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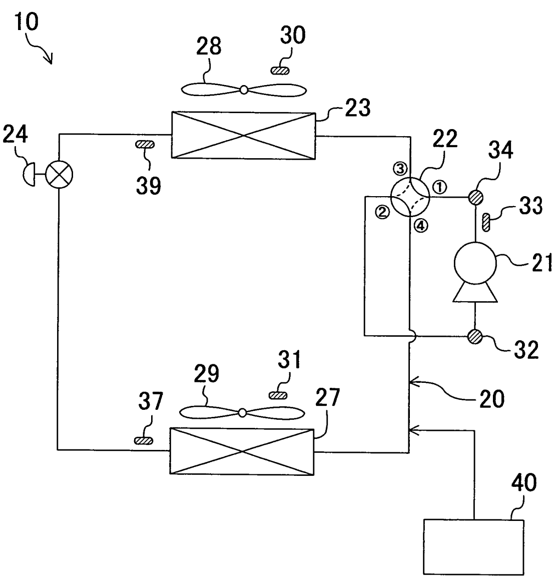
(54) FREEZING DEVICE

(57) The present disclosure allows for easy settling of control of capability of an refrigeration apparatus for performing a supercritical refrigeration cycle.

An air conditioner (10) includes: a refrigerant circuit (20) sequentially connecting a compressor (21), an outdoor heat exchanger (23), an outdoor expansion valve (24), and an indoor heat exchanger (27), and performing a supercritical refrigeration cycle in which a high pressure is a supercritical pressure or higher; and a controller (40) for controlling a plurality of objects of control including at least the compressor (21) and the outdoor expansion valve (24). The controller (40) concurrently controls the plurality of objects of control, thereby concurrently controlling a predetermined physical value as an index of an ability of the refrigeration apparatus, and the high pressure of the refrigeration cycle.

FIG.1



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a refrigeration apparatus including a refrigerant circuit for performing a supercritical refrigeration cycle.

BACKGROUND ART

[0002] In general, a capability of a refrigeration apparatus including a refrigerant circuit sequentially connecting a compression mechanism, a heat source side heat exchanger, an expansion mechanism, and a utilization side heat exchanger is controlled by controlling the compression mechanism and the expansion mechanism. Patent Document 1 shows an example of the refrigeration apparatus.

[0003] The refrigeration apparatus of the Patent Document 1 includes a compressor capacity controller for controlling the capacity of a compressor as the compression mechanism, and an expansion valve controller for controlling the degree of opening of an expansion valve as the expansion mechanism. The compressor capacity controller controls the capacity of the compressor based on a low pressure of a refrigerant flowing in the refrigerant circuit. The expansion valve controller controls the degree of opening of the expansion valve based on the temperature of the refrigerant at an outlet of an evaporator. Then, a control amount of the expansion valve controller is corrected based on the capacity of the compressor.

CITATION LIST

[0004]

PATENT DOCUMENT 1: Japanese Patent Publication No. 2002-22242

SUMMARY OF THE DISCLOSURE

TECHNICAL PROBLEM

[0005] Even if the refrigeration apparatus is configured to correct the control amount of the degree of opening of the expansion valve controlled by the expansion valve controller based on the capacity of the compressor, change of the degree of opening of the expansion valve leads to change of a circulation state of the refrigerant, thereby changing the low pressure of the refrigerant. In response to the change of the low pressure of the refrigerant, the compressor capacity controller adjusts the capacity of the compression mechanism. The change of the capacity of the compressor involves re-correction of the control amount of the expansion valve controller. Thus, a sequence of the correction of the control amount of the expansion valve controller, the change of the low pressure of the refrigerant, the change of the capacity of the compressor, and the re-correction of the control amount of the expansion valve controller occurs in a loop. The control of the low pressure by the compressor, and the control of the degree of superheat by the expansion valve cannot be easily settled.

[0006] In particular, a refrigeration apparatus for performing a supercritical refrigeration cycle in which a high pressure of the refrigerant is equal to or higher than a critical pressure has a problem of difficulty in settling the control.

[0007] From this point of view, the present disclosure is intended to allow for improved settling of the control of the capability of a refrigeration apparatus for performing the supercritical refrigeration cycle.

SOLUTION TO THE PROBLEM

[0008] The present disclosure has been achieved by paying attention to a large variation of enthalpy of the refrigerant at an outlet of a gas cooler relative to the change of the high pressure of the supercritical refrigeration cycle. Specifically, in cooling operation in the supercritical refrigeration cycle, the enthalpy of the refrigerant at the outlet of the gas cooler may greatly vary when the high pressure changes due to change of the low pressure. This leads to an event that is not caused by a subcritical refrigerant, i.e., the enthalpy of the refrigerant at an inlet of an indoor heat exchanger varies, thereby changing the degree of superheat of the refrigerant at an outlet of the indoor heat exchanger. As a result, the difficulty of settling of the control increases. Also in heating operation, the enthalpy of the refrigerant at the outlet of the gas cooler may greatly vary due to the change of the high pressure. This leads to great fluctuation of indoor air heating capability, thereby changing the temperature of the indoor air, and changing a target value of the temperature of the refrigerant at the outlet of the gas cooler. This vicious circle further increases the difficulty of settling of the control. Moreover, CO_2, which is a supercritical refrigerant, shows greater variation in refrigerant density when it is superheated as compared with chlorofluorocarbons (e.g., when an evaporating temperature is 5°C, and the degree of superheat varies from 0°C to 5°C, R410A shows a decrease in gas density of only 3.5 %, whereas CO_2 shows a decrease of as much as 6.5 %). Further, the supercritical refrigerant shows great variation in circulating amount and capability of the apparatus due to the change of the degree of superheat, thereby greatly affecting the controllability. In view of this, the present disclosure is intended to control the high pressure of the refrigeration cycle, and a predetermined physical value controlled by the control of the capability of the apparatus in a concurrent manner.

[0009] A first aspect of the disclosure is directed to a refrigeration apparatus including: a refrigerant circuit (20) sequentially connecting a compression mechanism (21), a heat source side heat exchanger (23), an expansion mechanism (24), and a utilization side heat exchanger (27), and performing a supercritical refrigeration cycle in which a high pressure is a supercritical pressure of a refrigerant or higher; and a control section (40) for controlling a plurality of objects of control including at least the compression mechanism (21) and the expansion mechanism (24). The control section (40) concurrently controls the plurality of objects of control, thereby concurrently controlling a predetermined physical value of the refrigeration apparatus, and the high pressure of the refrigeration cycle.

[0010] With this configuration, the predetermined physical value is controlled, while controlling the high pressure of the refrigeration cycle in the refrigerant circuit (20). Specifically, a different physical value can be controlled in consideration of the change of the high pressure of the refrigeration cycle, and the change of enthalpy of the refrigerant at an outlet of a gas cooler, due to adjustment of the objects of control. In this way, the plurality of objects of control are concurrently controlled so as to concurrently control the high pressure of the refrigeration cycle and the predetermined physical value, thereby controlling the objects of control by taking into account the effect of their changes on the high pressure and the predetermined physical value. Therefore, an event can be avoided in which the objects of control are independently controlled, and the corresponding high pressure of the refrigeration cycle and predetermined physical value are independently changed, and are affected by each other, thereby resulting in difficulty in settling the control. This allows for an improved convergence rate of the control of the predetermined physical value and the high pressure in the refrigeration apparatus.

[0011] In a second aspect of the disclosure related to the first aspect of the disclosure, the control section (40) receives the predetermined physical value, and the high pressure of the refrigeration cycle as inputs, generates control signals each corresponding to the plurality of objects of control by associating the physical value and the high pressure with each other, and outputs the control signals to the corresponding objects of control, respectively, thereby concurrently controlling the predetermined physical value, and the high pressure of the refrigeration cycle.

[0012] With this configuration, the control signals for controlling the plurality of objects of control, respectively, are generated by associating the input predetermined physical value and high pressure of the refrigeration cycle with each other. This allows for controlling the objects of control by taking both of the predetermined physical value and the high pressure into consideration, instead of controlling the objects of control by inputting any one of the predetermined physical value and the high pressure. Since the plurality of objects of control are concurrently controlled as described above, a control signal for one of the objects of control can be generated in consideration of the effect of adjustment of the other objects of control on the predetermined physical value and the high pressure.

[0013] In a third aspect of the disclosure related to the first or second aspect of the disclosure, the refrigeration apparatus further includes: a heat source side fan (28) for feeding air to the heat source side heat exchanger (23) in which the refrigerant exchanges heat with the air, wherein in cooling operation, the predetermined physical value includes an evaporating temperature of the refrigerant in the utilization side heat exchanger (27), and a degree of superheat of the refrigerant at an outlet of the utilization side heat exchanger (27), the objects of control further include the heat source side fan (28), and the control section (40) receives the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, and the high pressure of the refrigeration cycle as inputs, and concurrently controls the compression mechanism (21), the expansion mechanism (24), and the heat source side fan (28), thereby concurrently controlling the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, and the high pressure of the refrigeration cycle.

[0014] With this configuration, in the cooling operation, three objects of control, i.e., the compression mechanism (21), the expansion mechanism (24), and the heat source side fan (28), are concurrently controlled, thereby concurrently controlling the high pressure of the refrigeration cycle, the evaporating temperature of the refrigerant, and the degree of superheat of the refrigerant. Thus, the evaporating temperature and the degree of superheat of the refrigerant can be controlled with the high pressure of the refrigeration cycle stably controlled to a desired target value. This allows for an improved convergence rate of the control of the high pressure of the refrigeration cycle, the evaporating temperature of the refrigerant, and the degree of superheat of the refrigerant.

[0015] In a fourth aspect of the disclosure related to the first or second aspect of the disclosure, in heating operation, the predetermined physical value includes a degree of superheat of the refrigerant at an outlet of the heat source side heat exchanger (23), and the control section (40) receives the degree of superheat of the refrigerant, and the high pressure of the refrigeration cycle as inputs, and concurrently controls the compression mechanism (21) and the expansion mechanism (24), thereby concurrently controlling the degree of superheat of the refrigerant, and the high pressure of the refrigeration cycle.

[0016] With this configuration, in the heating operation, two objects of control, i.e., the compression mechanism (21) and the expansion mechanism (24), are concurrently controlled, thereby concurrently controlling the high pressure of the refrigeration cycle, and the degree of superheat of the refrigerant. Thus, the degree of superheat of the refrigerant can be controlled with the high pressure of the refrigeration cycle stably controlled to a desired target value. This allows for an improved convergence rate of the control of the high pressure of the refrigeration cycle, and the degree of superheat of the refrigerant.

[0017] In a fifth aspect of the disclosure related to the first or second disclosure, the compression mechanism includes a first compressor (21a) for sucking and compressing a low pressure refrigerant, and a second compressor (21b) for further compressing and discharging the refrigerant discharged from the first compressor (21a), the expansion mechanism includes a first expansion mechanism (24) for expanding a high pressure refrigerant, and a second expansion mechanism (26) for further expanding the refrigerant expanded to an intermediate pressure refrigerant by the first expansion mechanism (24). In cooling operation, the predetermined physical value includes an evaporating temperature of the refrigerant in the utilization side heat exchanger (27), a degree of superheat of the refrigerant at an outlet of the utilization side heat exchanger (27), and an intermediate pressure of the refrigeration cycle, and the control section (240) receives the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, the intermediate pressure of the refrigeration cycle, and the high pressure of the refrigeration cycle as inputs, and concurrently controls the first and second compressors (21a, 21b), and the first and second expansion mechanisms (24, 26), thereby concurrently controlling the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, the intermediate pressure of the refrigeration cycle, and the high pressure of the refrigeration cycle.

