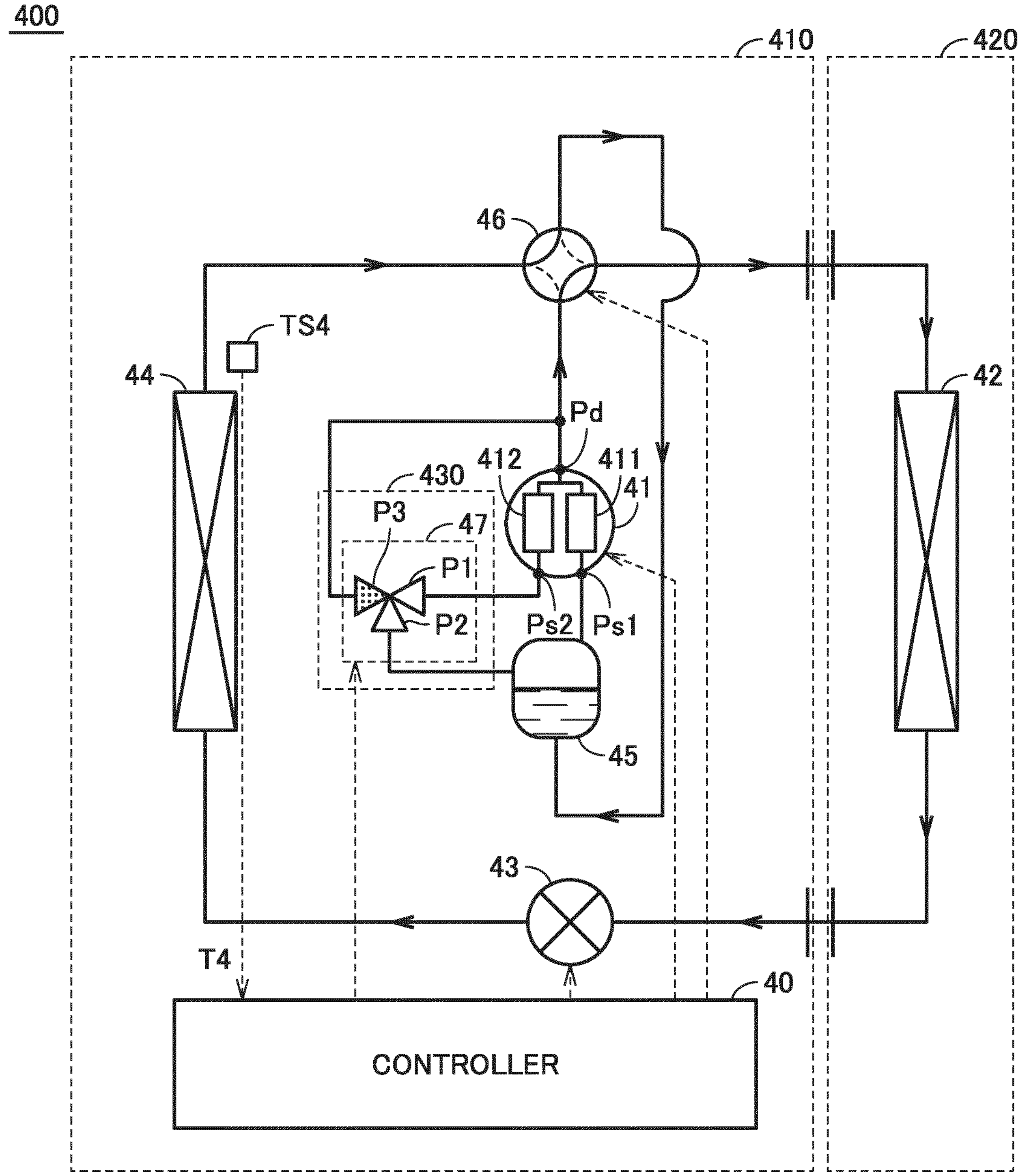