[0018] With this configuration, in the cooling operation, four objects of control, i.e., the first and second compressors (21a, 21b), and the first and second expansion mechanisms (24, 26), are concurrently controlled, thereby concurrently controlling the high pressure of the refrigeration cycle, the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, and the intermediate pressure. Thus, the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, and the intermediate pressure of the refrigeration cycle can be controlled with the high pressure of the refrigeration cycle stably controlled to a desired target value. This allows for an improved convergence rate of the control of the high pressure of the refrigeration cycle, the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, and the intermediate pressure of the refrigeration cycle.

[0019] In a sixth aspect of the disclosure related to the first or second aspect of the disclosure, the compression mechanism includes a first compressor (21a) for sucking and compressing a low pressure refrigerant, and a second compressor (21b) for further compressing and discharging the refrigerant discharged from the first compressor (21a), the expansion mechanism includes a first expansion mechanism (24) for expanding a high pressure refrigerant, and a second expansion mechanism (26) for further expanding the refrigerant expanded to an intermediate pressure refrigerant in the first expansion mechanism (24). In heating operation, the predetermined physical value includes an evaporating temperature of the refrigerant in the heat source side heat exchanger (23), a degree of superheat of the refrigerant at an outlet of the heat source side heat exchanger (23), and a gas cooler outlet temperature which is a temperature of the refrigerant at an outlet of the utilization side heat exchanger (27), and the control section (240) receives the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, the gas cooler outlet temperature of the refrigerant, and the high pressure of the refrigeration cycle as inputs, and concurrently controls the first and second compressors (21a, 21b), and the first and second expansion mechanisms (24, 26), thereby concurrently controlling the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, the gas cooler outlet temperature of the refrigerant, and the high pressure of the refrigeration cycle.

[0020] With this configuration, in the heating operation, four objects of control, i.e., the first and second compressors (21a, 21b), and the first and second expansion mechanisms (24, 26), are concurrently controlled, thereby concurrently controlling the high pressure of the refrigeration cycle, the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, and the gas cooler outlet temperature. Thus, the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, and the gas cooler outlet temperature can be controlled with the high pressure of the refrigeration cycle stably controlled to a desired target value. This allows for an improved convergence rate of the control of the high pressure of the refrigeration cycle, the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, and the gas cooler outlet temperature.

[0021] In a seventh aspect of the disclosure related to the first or second aspect of the disclosure, a plurality ones of the utilization side heat exchanger (27a, 27b) are connected in parallel with each other, the expansion mechanism includes a plurality of utilization side expansion mechanisms (26a, 26b) each corresponding to the utilization side heat exchangers (27a, 27b), and a heat source side expansion mechanism (24) provided between the utilization side heat exchangers (27a, 27b) and expansion mechanisms (26a, 26b), and the heat source side heat exchanger (23). In cooling operation, the predetermined physical value includes evaporating temperatures of the refrigerant in the utilization side heat exchangers (27a, 27b), and degrees of superheat of the refrigerant at outlets of the utilization side heat exchangers (27a, 27b), and the control section (340) receives the evaporating temperatures of the refrigerant, the degrees of superheat of the refrigerant in the utilization side heat exchangers (27a, 27b), and the high pressure of the refrigeration cycle as inputs, and concurrently controls the compression mechanism (21), the plurality of utilization side heat expansion mechanisms (26a, 26b), and the heat source side expansion mechanism (24), thereby concurrently controlling the evaporating temperatures of the refrigerant, and the degrees of superheat of the refrigerant in the utilization side heat exchangers (27a, 27b), and the high pressure of the refrigeration cycle.

[0022] With this configuration, in the cooling operation, a plurality of objects of control, i.e., the compression mechanism (21), the heat source side expansion mechanism (24), and the plurality of utilization side expansion mechanisms (26a, 26b), are concurrently controlled, thereby concurrently controlling the high pressure of the refrigeration cycle, and the evaporating temperatures of the refrigerant, and the degrees of superheat of the refrigerant at the utilization side heat exchangers (27a, 27b). Thus, the evaporating temperatures of the refrigerant, and the degrees of superheat of the refrigerant at the utilization side heat exchangers (27a, 27b) can be controlled with the high pressure of the refrigeration cycle stably controlled to a desired target value. This allows for an improved convergence rate of the control the high pressure of the refrigeration cycle, the evaporating temperatures of the refrigerant, and the degrees of superheat of the refrigerant at the utilization side heat exchangers (27a, 27b).

[0023] In an eighth aspect of the disclosure related to the first or second aspect of the disclosure, a plurality ones of the utilization side heat exchanger (27a, 27b) are connected in parallel with each other, the expansion mechanism includes a plurality of utilization side expansion mechanisms (26a, 26b) each corresponding to the utilization side heat exchangers (27a, 27b), and a heat source side expansion mechanism (24) provided between the utilization side heat exchangers (27a, 27b) and expansion mechanisms (26a, 26b), and the heat source side heat exchanger (23). In heating operation, the predetermined physical value includes a degree of superheat of the refrigerant at an outlet of the heat source side heat exchanger (23), and gas cooler outlet temperatures of the refrigerant which are temperatures of the refrigerant at outlets of the utilization side heat exchangers (27a, 27b), and the control section (340) receives the degree of superheat of the refrigerant, the gas cooler outlet temperatures of the refrigerant in the utilization side heat exchangers (27a, 27b), and the high pressure of the refrigeration cycle as inputs, and concurrently controls the compression mechanism (21), the plurality of utilization side expansion mechanisms (26a, 26b), and the heat source side expansion mechanism (24), thereby concurrently controlling the degree of superheat of the refrigerant, the gas cooler outlet temperatures of the refrigerant in the utilization side heat exchangers (27a, 27b), and the high pressure of the refrigeration cycle.

[0024] With this configuration, in the heating operation, a plurality of objects of control, i.e., the compression mechanism (21), the heat source side expansion mechanism (24), and the plurality of utilization side expansion mechanisms (26a, 26b), are concurrently controlled, thereby concurrently controlling the high pressure of the refrigeration cycle, the degree of superheat of the refrigerant, and the gas cooler outlet temperatures at the utilization side heat exchangers (27a, 27b). Thus, the degree of superheat of the refrigerant, and the gas cooler outlet temperatures of the refrigerant at the utilization side heat exchangers (27a, 27b) can be controlled with the high pressure of the refrigeration cycle stably controlled to a desired target value. This allows for an improved convergence rate of the control of the high pressure of the refrigeration cycle, the degree of superheat of the refrigerant, and the gas cooler outlet temperatures of the refrigerant at the utilization side heat exchangers (27a, 27b).

ADVANTAGES OF THE DISCLOSURE

[0025] According to the present disclosure, a plurality of objects of control are concurrently controlled, thereby concurrently controlling the predetermined physical value of the refrigeration apparatus, and the high pressure of the refrigeration cycle. Therefore, the predetermined physical value, and the high pressure of the refrigeration cycle can be controlled concurrently while concurrently considering the predetermined physical value and the high pressure of the refrigeration cycle, and considering the effect of the plurality of objects of control on the predetermined physical value and the high pressure of the refrigeration cycle. This allows for an improved convergence rate of the control of the predetermined physical value and the high pressure of the refrigeration apparatus.

[0026] According to the second aspect of the disclosure, the control signals for controlling the plurality of objects of control, respectively, are generated by associating the input predetermined physical value and high pressure of the refrigeration cycle with each other. Therefore, a control signal for one of the objects of control can be generated in concurrent consideration of the predetermined physical value and the high pressure, and in consideration of the effect of adjustment of the other objects of control on the predetermined physical value and the high pressure. This allows for an improved convergence rate of the control of the predetermined physical value and the high pressure of the refrigeration apparatus.

[0027] According to the third aspect of the disclosure, three objects of control, i.e., the compression mechanism (21), the expansion mechanism (24), and the heat source side fan (28), are concurrently controlled in the cooling operation, thereby concurrently controlling the high pressure of the refrigeration cycle, the evaporating temperature of the refrigerant, and the degree of superheat of the refrigerant. This allows for an improved convergence rate of the control of the high pressure of the refrigeration cycle, the evaporating temperature of the refrigerant, and the degree of superheat of the refrigerant.

[0028] According to the fourth aspect of the disclosure, two objects of control, i.e., the compression mechanism (21) and the expansion mechanism (24), are concurrently controlled in the heating operation, thereby concurrently controlling the high pressure of the refrigeration cycle, and the degree of superheat of the refrigerant. This allows for an improved convergence rate of the control of the high pressure of the refrigeration cycle, and the degree of superheat of the refrigerant.

[0029] According to the fifth aspect of the disclosure, four objects of control, i.e., the first and second compressors (21a, 2 1 b), and the first and second expansion mechanisms (24, 26), are concurrently controlled in the cooling operation in the refrigeration apparatus for performing a two-stage compression refrigeration cycle, thereby concurrently controlling the high pressure of the refrigeration cycle, the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, and the intermediate pressure of the refrigeration cycle. This allows for an improved convergence rate of the control of the high pressure of the refrigeration cycle, the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, and the intermediate pressure of the refrigeration cycle.

[0030] According to the sixth aspect of the disclosure, four objects of control, i.e., the first and second compressors (21a, 21b), and the first and second expansion mechanisms (24, 26), are concurrently controlled in the heating operation in the refrigeration apparatus for performing the two-stage compression refrigeration cycle, thereby concurrently controlling the high pressure of the refrigeration cycle, the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, and the gas cooler outlet temperature. This allows for an improved convergence rate of the control of the high pressure of the refrigeration cycle, the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, and the gas cooler outlet temperature.

[0031] According to the seventh aspect of the disclosure, a plurality of objects of control, i.e., the compression mechanism (21), the heat source side expansion mechanism (24), and a plurality of utilization side expansion mechanisms (26a, 26b), are concurrently controlled in the cooling operation of a so-called multi-type refrigeration apparatus including a plurality of indoor units, thereby concurrently controlling the high pressure of the refrigeration cycle, the evaporating temperature of the refrigerant, and the degrees of superheat at the heat utilization side heat exchangers (27a, 27b). This allows for an improved convergence rate of the control of the high pressure of the refrigeration cycle, the evaporating temperature of the refrigerant, and the degrees of superheat in the utilization side heat exchangers (27a, 27b).

[0032] According to the eighth aspect of the disclosure, a plurality of objects of control, i.e., the compression mechanism (21), the heat source side expansion mechanism (24), and a plurality of utilization side expansion mechanisms (26a, 26b), are concurrently controlled in the heating operation in the so-called multi-type refrigeration apparatus including a plurality of indoor units, thereby concurrently controlling the high pressure of the refrigeration cycle, the degree of superheat of the refrigerant, and the gas cooler outlet temperatures of the refrigerant at the utilization side heat exchangers (27a, 27b). This allows for an improved convergence rate of the control of the high pressure of the refrigeration cycle, the degree of superheat of the refrigerant, and the gas cooler outlet temperatures of the refrigerant in the utilization side heat exchangers (27a, 27b).

BRIEF DESCRIPTION OF THE DRAWINGS

[0033]

[FIG. 1] FIG. 1 is a piping diagram illustrating the structure of an air conditioner of a first embodiment.
[FIG. 2] FIG. 2 is a control block diagram of a controller in cooling operation.
[FIG. 3] FIG. 3 is a control block diagram of the controller in heating operation.
[FIG. 4] FIG. 4 is a piping diagram illustrating the structure of an air conditioner of a second embodiment.
[FIG. 5] FIG. 5 is a control block diagram of a controller in cooling operation.
[FIG. 6] FIG. 6 is a control block diagram of the controller in heating operation.
[FIG. 7] FIG. 7 is a piping diagram illustrating the structure of an air conditioner of a third embodiment.
[FIG. 8] FIG. 8 is a control block diagram of a controller in cooling operation.
[FIG. 9] FIG. 9 is a control block diagram of the controller in heating operation.
[FIG. 10] FIG. 10 is a piping diagram illustrating the structure of an air conditioner of another embodiment.
[FIG. 11] FIG. 11 is a piping diagram illustrating the structure of an air conditioner of still another embodiment.

DESCRIPTION OF EMBODIMENTS

[0034] Embodiments of the present disclosure will be described in detail with reference to the drawings.

[First Embodiment]

[0035] A first embodiment of the present disclosure will be described in detail with reference to the drawings.

[0036] As shown in FIG. 1, an air conditioner (10) of the present embodiment includes a refrigerant circuit (20), and a controller (40).

[0037] The refrigerant circuit (20) is a closed circuit filled with carbon dioxide (CO_2) as a refrigerant. The refrigerant circuit (20) is configured to perform a vapor compression refrigeration cycle by circulating the refrigerant. Further, the refrigerant circuit (20) is configured to perform a supercritical refrigeration cycle in which a high pressure is equal to or higher than a supercritical pressure of carbon dioxide (i.e., a refrigeration cycle in which a vapor pressure is equal to or higher than a supercritical temperature of carbon dioxide).

[0038] The refrigerant circuit (20) connects a compressor (21), a four way switching valve (22), an outdoor heat exchanger (23), an outdoor expansion valve (24), and an indoor heat exchanger (27).

[0039] Specifically, in the refrigerant circuit (20), a discharge side of the compressor (21) is connected to a first port of the four way switching valve (22), and a suction side of the compressor (21) is connected to a second port of the four way switching valve (22). In the refrigerant circuit (20), the outdoor heat exchanger (23), the outdoor expansion valve (24), and the indoor heat exchanger (27) are sequentially arranged in a path from a third port to a fourth port of the four way switching valve (22).

[0040] The compressor (21) is configured as a fully sealed variable capacity compressor. The compressor (21) sucks and compresses the refrigerant (carbon dioxide) to a supercritical pressure or higher, and then discharges the compressed refrigerant. Changing a frequency of AC fed to a motor (not shown) of the compressor (21) changes a rotation speed, i.e., a capacity, of the compressor (21). The compressor (21) constitutes a compression mechanism.

[0041] In the outdoor heat exchanger (23), outdoor air sucked by an outdoor fan (28) exchanges heat with the refrigerant. In the indoor heat exchanger (27), indoor air sucked by an indoor fan (29) exchanges heat with the refrigerant. The outdoor heat exchanger (23) constitutes a heat source side heat exchanger, and the indoor heat exchanger (27) constitutes a utilization side heat exchanger. The outdoor fan (28) constitutes a heat source side fan.

[0042] The outdoor expansion valve (24) is comprised of an electronic expansion valve whose degree of opening is variable, and whose valve element (not shown) is driven by a pulse motor (not shown). The outdoor expansion valve (24) constitutes an expansion mechanism.

[0043] The four way switching valve (22) is switchable between a first state where the first and third ports communicate with each other, and the second and fourth ports communicate with each other (a state indicated by a solid line in FIG. 1), and a second state where the first and fourth ports communicate with each other, and the second and third ports communicate with each other (a state indicated by a broken line in FIG. 1).

[0044] Thus, the air conditioner (10) is able to switchably perform cooling operation and heating operation by switching the four way switching valve (22).

[0045] In the cooling operation, the four way switching valve (22) is set to the first state. When the compressor (21) is operated in this state, the outdoor heat exchanger (23) functions as a radiator (a gas cooler), and the indoor heat exchanger (27) functions as an evaporator to perform the refrigeration cycle. Specifically, the refrigerant in the supercritical state discharged from the compressor (21) flows into the outdoor heat exchanger (23), and dissipates heat to the outdoor air. After the heat dissipation, the refrigerant expands (decreases in pressure) as it passes through the outdoor expansion valve (24), and then flows into the indoor heat exchanger (27). The refrigerant in the indoor heat exchanger (27) absorbs heat from the indoor air to evaporate, and the cooled indoor air is fed to the inside of the room. The evaporated refrigerant is sucked into and compressed in the compressor (21).

[0046] In the heating operation, the four way switching valve (22) is set to the second state. When the compressor (21) is operated in this state, the indoor heat exchanger (27) functions as a radiator (a gas cooler), and the outdoor heat exchanger (23) functions as an evaporator to perform the refrigeration cycle. Specifically, the refrigerant in the supercritical state discharged from the compressor (21) flows into the indoor heat exchanger (27), and dissipates heat to the indoor air. The heated indoor air is fed to the inside of the room. After the heat dissipation, the refrigerant expands (decreases in pressure) as it passes through the outdoor expansion valve (24). The refrigerant expanded by the outdoor expansion valve (24) flows into the outdoor heat exchanger (23), and absorbs heat from the outdoor air to evaporate. The evaporated refrigerant is sucked into and compressed in the compressor (21).

[0047] In the air conditioner (10) configured in this manner, the refrigerant circuit (20) includes an outdoor temperature sensor (30), an indoor temperature sensor (31), a low pressure sensor (32), a discharge temperature sensor (33), a high pressure sensor (34), a gas cooler outlet temperature sensor (37) for the heating operation, and a gas cooler outlet temperature sensor (39) for the cooling operation.

[0048] The outdoor temperature sensor (30) is a temperature sensing part for sensing the temperature of the outdoor air entering the outdoor heat exchanger (23). The indoor temperature sensor (31) is a temperature sensing part for sensing the temperature of the indoor air entering the indoor heat exchanger (27). The low pressure sensor (32) is a pressure sensing part for sensing the pressure of the refrigerant sucked into the compressor (21), i.e., the low pressure of the refrigeration cycle in the refrigerant circuit (20). The discharge temperature sensor (33) is a temperature sensing part for sensing the temperature of the refrigerant discharged from the compressor (21). The high pressure sensor (34) is a pressure sensing part for sensing the pressure of the refrigerant discharged from the compressor (21), i.e., the high pressure of the refrigeration cycle in the refrigerant circuit (20). The gas cooler outlet temperature sensor (37) for the heating operation is a temperature sensing part for sensing the temperature of the refrigerant at an outlet of the indoor heat exchanger (27) when the refrigerant circulates in the refrigerant circuit (20) in a heating cycle. The gas cooler outlet temperature sensor (39) for the cooling operation is a temperature sensing part for sensing the temperature of the refrigerant at an outlet of the outdoor heat exchanger (23) when the refrigerant circulates in the refrigerant circuit (20) in a cooling cycle.

[0049] The controller (40) is configured to receive output signals from the indoor temperature sensor (31), the low pressure sensor (32), the discharge temperature sensor (33), and the high pressure sensor (34), and to control an operation frequency of the compressor (21), the degree of opening of the outdoor expansion valve (24), and an operation frequency of the outdoor fan (28). The controller (40) functions as a control section.

[0050] The controller (40) includes, as shown in FIGS. 2 and 3, a target low pressure calculator (41) for calculating a target low pressure Pls which is a target value of the low pressure of the refrigeration cycle, a target high pressure calculator (42) for calculating a target high pressure Phs which is a target value of the high pressure of the refrigeration cycle, a target discharge temperature calculator (43) for calculating a target discharge temperature T1s which is a target value of the discharge temperature of the refrigerant, and a control signal generator (49) for generating control signals transmitted to the compressor (21), the outdoor expansion valve (24), and the outdoor fan (28). The controller (40) performs the control in different ways for the cooling operation and the heating operation. That is, components operated in the cooling operation are different from those operated in the heating operation. Therefore, a control block for the cooling operation is shown in FIG. 2, and a control block for the heating operation is shown in FIG. 3.

[0051] The target low pressure calculator (41) calculates the target low pressure Pls based on a temperature deviation et between a set temperature Ts and the output signal from the indoor temperature sensor (31) (i.e., an indoor temperature Ta).

[0052] In the cooling operation, the target high pressure calculator (42) calculates the target high pressure Phs based on the output signal from the outdoor temperature sensor (30) (i.e., an outdoor temperature T0), and the output signal from the gas cooler outlet temperature sensor (39) for the cooling operation (i.e., a gas cooler outlet temperature T4). In the heating operation, the target high pressure calculator (42) calculates the target high pressure Phs based on the temperature deviation et, and the output signal from the gas cooler outlet temperature sensor (37) for the heating operation (i.e., the gas cooler outlet temperature T4).

[0053] The target discharge temperature calculator (43) calculates the target discharge temperature T1s based on the temperature deviation et, the output signal from the low pressure sensor (32) (i.e., an actual low pressure Pl), the output signal from the high pressure sensor (34) (i.e., an actual high pressure Ph), an operation frequency fc of the compressor (21), and the outdoor temperature T0. More specifically, the target discharge temperature calculator (43) calculates the target discharge temperature T1s corresponding to a target degree of superheat based on the temperature deviation et, the actual low pressure Pl, the actual high pressure Ph, the operation frequency fc of the compressor (21), and the outdoor temperature T0.

[0054] The target low pressure calculator (41), the target high pressure calculator (42), and the target discharge temperature calculator (43) have maps and functions, respectively. Each of the calculators is configured to deliver an output value (a target value) corresponding to the input.

[0055] Signals input to the control signal generator (49) in the cooling operation are different from those input to the control signal generator (49) in the heating operation. The control signal generator (49) has a plurality of PID control sections (p1a, p2a, ..., p2b, p2b, ...) each having a control parameter corresponding to the input signal.

[0056] In the cooling operation, the control signal generator (49) receives a low pressure deviation e1 between the target low pressure Pls calculated by the target low pressure calculator (41) and the actual low pressure Pl from the low pressure sensor (32), a high pressure deviation e2 between the target high pressure Phs calculated by the target high pressure calculator (42) and the actual high pressure Ph from the high pressure sensor (34), and a discharge temperature deviation e3 between the target discharge temperature T1s calculated by the target discharge temperature calculator (43) and the output signal from the discharge temperature sensor (33) (i.e., an actual discharge temperature T1).

[0057] Nine PID control sections (p1a, p2a, ...) of the control signal generator (49) are operated in the cooling operation. Specifically, the low pressure deviation e1 input to the control signal generator (49) is input to the first to third PID control sections (p1a, p2a, p3a), the high pressure deviation e2 is input to the fourth to sixth PID control sections (p4a, p5a, p6a), and the discharge temperature deviation e3 are input to the seventh to ninth PID control sections (p7a, p8a, p9a).

[0058] Each of the first to ninth PID control sections (p1a, p2a, ...) delivers an output generated by multiplying the input deviation by a predetermined control parameter. As a result, the control signal generator (49) generates a compressor frequency control signal Δfc by adding the output signals from the first, fourth, and seventh PID control sections (p1a, p4a, p7a), generates an expansion valve control signal Δev by adding the output signals from the second, fifth, and eighth PID control sections (p2a, p5a, p8a), and generates a fan frequency control signal Δff by adding the output signals from the third, sixth, and ninth PID control sections (p3a, p6a, p9a).

[0059] The compressor frequency control signal Δfc, the expansion valve control signal Δev, and the fan frequency control signal Δff generated in this manner are output to the air conditioner (10).

[0060] In the air conditioner (10), a frequency of AC fed to the motor of the compressor (21) (i.e., the operation frequency) is set to a value corresponding to the compressor frequency control signal Δfc, thereby changing the rotation speed of the compressor (21). Thus, the capacity of the compressor (21) varies according to the compressor frequency control signal Δfc.