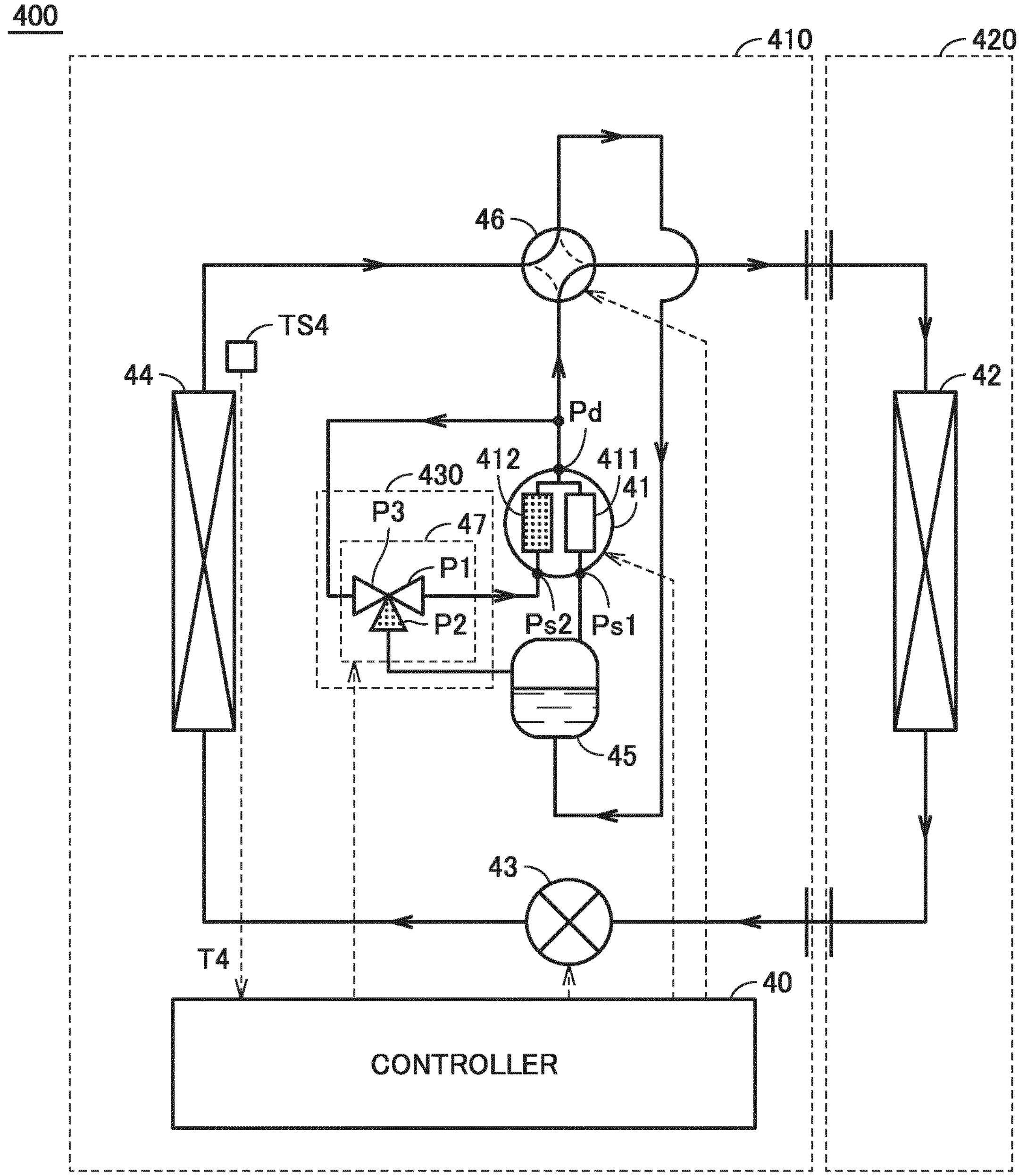

400
410
420
46
TS4
44
42
Pd
412
411
41
430
P3
47
P1
P2
Ps2
Ps1
45
43
T4
40
CONTROLLER

FIG.16



400
410
420
46
TS4
44
42
Pd
412
411
41
430
P3
47
P1
P2
Ps2
Ps1
45
43
T4
40
CONTROLLER

FIG.17



400
410
420
46
TS4
44
42
Pd
412
411
41
430
P3
47
P1
P2
Ps2
Ps1
45
43
T4
40
CONTROLLER

FIG.18

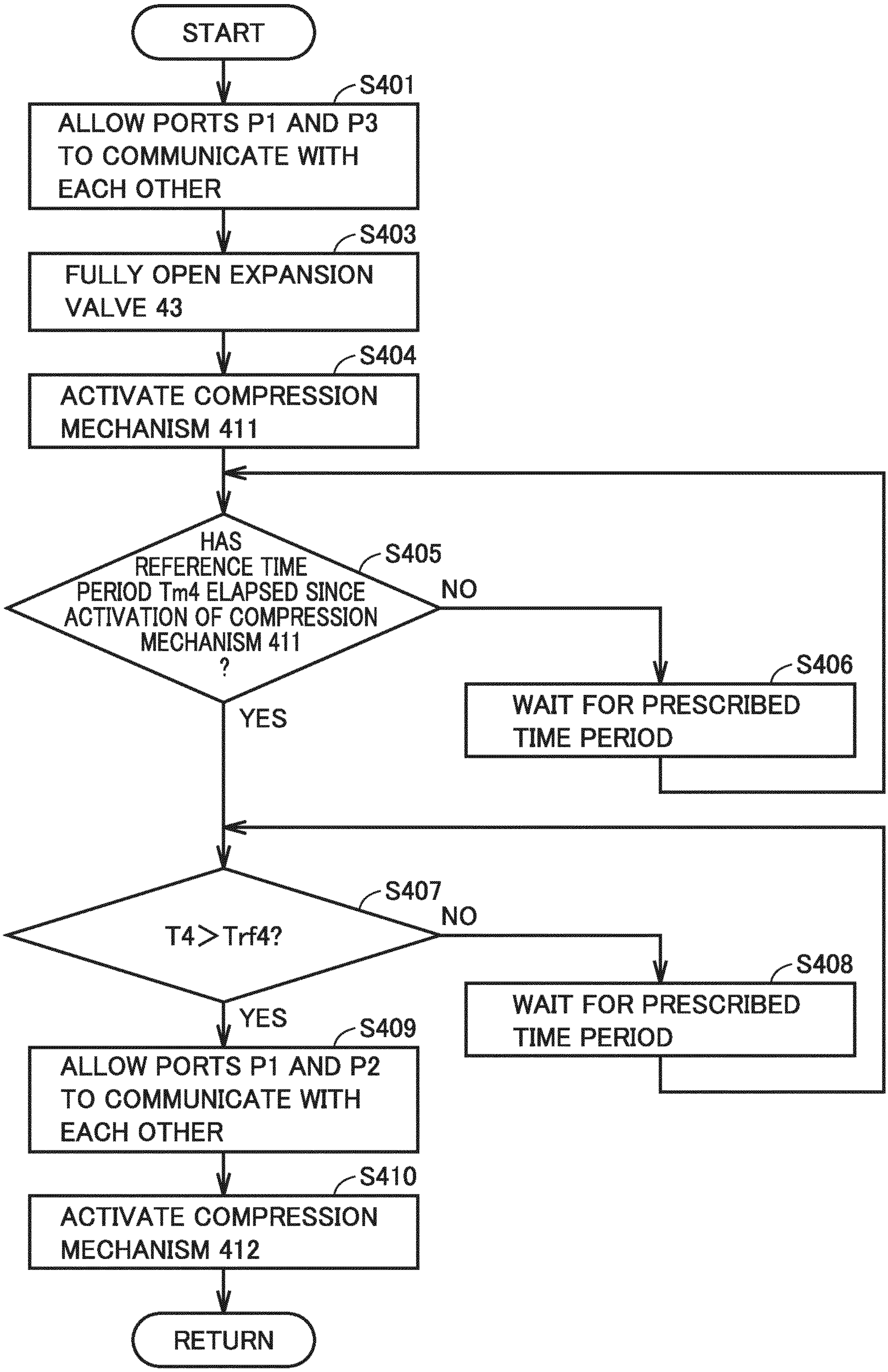

START
S401
ALLOW PORTS P1 AND P3 TO COMMUNICATE WITH EACH OTHER
S403
FULLY OPEN EXPANSION VALVE 43
S404
ACTIVATE COMPRESSION MECHANISM 411
S405
HAS REFERENCE TIME PERIOD Tm4 ELAPSED SINCE ACTIVATION OF COMPRESSION MECHANISM 411 ?
NO
S406
WAIT FOR PRESCRIBED TIME PERIOD
YES
S407
T4>Trf4?
NO
S408
WAIT FOR PRESCRIBED TIME PERIOD
YES
S409
ALLOW PORTS P1 AND P2 TO COMMUNICATE WITH EACH OTHER
S410
ACTIVATE COMPRESSION MECHANISM 412
RETURN