[0061] A pulse number of the signal fed to the pulse motor of the outdoor expansion valve (24) is set to a value corresponding to the expansion valve control signal Δev. Thus, the pulse motor of the outdoor expansion valve (24) rotates by an angle corresponding to the pulse number, thereby adjusting the degree of opening of the valve according to the expansion valve control signal Δev.

[0062] Further, a frequency of AC fed to the motor of the outdoor fan (28) (i.e., the operation frequency) is set to a value corresponding to the fan frequency control signal Δff, thereby changing the rotation speed of the outdoor fan (28). Thus, a flow rate of air fed from the outdoor fan (28) to the outdoor heat exchanger (23) varies according to the fan frequency control signal Δff.

[0063] The low pressure P1, the discharge temperature T1, and the high pressure Ph of the air conditioner (10) operated in this operation state are fed back to the controller (40) through the low pressure sensor (32), the discharge temperature sensor (33), and the high pressure sensor (34). In this way, the controller (40) performs feed back control to set the low pressure Pl (and an evaporating temperature), the discharge temperature T1 (and the degree of superheat), and the high pressure Ph to the target values corresponding to the operation state, respectively.

[0064] As described above, each of the compressor frequency control signal Δfc, the expansion valve control signal Δev, and the fan frequency control signal Δff is generated by associating the low pressure deviation e1, the high pressure deviation e2, and the discharge temperature deviation e3 with each other. Specifically, for example, unlike a refrigeration apparatus in which the low pressure of the refrigeration cycle is controlled by the compressor (21), the discharge temperature of the refrigerant is controlled by the outdoor expansion valve (24), and the high pressure of the refrigeration cycle is controlled by the outdoor fan (28), objects of the control corresponding to the physical values, respectively, are not controlled independently. Instead of this, the compressor (21), the outdoor expansion valve (24), and the outdoor fan (28) are concurrently controlled, thereby concurrently, or simultaneously controlling the high pressure, the low pressure, and the discharge temperature. Specifically, each of the low pressure, the high pressure, and the discharge temperature is not controlled only by one of the compressor (21), the outdoor expansion valve (24), and the outdoor fan (28), but is controlled by all the compressor (21), the outdoor expansion valve (24), and the outdoor fan (28). More specifically, each of the objects of the control, i.e., the compressor (21), the outdoor expansion valve (24), and the outdoor fan (28), is controlled not only based on the changes of the low pressure, the high pressure, and the discharge temperature resulting from the control solely of the each of the objects of control, but is controlled based on the changes of the low pressure, the high pressure, and the discharge temperature resulting from the control of the other objects of control (in other words, the control parameters of the first to nine PID control sections (p1a, p2a, ...) are determined so as to take these changes into account).

[0065] In the heating operation, the control signal generator (49) receives the high pressure deviation e2 between the target high pressure Phs calculated by the target high pressure calculator (42) and the actual high pressure Ph from the high pressure sensor (34), and the discharge temperature deviation e3 between the target discharge temperature T1s calculated by the target discharge temperature calculator (43) and the actual discharge temperature T1 of the discharge temperature sensor (33).

[0066] In the heating operation, four PID control sections (p1b, p2b, ...) of the control signal generator (49) are operated. Specifically, the discharge temperature deviation e3 input to the control signal generator (49) is input to the first and second PID control sections (p1b, p2b), and the high pressure deviation e2 is input to the third and fourth PID control sections (p3b, p4b).

[0067] Each of the first to fourth PID control sections (p1b, p2b, ...) delivers an output generated by multiplying the input deviation by a predetermined control parameter. As a result, the control signal generator (49) generates the compressor frequency control signal Δfc by adding the output signals from the first and third PID control sections (p1b, p3b), and generates the expansion valve control signal Δev by adding the output signals from the second and fourth PID control sections (p2b, p4b).

[0068] The compressor frequency control signal Δfc and the expansion valve control signal Δev generated in this manner are output to the air conditioner (10).

[0069] In the air conditioner (10), the capacity of the compressor (21) varies according to the compressor frequency control signal Δfc, and the degree of opening of the outdoor expansion valve (24) is adjusted according to the expansion valve control signal Δev.

[0070] The discharge temperature T1 and the high pressure Ph of the air conditioner (10) operated in this operation state are fed back to the controller (40) through the discharge temperature sensor (33) and the high pressure sensor (34). In this way, the controller (40) performs feed back control to set the discharge temperature T1 (and the degree of superheat), and the high pressure Ph to target values corresponding to the operation state, respectively.

[0071] As described above, each of the compressor frequency control signal Δfc and the expansion valve control signal Δev are generated by associating the high pressure deviation e2 and the discharge temperature deviation e3 with each other. Specifically, for example, unlike a refrigeration apparatus in which the high pressure of the refrigeration cycle is controlled by the compressor (21), and the discharge temperature of the refrigerant is controlled by the outdoor expansion valve (24), the objects of control corresponding to the physical values, respectively, are not controlled independently. Instead of this, the compressor (21) and the outdoor expansion valve (24) are concurrently controlled, thereby concurrently, or simultaneously controlling the high pressure and the discharge temperature. Specifically, each of the high pressure and the discharge temperature is not controlled by only one of the compressor (21) and the outdoor expansion valve (24), but is controlled by both of the compressor (21) and the outdoor expansion valve (24). More specifically, each of the objects of control, i.e., the compressor (21) and the outdoor expansion valve (24), is controlled not only based on the changes of the high pressure and the discharge temperature resulting solely from the control of the each of the objects of control, but is controlled based on the changes of the high pressure and the discharge temperature resulting from the control of the other objects of control (in other words, the control parameters of the first to fourth PID control sections (p1b, p2b, ...) are determined so as to take these changes into account).

[0072] Thus, according to the first embodiment, the plurality of objects of control (e.g., the compressor (21), the outdoor expansion valve (24), etc.) are simultaneously controlled in such a manner that the high pressure of the refrigeration cycle, and the predetermined physical value of the air conditioner (10) are adjusted to the predetermined target values corresponding to the operation state. At the same time, each of the objects of control is controlled in consideration of the changes of the physical value and the high pressure of the refrigeration cycle resulting from the control of the plurality of objects of control. According to these schemes, the capability of the air conditioner (10) (e.g., the low pressure, the degree of superheat, etc., in the cooling operation) can be controlled with the high pressure stably kept to the target value corresponding to the operation state. This can avoid an event in which the control of a target physical value cannot be easily settled, i.e., an event in which adjustment of a first physical value changes a second physical value, and correction of the change of the second physical value by adjusting the second physical value changes a third physical value or the first physical value already adjusted, thereby involving another adjustment. This allows for an improved convergence rate of the control of the capability and the high pressure of the air conditioner (10).

[0073] According to the present embodiment, three physical values, i.e., the low pressure, the high pressure, and the discharge temperature, are controlled by three objects of control, i.e., the compressor (21), the outdoor expansion valve (24), and the outdoor fan (28), in the cooling operation. In the heating operation, two physical values, i.e., the high pressure and the discharge temperature, are controlled by two objects of control, i.e., the compressor (21) and the outdoor expansion valve (24). However, some of the objects of control easily have an effect on the physical values, but some do not. That is, even when one of the objects of control is changed, some physical values are less susceptible to the change. In the present embodiment, all the physical values to be controlled are input, and they are associated with each other to generate control signals each corresponding to the objects of control. Instead of this, in generating a control signal for one of the objects of control to which a certain physical value is less susceptible, the degree of association of the certain physical value may be reduced or eliminated (specifically, among the PID control sections (p1a, ..., p1b, ...) for generating the control signal for the object of control to which a certain physical value is less susceptible, a control parameter of one of the PID control sections corresponding to the certain physical value may be reduced or reduced to zero.)

[Second Embodiment]

[0074] A second embodiment of the present disclosure will be described below.

[0075] An air conditioner (210) of the second embodiment is different from the air conditioner (10) of the first embodiment in that two expansion valves (24, 26) are provided between an outdoor heat exchanger (23) and an indoor heat exchanger (27) of a refrigerant circuit (220), and that two compressors (21a, 21b) are provided to perform a two-stage compression refrigeration cycle.

[0076] Specifically, as shown in FIG. 4, the air conditioner (210) includes a refrigerant circuit (220), and a controller (240).

[0077] The refrigerant circuit (220) connects a low pressure first compressor (21a), a high pressure second compressor (21b), a four way switching valve (22), an outdoor heat exchanger (23), an outdoor expansion valve (24), a gas-liquid separator (25), an indoor expansion valve (26), and an indoor heat exchanger (27).

[0078] Specifically, in the refrigerant circuit (220), a discharge side of the second compressor (21b) is connected to a first port of the four way switching valve (22), and a suction side of the first compressor (21a) is connected to a second port of the four way switching valve (22). The first compressor (21a) and the second compressor (21b) are connected through a pipe in such a manner that the refrigerant compressed in and discharged from the first compressor (21a) is sucked into the second compressor (21b) for further compression. In the refrigerant circuit (220), the outdoor heat exchanger (23), the outdoor expansion valve (24), the gas-liquid separator (25), the indoor expansion valve (26), and the indoor heat exchanger (27) are sequentially arranged in a path from a third port to a fourth port of the four way switching valve (22). The gas-liquid separator (25) is connected to the pipe connecting the first compressor (21a) and the second compressor (21b) through a first intermediate pressure refrigerant pipe (25a).

[0079] The first and second compressors (21a, 21b) are the same as the compressor of the first embodiment. The first and second compressors (21a, 21b) constitute a compression mechanism.

[0080] Each of the outdoor expansion valve (24) and the indoor expansion valve (26) is comprised of an electronic expansion valve whose degree of opening is variable, and whose valve element (not shown) is driven by a pulse motor (not shown). The outdoor expansion valve (24) constitutes a first expansion mechanism, and the indoor expansion valve (26) constitutes a second expansion mechanism.

[0081] The gas-liquid separator (25) is a longitudinal, cylindrical hermetic container. The gas-liquid separator (25) is connected to the outdoor expansion valve (24) and the indoor expansion valve (26) through a bridge circuit (50).

[0082] Specifically, the outdoor expansion valve (24) is connected to one of terminals of the bridge circuit (50) through a second intermediate pressure refrigerant pipe (25b). The indoor expansion valve (26) is connected to a second terminal of the bridge circuit (50) through a third intermediate pressure refrigerant pipe (25c). An end of a refrigerant inlet pipe (25d) is connected to a third terminal of the bridge circuit (50), and the other end of the refrigerant inlet pipe (25d) is connected to the gas-liquid separator (25). The other end of the refrigerant inlet pipe (25d) penetrates an upper surface of the hermetic container serving as the gas-liquid separator (25), and is positioned in an upper portion of space inside the container. An end of a refrigerant outlet pipe (25e) is connected to a fourth terminal of the bridge circuit (50), and the other end of the refrigerant outlet pipe (25e) is connected to the gas-liquid separator (25). The other end of the refrigerant outlet pipe (25e) penetrates the upper surface of the hermetic container of the gas-liquid separator (25), and is positioned in a lower portion of the space inside the container.

[0083] An end of the first intermediate pressure refrigerant pipe (25a) close to the gas-liquid separator (25) penetrates the upper surface of the hermetic container of the gas-liquid separator (25), and is positioned in the upper portion of the space inside the container.

[0084] Like the air conditioner of the first embodiment, the air conditioner (210) is able to switchably perform cooling operation and heating operation by switching the four way switching valve (22).