FIG.19

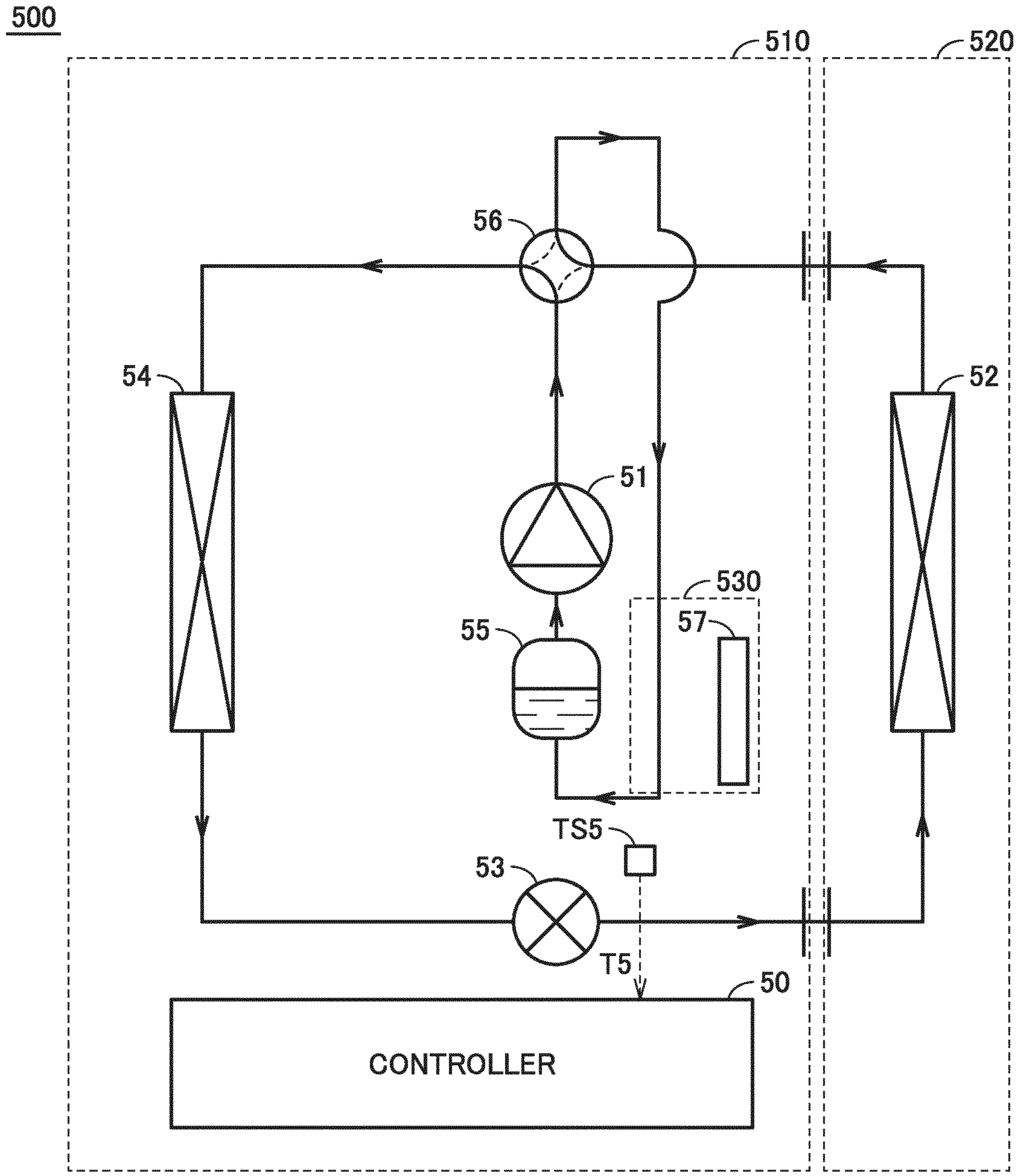


FIG.20