[0085] In the cooling operation, the four way switching valve (22) is set to the first state. When the first and second compressors (21a, 21b) are driven in this state, the outdoor heat exchanger (23) functions as a radiator (a gas cooler), and the indoor heat exchanger (27) functions as an evaporator to perform the refrigeration cycle. Specifically, an intermediate pressure refrigerant discharged from the first compressor (21a) is compressed in the second compressor (21b) to the supercritical state. The supercritical refrigerant flows into the outdoor heat exchanger (23), and dissipates heat to the outdoor air. After the heat dissipation, the high pressure refrigerant decreases in pressure in the outdoor expansion valve (24) to become a gas-liquid two phase intermediate pressure refrigerant, and flows into the gas-liquid separator (25) through the second intermediate pressure refrigerant pipe (25b), the bridge circuit (50), and the refrigerant inlet pipe (25d). The intermediate pressure refrigerant entered the gas-liquid separator (25) is separated to a liquid refrigerant and a gaseous refrigerant. The intermediate pressure gaseous refrigerant flows from the upper portion in the space inside the gas-liquid separator (25) to the suction side of the second compressor (21b) through the first intermediate pressure refrigerant pipe (25a), merges with the intermediate pressure gaseous refrigerant discharged from the first compressor (21a), and is sucked into the second compressor (21b). The intermediate pressure liquid refrigerant is temporarily stored in the lower portion of the space inside the gas-liquid separator (25), and then exits from the lower portion of the space to pass through the refrigerant outlet pipe (25e), the bridge circuit (50), and the third intermediate pressure refrigerant pipe (25c). Then, the intermediate pressure liquid refrigerant expands (decreases in pressure) in the indoor expansion valve (26) to become a gas-liquid two phase low pressure refrigerant, and flows into the indoor heat exchanger (27). In the indoor heat exchanger (27), the refrigerant absorbs heat from the indoor air to evaporate, and the cooled indoor air is fed to the inside of the room. The evaporated refrigerant is sucked into and compressed in the first compressor (21a).

[0086] In the heating operation, the four way switching valve (22) is set to the second state. When the first and second compressors (21a, 21b) are operated in this state, the indoor heat exchanger (27) functions as a radiator (a gas cooler), and the outdoor heat exchanger (23) functions as an evaporator to perform the refrigeration cycle. Specifically, an intermediate pressure gaseous refrigerant discharged from the first compressor (21a) is compressed in the second compressor (21b) to the supercritical state. The supercritical refrigerant flows into the indoor heat exchanger (27), and dissipates heat to the indoor air. The heated indoor air is fed to the inside of the room. After the heat dissipation, the refrigerant decreases in pressure in the indoor expansion valve (26) to become a gas-liquid two phase intermediate pressure refrigerant, and flows into the gas-liquid separator (25) through the third intermediate pressure refrigerant pipe (25c), the bridge circuit (50), and the refrigerant inlet pipe (25d). The intermediate pressure refrigerant entered the gas-liquid separator (25) is separated into a liquid refrigerant and a gaseous refrigerant. The intermediate pressure gaseous refrigerant flows from the upper portion of the space inside the gas-liquid separator (25) to the suction side of the second compressor (21b) through the first intermediate pressure refrigerant pipe (25a), merges with the intermediate pressure gaseous refrigerant discharged from the first compressor (21a), and is sucked into the second compressor (21b). The intermediate pressure liquid refrigerant is temporarily stored in the lower portion of the space inside the gas-liquid separator (25), and then flows from the lower portion of the space to the outdoor expansion valve (24) through the refrigerant outlet pipe (25e), the bridge circuit (50), and the second intermediate pressure refrigerant pipe (25b). The intermediate pressure liquid refrigerant expands (decreases in pressure) as it passes through the outdoor expansion valve (24) to become a gas-liquid two phase low pressure refrigerant, and flows into the outdoor heat exchanger (23). In the outdoor heat exchanger (23), the refrigerant absorbs heat from the outdoor air to evaporate. The evaporated refrigerant is sucked into and compressed in the first compressor (2 1 a).

[0087] The air conditioner (210) configured in this manner includes, in the refrigerant circuit (220), an indoor temperature sensor (31), a low pressure sensor (32), a discharge temperature sensor (33), a high pressure sensor (34), a suction temperature sensor (35), an intermediate pressure saturation temperature sensor (36), a gas cooler outlet temperature sensor (37) for the heating operation.

[0088] The indoor temperature sensor (31) is a temperature sensing part for sensing the temperature of the indoor air entering the indoor heat exchanger (27). The low pressure sensor (32) is a pressure sensing part for sensing the pressure of the refrigerant sucked into the first compressor (21a), i.e., the low pressure of the refrigeration cycle in the refrigerant circuit (220). The discharge temperature sensor (33) is a temperature sensing part for sensing the temperature of the refrigerant discharged from the second compressor (21b). The high pressure sensor (34) is a pressure sensing part for sensing the pressure of the refrigerant discharged from the second compressor (21b), i.e., the high pressure of the refrigeration cycle in the refrigerant circuit (220). The suction temperature sensor (35) is a temperature sensing part for sensing the temperature of the refrigerant sucked into the first compressor (21a). The intermediate pressure saturation temperature sensor (36) is arranged in the refrigerant outlet pipe (25e) connecting the bridge circuit (50) and the gas-liquid separator (25), and functions as a temperature sensing part for sensing the temperature of the intermediate pressure refrigerant, i.e., the intermediate pressure saturation temperature of the refrigeration cycle. The gas cooler outlet temperature sensor (37) for the heating operation is a temperature sensing part for sensing the temperature of the refrigerant at an outlet of the indoor heat exchanger (27) when the refrigerant circulates in the refrigerant circuit (220) in a heating cycle.

[0089] The controller (240) is configured to receive output signals from the indoor temperature sensor (31), the low pressure sensor (32), the high pressure sensor (34), the suction temperature sensor (35), the intermediate pressure saturation temperature sensor (36), and the gas cooler outlet temperature sensor (37) for the heating operation, and to control the operation frequencies of the first and second compressors (21a, 21b), and the degrees of opening of the outdoor and indoor expansion valves (24, 26).

[0090] The controller (240) includes, as shown in FIGS. 5 and 6, a target low pressure calculator (41) for calculating a target low pressure Pls which is a target value of the low pressure of the refrigeration cycle, a target high pressure calculator (42) for calculating a target high pressure Phs which is a target value of the high pressure of the refrigeration cycle, a target superheat degree calculator (44) for calculating the target degree of superheat SHs of the refrigerant which is a target value of the degree of superheat of the refrigerant, an actual superheat degree calculator (45) for calculating the actual degree of superheat SH of the refrigerant, a target intermediate pressure saturation temperature calculator (46) for calculating a target intermediate pressure saturation temperature T3s which is a target value of the intermediate pressure saturation temperature of the refrigerant, a target gas cooler outlet temperature calculator (47) for calculating a target gas cooler outlet temperature T4s which is a target value of the temperature of the refrigerant at an outlet of the gas cooler in the heating operation, and a control signal generator (249) for generating control signals transmitted to the first and second compressors (21a, 21b), and the outdoor and indoor expansion valves (24, 26). The controller (240) performs the control in different ways for the cooling operation and the heating operation. Therefore, a control block for the cooling operation is shown in FIG. 5, and a control block for the heating operation is shown in FIG. 6.

[0091] In the cooling operation, the target superheat degree calculator (44) calculates the target degree of superheat SHs of one of the outdoor heat exchanger (23) and the indoor heat exchanger (27) functioning as an evaporator based on a temperature deviation et between a set temperature Ts and an indoor temperature Ta from the indoor temperature sensor (31). In the heating operation, the target superheat degree calculator (44) calculates the target degree of superheat SHs based on the temperature deviation et and an outdoor temperature T0 from the outdoor temperature sensor (30).

[0092] The actual superheat degree calculator (45) calculates the actual degree of superheat SH of the refrigerant at an outlet of a heat exchanger functioning as an evaporator of the outdoor heat exchanger (23) and the indoor heat exchanger (27) based on an actual low pressure Pl from the low pressure sensor (32) and an actual suction temperature T2 from the suction temperature sensor (35).

[0093] The target intermediate pressure saturation temperature calculator (46) calculates the target intermediate pressure saturation temperature T3s based on at least one of the outdoor temperature T0 from the outdoor temperature sensor (30), the indoor temperature Ta from the indoor temperature sensor (31), an actual high pressure Ph from the high pressure sensor (34), the actual low pressure Pl from the low pressure sensor (32), the target high pressure Phs calculated by the target high pressure calculator (42), and the target low pressure Pls calculated by the target low pressure calculator (41).

[0094] The target gas cooler outlet temperature calculator (47) calculates the target gas cooler outlet temperature T4s, which is a target value of the temperature of the refrigerant at the outlet of the indoor heat exchanger (27) when the indoor heat exchanger (27) functions as a radiator, based on the temperature deviation et.

[0095] The target superheat degree calculator (44), the actual superheat degree calculator (45), and the target intermediate pressure saturation temperature calculator (46) have maps and functions, respectively. Each of them is configured to deliver an output value (a target value) corresponding to the input.

[0096] Signals input to the control signal generator (249) in the cooling operation are different from those input to the control signal generator (249) in the heating operation. The control signal generator (249) has a plurality of PID control sections (p1a, p2a, ..., p1b, p2b, ...) each having a control parameter corresponding to the input signal.

[0097] In the cooling operation, the control signal generator (49) receives a low pressure deviation e1 between the target low pressure Pls calculated by the target low pressure calculator (41) and the actual low pressure Pl from the low pressure sensor (32), a high pressure deviation e2 between the target high pressure Phs calculated by the target high pressure calculator (42) and the actual high pressure Ph from the high pressure sensor (34), a superheat degree deviation e4 between the target degree of superheat SHs calculated by the target superheat degree calculator (44) and the actual degree of superheat SH calculated by the actual superheat degree calculator (45), and an intermediate pressure saturation temperature deviation e5 between the target intermediate pressure saturation temperature T3s calculated by the target intermediate pressure saturation temperature calculator (46) and the output signal from the intermediate pressure saturation temperature sensor (36) (i.e., an actual intermediate pressure saturation temperature T3).

[0098] In the cooling operation, sixteen PID control sections (p1c, p2c, ...) of the control signal generator (249) are operated. Specifically, the high pressure deviation e2 input to the control signal generator (249) is input to the first to fourth PID control sections (p 1 c-p4c), the intermediate pressure saturation temperature deviation e5 is input to the fifth to eighth PID control sections (p5c-p8c), the low pressure deviation e1 is input to the ninth to twelfth PID control sections (p9c-p12c), and the superheat degree deviation e4 is input to the thirteenth to sixteenth PID control sections (p13c-p16c).

[0099] Each of the first to sixteenth PID control sections (p1c, p2c, ...) delivers an output generated by multiplying the input deviation by a predetermined control parameter. As a result, the control signal generator (249) generates a first compressor frequency control signal Δfc1 by adding the output signals from the first, fifth, ninth, and thirteenth PID control sections (p1c, p5c, p9c, p13c), generates a second compressor frequency control signal Δfc2 by adding the output signals from the second, sixth, tenth, and fourteenth PID control sections (p2c, p6c, p10c, p14c), generates an outdoor expansion valve control signal Δev1 by adding the output signals from the third, seventh, eleventh, and fifteenth PID control sections (p3c, p7c, p11c, p15c), and generates an indoor expansion valve control signal Δev2 by adding the output signals from the fourth, eighth, twelfth, and sixteenth PID control sections (p4c, p8c, p12c, p16c).

[0100] The first compressor frequency control signal Δfc1, the second compressor frequency control signal Δfc2, the outdoor expansion valve control signal Δev1, and the indoor expansion valve control signal Δev2 generated in this manner are output to the air conditioner (210).