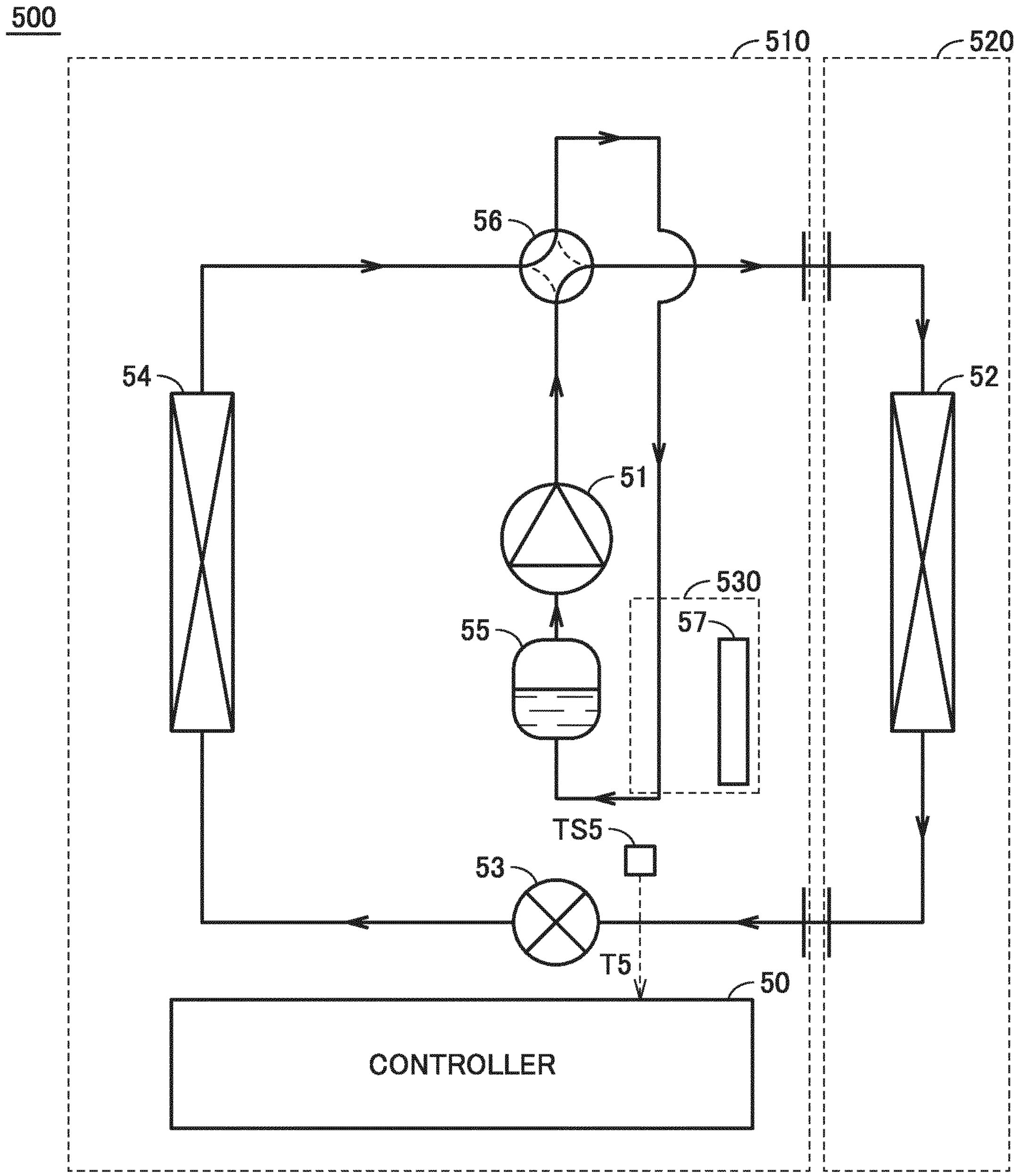


FIG.21

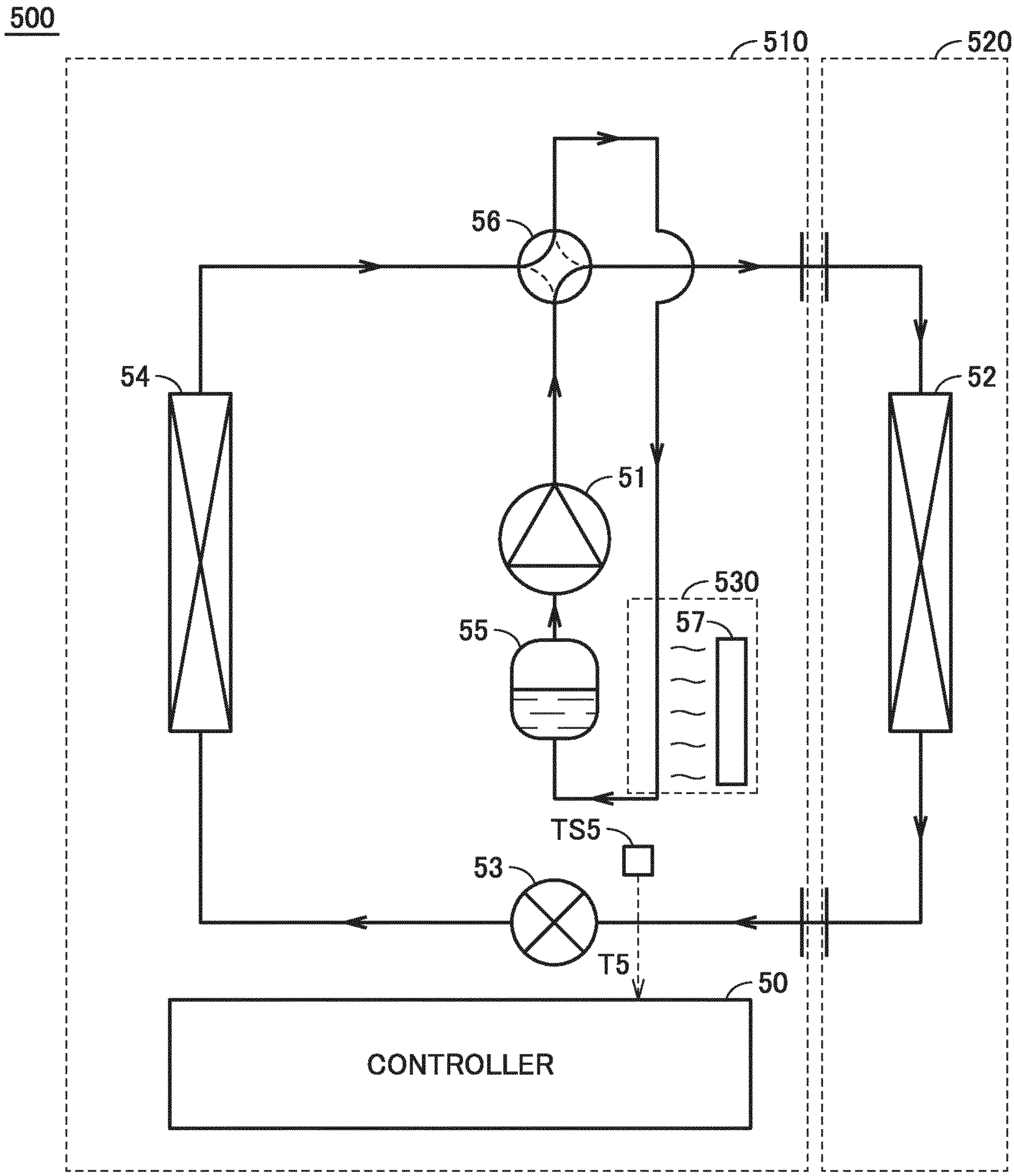
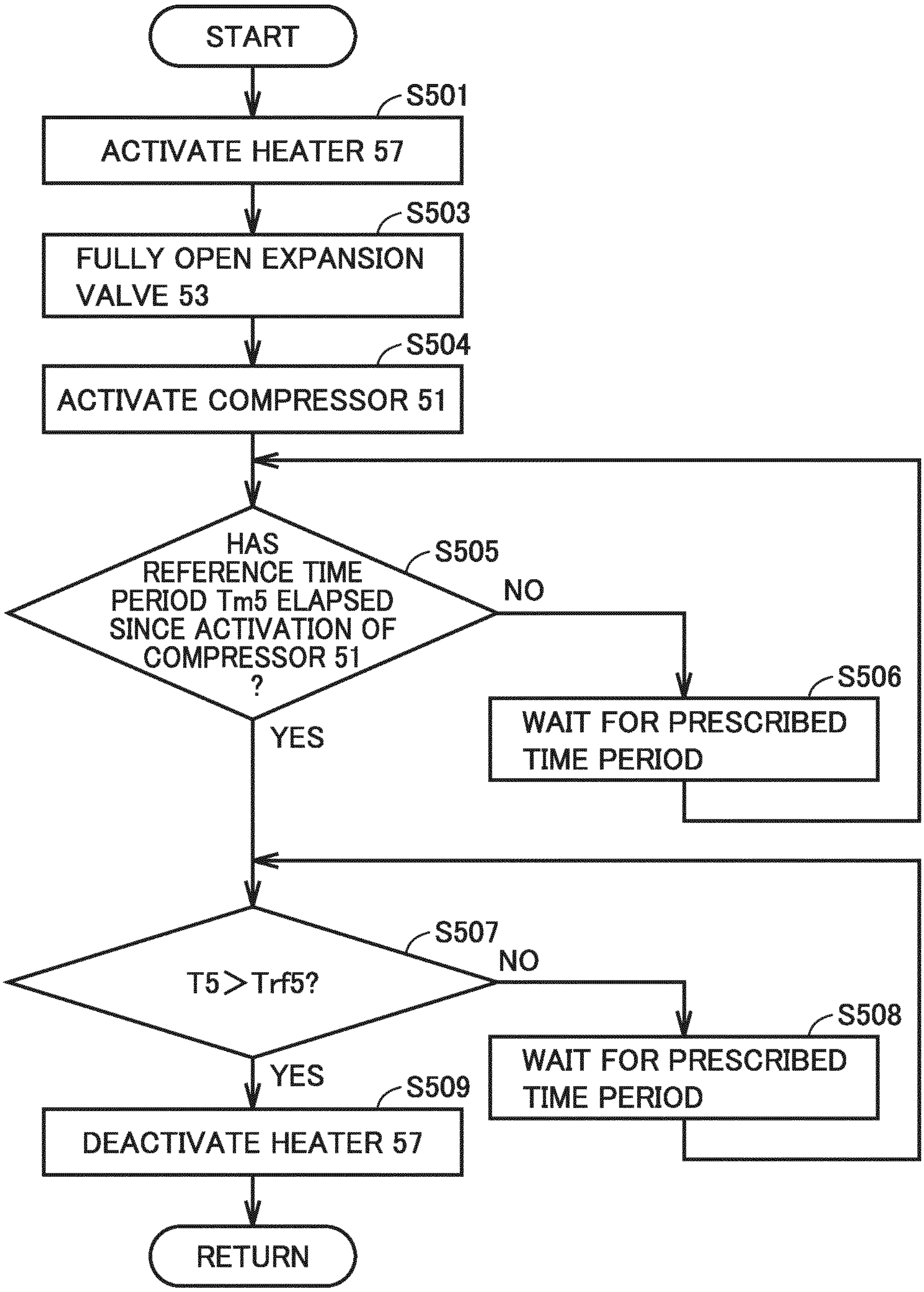