[0101] In the air conditioner (210), the capacity of the first compressor (21a) varies to a value corresponding to the first compressor frequency control signal Δfc1, and the capacity of the second compressor (21b) varies to a value corresponding to the second compressor frequency control signal Δfc2.

[0102] The degree of opening of the outdoor expansion valve (24) is adjusted according to the outdoor expansion valve control signal Δev1, and the degree of opening of the indoor expansion valve (26) is also adjusted according to the indoor expansion valve control signal Δev2.

[0103] The low pressure P1, the high pressure Ph, the suction temperature T2, and the intermediate pressure saturation temperature T3 in the air conditioner (210) operated in this operation state are fed back to the controller (240) through the low pressure sensor (32), the high pressure sensor (34), the suction temperature sensor (35), and the intermediate pressure saturation temperature sensor (36). Thus, the controller (240) performs feed back control to set the low pressure P1, the high pressure Ph, the degree of superheat SH, and the intermediate pressure saturation temperature T3 to target values corresponding to the operation state, respectively.

[0104] As described above, each of the first and second compressor frequency control signals Δfc1 and Δfc2, and the outdoor and indoor expansion valve control signals Δev1 and Δev2 are generated by associating the low pressure deviation e1, the high pressure deviation e2, the superheat degree deviation e4, and the intermediate pressure saturation temperature deviation e5 with each other. Specifically, the objects of control each corresponding to the physical values are not controlled independently, but the first and second compressors (21a, 21b), and the outdoor and indoor expansion valves (24, 26) are controlled concurrently, thereby concurrently, or simultaneously controlling the low pressure, the high pressure, the degree of superheat, and the intermediate pressure saturation temperature. That is, each of the low pressure, the high pressure, the degree of superheat, and the intermediate pressure saturation temperature is not controlled only by one of the first and second compressors (21a, 21b), and the outdoor and indoor expansion valves (24, 26), but is controlled by all the first and second compressors (21a, 21b), and the outdoor and indoor expansion valves (24, 26). More specifically, each of the objects of control, i.e., the first and second compressors (21a, 21b), and the outdoor and indoor expansion valves (24, 26), is controlled not only based on the changes of the low pressure, the high pressure, the degree of superheat, and the intermediate pressure saturation temperature resulting solely from the control of the each of the objects of control, but is controlled based on the changes of the low pressure, the high pressure, the degree of superheat, and the intermediate pressure saturation temperature resulting from the control of the other objects of control (in other words, the control parameters of the first to sixteenth PID control sections (p1c, p2c, ...) are determined so as to take these changes into account).

[0105] In the heating operation, the control signal generator (249) receives the high pressure deviation e2 between the target high pressure Phs calculated by the target high pressure calculator (42) and the actual high pressure Ph from the high pressure sensor (34), the superheat degree deviation e4 between the target degree of superheat SHs calculated by the target superheat degree calculator (44) and the actual degree of superheat SH calculated by the actual superheat degree calculator (45), the intermediate pressure saturation temperature deviation e5 between the target intermediate pressure saturation temperature T3s calculated by the target intermediate pressure saturation temperature calculator (46) and the actual intermediate pressure saturation temperature T3 from the intermediate pressure saturation temperature sensor (36), and the gas cooler outlet temperature deviation e6 between the target gas cooler outlet temperature T4s calculated by the target gas cooler outlet temperature calculator (47) and the output signal from the gas cooler output temperature sensor (37) for the heating operation (i.e., an actual gas cooler outlet temperature T4).

[0106] In the heating operation, sixteen PID control sections (p1d, p2d, ...) of the control signal generator (249) different from those operated in the cooling operation are operated. Specifically, the high pressure deviation e2 input to the control signal generator (249) is input to the first to the fourth PID control sections (p1d-p4d), the intermediate pressure saturation temperature deviation e5 is input to the fifth to the eighth PID control sections (p5d-p8d), the gas cooler outlet temperature deviation e6 is input to the ninth to twelfth PID control sections (p9d-p12d), and the superheat degree deviation e4 is input to the thirteenth to sixteenth PID control sections (p13d-p16d).

[0107] Each of the first to sixteenth PID control sections (p1d, p2d, ...) delivers an output by multiplying the input deviation by a predetermined control parameter. As a result, the control signal generator (249) generates a first compressor frequency control signal Δfc1 by adding the output signals from the first, fifth, ninth, and thirteenth PID control sections (p1d, p5d, p9d, p13d), generates a second compressor frequency control signal Δfc2 by adding the output signals from the second, sixth, tenth, and fourteenth PID control sections (p2d, p6d, p10d, p14d), generates an outdoor expansion valve control signal Δev1 by adding the output signals from the third, seventh, eleventh, and fifteenth PID control sections (p3d, p7d, p11d, p15d), and generates an indoor expansion valve control signal Δev2 by adding the fourth, eighth, twelfth, and sixteenth PID control sections (p4d, p8d, p12d, p16d).

[0108] The first compressor frequency control signal Δfc1, the second compressor frequency control signal Δfc2, the outdoor expansion valve control signal Δev1, and the indoor expansion valve control signal Δev2 generated in this manner are output to the air conditioner (210).

[0109] In the air conditioner (210), the capacity of the first compressor (21a) varies according to the first compressor frequency control signal Δfc1, the capacity of the second compressor (21b) varies according to the second compressor frequency control signal Δfc2. The degree of opening of the outdoor expansion valve (24) is adjusted according to the outdoor expansion valve control signal Δev1, and the degree of opening of the indoor expansion valve (26) is adjusted according to the expansion valve control signal Δev2.

[0110] The high pressure Ph, the suction temperature T2, the intermediate pressure saturation temperature T3, and the gas cooler outlet temperature T4 in the air conditioner (210) operated in this operation state are fed back to the controller (240) through the high pressure sensor (34), the suction temperature sensor (35), the intermediate pressure saturation temperature sensor (36), and the gas cooler outlet temperature sensor (37) for the heating operation. Thus, the controller (240) performs feed back control to set the high pressure Ph, the degree of superheat SH, the intermediate pressure saturation temperature T3, and the gas cooler outlet temperature T4 to target values corresponding to the operation state, respectively.

[0111] The first and second compressor frequency control signals Δfc1 and Δfc2, and the outdoor and indoor expansion valve control signals Δev1 and Δev2 are generated by associating the high pressure deviation e2, the superheat degree deviation e4, the intermediate pressure saturation temperature deviation e5, and the gas cooler outlet temperature deviation e6 with each other. Specifically, the objects of control each corresponding to the physical values are not controlled independently, but the first and second compressors (21a, 21b), and the outdoor and indoor expansion valves (24, 26) are concurrently controlled, thereby concurrently, or simultaneously controlling the high pressure, the degree of superheat, the intermediate pressure saturation temperature, and the gas cooler outlet temperature. That is, each of the high pressure, the degree of superheat, the intermediate pressure saturation temperature, and the gas cooler outlet temperature is not controlled only by one of the first and second compressors (21a, 21b), and the outdoor and indoor expansion valves (24, 26), but is controlled by all the first and second compressors (21a, 21b), and the outdoor and indoor expansion valves (24, 26). More specifically, each of the objects of control, i.e., the first and second compressors (21a, 21b), and the outdoor and indoor expansion valves (24, 26), is controlled not only based on the changes of the high pressure, the degree of superheat, the intermediate pressure saturation temperature, and the gas cooler outlet temperature resulting from the control of the each of the objects of control, but is controlled based on the changes of the high pressure, the degree of superheat, the intermediate pressure saturation temperature, and the gas cooler outlet temperature resulting from the control of the other objects of control (in other words, the control parameters of the first to sixteenth PID control sections (p1c, p2c, ...) are determined so as to take these changes into account).

[0112] Thus, according to the second embodiment, the plurality of objects of control (e.g., the first compressor (21a), the outdoor expansion valve (24), etc.) are simultaneously controlled in such a manner that the high pressure of the refrigeration cycle, and the predetermined physical value of the air conditioner (210) are adjusted to the predetermined target values corresponding to the operation state. At the same time, each of the objects of control is controlled in consideration of the changes of the physical value and the high pressure of the refrigeration cycle resulting from the control of the plurality of objects of control. According to these schemes, the capability of the air conditioner (210) (e.g., the low pressure, the degree of superheat, etc., in the cooling operation) can be controlled with the high pressure stably kept to the target value corresponding to the operation state. This can avoid an event in which the control of a target physical value cannot be easily settled, i.e., an event in which adjustment of a first physical value changes a second physical value, and correction of the change of the second physical value by adjusting the second physical value changes a third physical value or the first physical value already adjusted, thereby involving another adjustment. This allows for an improved convergence rate of the control of the capability and the high pressure of the air conditioner (210).

[0113] According to the present embodiment, four physical values, i.e., the low pressure, the high pressure , the degree of superheat, and the intermediate pressure saturation temperature, are controlled by four objects of control, i.e., the first and second compressors (21a, 21b), and the outdoor and indoor expansion valves (24, 26), in the cooling operation. In the heating operation, four physical values, i.e., the high pressure, the degree of superheat, the intermediate pressure saturation temperature, and the gas cooler outlet temperature, are controlled by four objects of control, i.e., the first and second compressors (21a, 21b), and the outdoor and indoor expansion valves (24, 26). However, some of the objects of control easily have an effect on the physical values, but some do not. That is, even when one of the objects of control is changed, some physical values are less susceptible to the change. In the present embodiment, all the physical values to be controlled are input, and they are associated with each other to generate control signals each corresponding to the objects of control. In generating a control signal for one of the objects of control to which a certain physical value is less susceptible, the degree of association of the certain physical value may be reduced or eliminated (specifically, among the PID control sections (p1c, ..., p1d, ...) for generating the control signal for the object of control to which a certain physical value is less susceptible, a control parameter of one of the PID control sections corresponding to the certain physical value may be reduced or reduced to zero.)

[Third Embodiment]

[0114] A third embodiment of the present disclosure will be described below.

[0115] An air conditioner (310) of the third embodiment is different from the air conditioner (10) of the first embodiment in that a plurality of indoor heat exchangers (27a, 27b) are provided in a refrigerant circuit (320).

[0116] Specifically, the air conditioner (310) includes a refrigerant circuit (320), and a controller (340) as shown in FIG. 7.

[0117] The refrigerant circuit (320) connects a compressor (21), a four way switching valve (22), an outdoor heat exchanger (23), an outdoor expansion valve (24), a receiver (25), a first and second indoor expansion valves (26a, 26b), and first and second indoor heat exchangers (27a, 27b). In this refrigerant circuit (320), a plurality of (two in the present embodiment) indoor heat exchangers (27a, 27b) are connected in parallel, and an indoor expansion valve (26a (26b)) is connected to each of the indoor heat exchangers (27a (27b)).

[0118] Specifically, in the refrigerant circuit (320), a discharge side of the compressor (21) is connected to a first port of the four way switching valve (22), and a suction side of the compressor (21) is connected to a second port of the four way switching valve (22). In the refrigerant circuit (320), the outdoor heat exchanger (23), the outdoor expansion valve (24), the receiver (25), the two indoor expansion valves (26a, 26b), and the two indoor heat exchangers (27a, 27b) are sequentially arranged in a path from a third port to a fourth port of the four way switching valve (22).

[0119] Each of the outdoor expansion valve (24), and the first and second indoor heat expansion valves (26a, 26b) is comprised of an electronic expansion valve whose degree of opening is variable, and whose valve element (not shown) is driven by a pulse motor (not shown). The outdoor expansion valve (24) constitutes a heat source side expansion mechanism, and the first and second indoor expansion valves (26a, 26b) constitute a utilization side expansion mechanism.

[0120] The first and second indoor heat exchangers (27a, 27b) are provided with first and second indoor fans (29a, 29b), respectively.

[0121] Like the air conditioner of the first embodiment, the air conditioner (310) is able to switchably perform cooling operation and heating operation by switching the four way switching valve (22).

[0122] In the cooling operation, the four way switching valve (22) is set to the first state. When the compressor (21) is operated in this state, the outdoor heat exchanger (23) functions as a radiator, and the first and second indoor heat exchangers (27a, 27b) function as evaporators to perform the refrigeration cycle. Specifically, the refrigerant in the supercritical state discharged from the compressor (21) flows into the outdoor heat exchanger (23), and dissipates heat to the outdoor air. After the heat dissipation, the refrigerant expands (decreases in pressure) as it passes through the outdoor expansion valve (24). The expanded refrigerant passes through the receiver (25), and is branched, and the branched flows of the refrigerant pass through the first and second indoor expansion valves (26a, 26b). At this time, the refrigerant further expands (decreases in pressure), and flows into the first and second indoor heat exchangers (27a, 27b). That is, the refrigerant flowing between the outdoor expansion valve (24) and the indoor expansion valves (26a, 26b), and in the receiver (25) is at an intermediate pressure. In the first and second indoor heat exchangers (27a, 27b), the refrigerant absorbs heat from the indoor air to evaporate, and the cooled air is fed to the inside of the room. The evaporated refrigerant is sucked into and compressed in the compressor (21).

[0123] In the heating operation, the four way switching valve (22) is set to the second state. When the compressor (21) is operated in this state, the first and second indoor heat exchangers (27a, 27b) function as radiators, and the outdoor heat exchanger (23) functions as an evaporator to perform the refrigeration cycle. Specifically, the refrigerant discharged from the compressor (21) in the supercritical state is branched, and the branched flows of the refrigerant enter the first and second indoor heat exchangers (27a, 27b), respectively, and dissipate heat to the indoor air. The heated indoor air is fed to the inside of the room. After the heat dissipation, the refrigerant expands (decreases in pressure) as it passes through the second indoor expansion valves (26a, 26b). The expanded refrigerant passes through the receiver (25), and then further expands (decreases in pressure) as it passes through the outdoor expansion valve (24). That is, the refrigerant flowing between the first and second indoor expansion valves (26a, 26b) and the outdoor expansion valve (24), and in the receiver (25) is at the intermediate pressure. The refrigerant expanded by the outdoor expansion valve (24) flows into the outdoor heat exchanger (23), and absorbs heat from the outdoor air to evaporate. The evaporated refrigerant is sucked into and compressed in the compressor (21).

[0124] The air conditioner (310) configured in this manner includes, in the refrigerant circuit (320), first and second indoor temperature sensors (31a, 31b), a low pressure sensor (32), a high pressure sensor (34), a suction temperature sensor (35), first and second gas cooler outlet temperature sensors (37a, 37b) for the heating operation, first and second evaporator outlet temperature sensors (38a, 38b), and a gas cooler outlet temperature sensor (39) for the cooling operation.

[0125] The first and second indoor temperature sensors (31a, 31b) are sensing parts for sensing the temperatures of the flows of the indoor air entering the first and second indoor heat exchangers (27a, 27b), and are provided for the first and second indoor heat exchangers (27a, 27b), respectively. The first and second gas cooler outlet temperature sensors (37a, 37b) for the heating operation are temperature sensing parts for sensing the temperatures of the refrigerant at the outlets of the first and second indoor heat exchangers (27a, 27b), respectively, when the refrigerant circulates in the refrigerant circuit (320) in the heating cycle. The first and second gas cooler outlet temperature sensors (37a, 3 7b) for the heating operation are provided for the first and second indoor heat exchangers (27a, 27b), respectively. The first and second evaporator outlet temperature sensors (38a, 38b) are temperature sensing parts for sensing the temperatures of the refrigerant at the outlets of the first and second indoor heat exchangers (27a, 27b), respectively, when the refrigerant circulates in the refrigerant circuit (320) in the cooling cycle, and are provided for the first and second indoor heat exchangers (27a, 27b), respectively.

[0126] The controller (340) is configured to receive output signals from the first and second indoor temperature sensors (31a, 31 b), the low pressure sensor (32), the high pressure sensor (34), the suction temperature sensor (35), the first and second gas cooler outlet temperature sensors (37a, 37b) for the heating operation, and the first and second evaporator outlet temperature sensors (38a, 38b), and to control the operation frequency of the compressor (21), and the degrees of opening of the outdoor, first, and second indoor expansion valves (24, 26a, 26b).

[0127] The controller (340) includes, as shown in FIGS. 8 and 9, a target low pressure calculator (41) for calculating a target low pressure Pls which is a target value of the low pressure of the refrigeration cycle, a target high pressure calculator (42) for calculating a target high pressure Phs which is a target value of the high pressure of the refrigeration cycle, an actual superheat degree calculator (45) for calculating the actual degree of superheat SH which is the actual degree of superheat of the refrigerant, a target first superheat degree calculator (44a) for calculating a target first degree of superheat SHas which is a target value of the degree of superheat of the refrigerant at the outlet of the first indoor heat exchanger (27a) in the cooling operation, a target second superheat degree calculator (44b) for calculating a target second degree of superheat SHbs which is a target value of the degree of superheat of the refrigerant at the outlet of the second indoor heat exchanger (27b) in the cooling operation, a target first gas cooler outlet temperature calculator (47a) for calculating a target first gas cooler outlet temperature T4as which is a target value of the temperature of the refrigerant at the outlet of the first indoor heat exchanger (27a) in the heating operation, a target second gas cooler outlet temperature (47b) for calculating a target second gas cooler outlet temperature T4bs which is a target value of the temperature of the refrigerant at the outlet of the second indoor heat exchanger (27b) in the heating operation, a target superheat degree calculator (44) for calculating the target degree of superheat SHs which is a target value of the degree of superheat of the refrigerant at the outlet of the outdoor heat exchanger (23) in the heating operation, and a control signal generator (349) for generating control signals transmitted to the compressor (21), and the outdoor, first, and second indoor expansion valves (24, 26a, 26b). The controller (340) performs the control in different ways for the cooling operation and the heating operation. Therefore, a control block for the cooling operation is shown in FIG. 8, and a control block for the heating operation is shown in FIG. 9.

[0128] The target low pressure calculator (41) calculates the target low pressure Pls of the air conditioner (310) as a whole based on a temperature deviation eta between a set temperature Tsa of the first indoor heat exchanger (27a) and an indoor temperature Taa from the first indoor temperature sensor (31 a), and a temperature deviation etb between a set temperature Tsb of the second indoor heat exchanger (27b) and an indoor temperature Tab from the second indoor temperature sensor (31b).

[0129] In the cooling operation, the target high pressure calculator (42) calculates the target high pressure Phs of the air conditioner (310) based on an outdoor temperature T0 from the outdoor temperature sensor (30), and a gas cooler outlet temperature T4 from the gas cooler outlet temperature sensor (39) for the cooling operation. In the heating operation, the target high pressure calculator (42) calculates the target high pressure Phs of the air conditioner (310) based on at least one of the temperature deviation eta of the first indoor heat exchanger (27a), the temperature deviation etb of the second indoor heat exchanger (27b), the target first gas cooler outlet temperature T4as calculated by the target first gas cooler outlet temperature calculator (47a), the target second gas cooler outlet temperature T4bs calculated by the target second gas cooler outlet temperature calculator (47b), and the first and second gas cooler outlet temperatures T4a, T4b from the first and second gas cooler outlet temperature sensors (37a, 37b) for the heating operation.

[0130] The target first superheat degree calculator (44a) calculates the target first degree of superheat SHas based on the temperature deviation eta of the first indoor heat exchanger (27a).

[0131] The target second superheat degree calculator (44b) calculates the target second degree of superheat SHbs based on the temperature deviation etb of the second indoor heat exchanger (27b).

[0132] In the cooling operation, the actual superheat degree calculator (45) calculates an actual first or actual second degree of superheat SHa or SHb, which is the actual degree of superheat of the refrigerant at the outlet of the first or second indoor heat exchanger (27a, 27b), based on the actual low pressure Pl from the low pressure sensor (32), and the first or second evaporator outlet temperature T5a or Tbb from the first or second evaporator outlet temperature sensor (38a, 38b). In the heating operation, the actual superheat degree calculator (45) calculates the actual degree of superheat SH, which is the actual degree of superheat of the refrigerant at the outlet of the outdoor heat exchanger (23), based on the actual low pressure Pl from the low pressure sensor (32), and the actual suction temperature T2 from the suction temperature sensor (35).

[0133] The target first gas cooler outlet temperature calculator (47a) calculates the target first gas cooler outlet temperature T4as based on the temperature deviation eta of the first indoor heat exchanger (27a).

[0134] The target second gas cooler outlet temperature calculator (47b) calculates the target second gas cooler outlet temperature T4bs based on the temperature deviation etb of the second indoor heat exchanger (27b).

[0135] The target low pressure calculator (41), the target high pressure calculator (42), the target first superheat degree calculator (44a), the target second superheat degree calculator (44b), the target superheat degree calculator (44), the target first gas cooler outlet temperature calculator (47a), and the target second gas cooler outlet temperature calculator (47b) have maps and functions, respectively. Each of them is configured to output an output value corresponding to the input.

[0136] Signals input to the control signal generator (349) in the cooling operation are different from those input to the control signal generator (349) in the heating operation. The control signal generator (349) has PID control sections (p1e, p2e, ..., p1f, p2f, ...) each having a control parameter corresponding to the input signal.

[0137] In the cooling operation, the control signal generator (349) receives a low pressure deviation e1 between the target low pressure Pls calculated by the target low pressure calculator (41) and the actual low pressure Pl from the low pressure sensor (32), a high pressure deviation e2 between the target high pressure Phs calculated by the target high pressure calculator (42) and the actual high pressure Ph from the high pressure sensor (34), a first superheat degree deviation e4a between the target degree of superheat SHas calculated by the target first superheat degree calculator (44a) and the actual first degree of superheat SHa of the first indoor heat exchanger (27a) calculated by the actual superheat degree calculator (45), and the second superheat degree deviation e4b between the target degree of superheat SHbs calculated by the target second superheat degree calculator (44b) and the actual second degree of superheat SHb of the second indoor heat exchanger (27b) calculated by the actual superheat degree calculator (45).

[0138] In the cooling operation, sixteen PID control sections (p1e, p2e, ...) of the control signal generator (349) are operated. Specifically, the low pressure deviation e1 input to the control signal generator (349) is input to the first to fourth PID control sections (p 1 e-p4e), the high pressure deviation e2 is input to the fifth to eighth PID control sections (p5e-p8e), the first superheat degree deviation e4a is input to the ninth to twelfth PID control sections (p9e-p12e), and the second superheat degree deviation e4b is input to the thirteenth to sixteenth PID control sections (p13e-p16e).

[0139] Each of the first to sixteenth PID control sections (p1e, p2e, ...) delivers an output generated by multiplying the input deviation by a predetermined control parameter. Specifically, the control signal generator (349) generates a compressor frequency control signal Δfc by adding output signals from the first, fifth, ninth, and thirteenth PID control sections (p1e, p5e, p9e, p13e), generates an outdoor expansion valve control signal Δev1 by adding output signals from the second, sixth, tenth, and fourteenth PID control sections (p2e, p6e, p10e, p14e), generates a first indoor expansion valve control signal Δev2a by adding output signals from the third, seventh, eleventh, and fifteenth PID control sections (p3e, p7e, p11e, p15e), and generates a second indoor expansion valve control signal Δev2b by adding output signals from the fourth, eighth, twelfth, and sixteenth PID control sections (p4e, p8e, p12e, p16e).