FIG.22


START
S501
ACTIVATE HEATER 57
S503
FULLY OPEN EXPANSION VALVE 53
S504
ACTIVATE COMPRESSOR 51
S505
HAS REFERENCE TIME PERIOD Tm5 ELAPSED SINCE ACTIVATION OF COMPRESSOR 51 ?
NO
S506
WAIT FOR PRESCRIBED TIME PERIOD
YES
S507
T5＞Trf5?
NO
S508
WAIT FOR PRESCRIBED TIME PERIOD
YES
S509
DEACTIVATE HEATER 57
RETURN

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/031273

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. F25B1/00(2006.01)i, F25B5/04(2006.01)i, F25B13/00(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl. F25B1/00, F25B5/04, F25B13/00

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	1971-2019
Registered utility model specifications of Japan	1996-2019
Published registered utility model applications of Japan	1994-2019

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 5-306841 A (MITSUBISHI HEAVY INDUSTRIES, LTD.) 19 November 1993, paragraphs [0007]-[0016], fig. 1, 2 (Family: none)	1, 3, 8-11 2, 4-7
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 12221/1991 (Laid-open No. 103570/1992) (FUJITSU GENERAL LIMITED) 07 September 1992, paragraphs [0007], [0008], fig. 1 (Family: none)	1-11

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

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"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
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23.10.2019	05.11.2019

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2015094558 A **[0002] [0003]**