[0140] The compressor frequency control signal Δfc, the outdoor expansion valve control signal Δev1, the first indoor expansion valve control signal Δev2a, and the second indoor expansion valve control signal Δev2b are output to the air conditioner (310).

[0141] In the air conditioner (310), the capacity of the compressor (21) varies to a value corresponding to the compressor frequency control signal Δfc.

[0142] The degree of opening of the outdoor expansion valve (24) is adjusted according to the outdoor expansion valve control signal Δev1, and the degree of opening of the first indoor expansion valve (26a) is adjusted according to the first indoor expansion valve control signal Δev2a, and the degree of opening of the second indoor expansion valve (26b) is adjusted according to the second indoor expansion valve control signal Δev2b.

[0143] The low pressure P1, the high pressure Ph, the first evaporator outlet temperature T5a of the first indoor heat exchanger (27a), and the second evaporator outlet temperature T5b of the second indoor heat exchanger (27b) of the air conditioner (310) operated in this operation state are fed back to the controller (340) through the low pressure sensor (32), the high pressure sensor (34), and the first and second evaporator outlet temperature sensors (38a, 38b). Thus, the controller (340) performs feed back control to set the low pressure P1, the high pressure Ph, and the first and second degrees of superheat SHa and SHb to target values corresponding to the operation state, respectively.

[0144] As described above, each of the compressor frequency control signal Δfc, and the outdoor, first indoor, and second indoor expansion valve control signals Δev1, Δev2a, and Δev2b is generated by associating the low pressure deviation e1, the high pressure deviation e2, the first superheat degree deviation e4a, and the second superheat degree deviation e4b with each other. Specifically, the objects of control each corresponding to the physical values are not controlled independently, but the compressor (21), the outdoor expansion valve (24), and the first and second indoor expansion valves (26a, 26b) are controlled concurrently, thereby concurrently, or simultaneously controlling the low pressure, the high pressure, the first degree of superheat, and the second degree of superheat. That is, each of the low pressure, the high pressure, the first degree of superheat, and the second degree of superheat is not controlled only by one of the compressor (21), the outdoor expansion valve (24), and the first and second indoor expansion valves (26a, 26b), but is controlled by all the compressor (21), the outdoor expansion valve (24), and the first and second indoor expansion valves (26a, 26b). More specifically, each of the objects of control, i.e., the compressor (21), the outdoor expansion valve (24), and the first and second indoor expansion valves (26a, 26b), is not controlled not only based on the changes of the low pressure, the high pressure, the first degree of superheat, and the second degree of superheat resulting from the control of the each of the objects of control, but is controlled based on the changes of the low pressure, the high pressure, the first degree of superheat, and the second degree of superheat resulting from the control of the other objects of control (in other words, the control parameters of the first to sixteenth PID control sections (p1e, p2e, ...) are determined so as to take these changes into account).

[0145] In the heating operation, the control signal generator (349) receives a high pressure deviation e2 between the target high pressure Phs calculated by the target high pressure calculator (42) and the actual high pressure Ph from the high pressure sensor (34), a superheat degree deviation e4 between the target degree of superheat SHs calculated by the target superheat degree calculator (44) and the actual degree of superheat SH calculated by the actual superheat degree calculator (45), a first gas cooler outlet temperature deviation e6a between the target first gas cooler outlet temperature T4as calculated by the target first gas cooler outlet temperature calculator (47a) and the actual first gas cooler outlet temperature T4a from the first gas cooler outlet temperature sensor (37a) for the heating operation, and a second gas cooler outlet temperature deviation e6b between the target second gas cooler outlet temperature T4bs calculated by the target second gas cooler outlet temperature calculator (47b) and the actual second gas cooler outlet temperature T4b from the second gas cooler outlet temperature sensor (37b) for the heating operation.

[0146] In the heating operation, sixteen PID control sections (p1f, p2f, ...) of the control signal generator (349) different from those operated in the cooling operation are operated. Specifically, the high pressure deviation e2 input to the control signal generator (349) is input to the first to fourth PID control sections (p1f-p4f), the first gas cooler outlet temperature deviation e6a is input to the fifth to the eighth PID control sections (p5f- p8f), the second gas cooler outlet temperature deviation e6b is input to the ninth to the twelfth PID control sections (p9f-p12f), and the superheat degree deviation e4 is input to the thirteenth to sixteenth PID control sections (p13f-p16f).

[0147] Each of the first to sixteenth PID control sections (p1f, p2f, ...) delivers an output generated by multiplying the input deviation by a predetermined control parameter. Specifically, the control signal generator (349) generates a compressor frequency control signal Δfc by adding output signals from the first, fifth, ninth, and thirteenth PID control sections (p1f, p5f, p9f, p13f), generates an outdoor expansion valve control signal Δev1 by adding output signals from the second, sixth, tenth, and fourteenth PID control sections (p2f, p6f, p10f, p14f), generates a first indoor expansion valve control signal Δev2a by adding output signals from the third, seventh, eleventh, and fifteenth PID control sections (p3f, p7f, p11f, p15f), and generates a second indoor expansion valve control signal Δev2b by adding output signals from the fourth, eighth, twelfth, and sixteenth PID control sections (p4f, p8f, p12f, p16f).

[0148] The compressor frequency control signal Δfc, the outdoor expansion valve control signal Δev1, the first indoor expansion valve control signal Δev2a, and the second indoor expansion valve control signal Δev2b generated in this manner are output to the air conditioner (310).

[0149] In the air conditioner (310), the capacity of the compressor (21) varies to a value corresponding to the compressor frequency control signal Δfc.

[0150] The degree of opening of the outdoor expansion valve (24) is adjusted according to the outdoor expansion valve control signal Δev1, the degree of the first indoor expansion valve (26a) is adjusted according to the first indoor expansion valve control signal Δev2a, and the degree of opening of the second indoor expansion valve (26b) is adjusted according to the second indoor expansion valve control signal Δev2b.

[0151] The low pressure P1, the high pressure Ph, the first gas cooler outlet temperature T4a of the first indoor heat exchanger (27a), and the second gas cooler outlet temperature T4b of the second indoor heat exchanger (27b) in the air conditioner (310) operated in this operation state are fed back to the controller (340) through the low pressure sensor (32), the high pressure sensor (34), and the first and second gas cooler outlet temperature sensors (37a, 37b) for the heating operation. Thus, the controller (340) performs feed back control to set the low pressure P1, the high pressure Ph, and the first and second degrees of superheat SHa and SHb to target values corresponding to the operation state, respectively.

[0152] Each of the compressor frequency control signal Δfc, the outdoor expansion valve control signal Δev1, and the first and second indoor expansion valve control signals Δev2a and Δev2b is generated by associating the high pressure deviation e2, the superheat degree deviation e4, the first gas cooler outlet temperature deviation e6a, and the second gas cooler outlet temperature deviation e6b with each other. Specifically, the objects of control each corresponding to the physical values are not controlled independently, but the compressor (21), the outdoor expansion valve (24), and the first and second indoor expansion valves (26a, 26b), are controlled concurrently, thereby concurrently, or simultaneously controlling the high pressure, the degree of superheat, the first gas cooler outlet temperature, and the second gas cooler outlet temperature. That is, each of the high pressure, the degree of superheat, the first gas cooler outlet temperature, and the second gas cooler outlet temperature is not controlled only by one of the compressor (21), the outdoor expansion valve (24), and the first and second indoor expansion valves (26a, 26b), but is controlled by all the compressor (21), the outdoor expansion valve (24), and the first and second indoor expansion valves (26a, 26b). More specifically, the objects of control, i.e., the compressor (21), the outdoor expansion valve (24), and the first and second indoor expansion valves (26a, 26b) is controlled not only based on the changes of the high pressure, the degree of superheat, the first gas cooler outlet temperature, and the second gas cooler outlet temperature resulting from the control of the each of the objects of control, but is controlled based on the changes of the high pressure, the degree of superheat, the first and second gas cooler outlet temperatures resulting from the control of the other objects of control (in other words, the control parameters of the first to sixteenth PID control sections (p1f, p2f, ...) are determined so as to take these changes into account).

[0153] Thus, according to the third embodiment, the plurality of objects of control (e.g., the compressor (21), the outdoor expansion valve (24), etc.) are simultaneously controlled in such a manner that the high pressure of the refrigeration cycle, and the predetermined physical value of the air conditioner (310) are adjusted to the predetermined target values corresponding to the operation state. At the same time, each of the objects of control is controlled in consideration of the changes of the physical value and the high pressure of the refrigeration cycle resulting from the control of the plurality of objects of control. According to these schemes, the capability of the air conditioner (310) (e.g., the low pressure, the degree of superheat, etc. in the cooling operation) can be controlled with the high pressure stably kept to the target value corresponding to the operation state. This can avoid an event in which the control of a target physical value cannot be easily settled, i.e., an event in which adjustment of a first physical value changes a second physical value, and correction of the change of the second physical value by adjusting the second physical value changes a third physical value or the first physical value already adjusted, thereby involving another adjustment. This allows for improved settling of the control of the capability and the high pressure of the air conditioner (310).

[0154] In the present embodiment, four physical values, i.e., the low pressure, the high pressure, the first degree of superheat, and the second degree of superheat, are controlled by the four objects of control, i.e., the compressor (21), the outdoor expansion valve (24), and the first and second indoor expansion valves (26a, 26b), in the cooling operation. In the heating operation, four physical values, i.e., the high pressure, the first gas cooler outlet temperature, the second gas cooler outlet temperature, and the degree of superheat, are controlled by four objects of control, i.e., the compressor (21), the outdoor expansion valve (24), and the first and second indoor expansion valves (26a, 26b). However, some of the objects of control easily have an effect on the physical values, but some do not. That is, even when one of the objects of control is changed, some physical values are less susceptible to the change. In the present embodiment, all the physical values to be controlled are input, and they are associated with each other to generate control signals each corresponding to the objects of control. In generating a control signal for one of the objects of control to which a certain physical value is less susceptible, the degree of association of the certain physical value may be reduced or eliminated (specifically, among the PID control sections (ple, ..., plf, ...) for generating the control signal for the object of control to which a certain physical value is less susceptible, a control parameter of one of the PID control sections corresponding to the certain physical value may be reduced or reduced to zero.)

[Other Embodiments]

[0155] The above-described embodiments may be modified in the following manner.

[0156] Specifically, the present disclosure is not limited to the refrigerant circuit described in the above embodiments, but is applicable to any refrigerant circuits. For example, as shown in FIG. 10, the disclosed technique may be applied to a multi-type air conditioner (410) which performs a two-stage compression refrigeration cycle, and includes a plurality of indoor units. In this case, for example, the high pressure, the low pressure, the first evaporator outlet temperature, the second evaporator outlet temperature, and the intermediate pressure saturation temperature may be input, and these physical values may be associated to generate control signals for controlling the first and second compressors (21a, 21 b), the first and second indoor expansion valves (26a, 26b), and the outdoor expansion valve (24), respectively. As a result, the control signals for the first and second compressors (21a, 21b), the first and second indoor expansion valves (26a, 26b), and the outdoor expansion valve (24) are generated, i.e., the first and second compressors (21a, 21b), the first and second indoor expansion valves (26a, 26b), and the outdoor expansion valve (24) are controlled, in such a manner that the high pressure, the low pressure, the first evaporator outlet temperature, the second evaporator outlet temperature, and the intermediate pressure saturation temperature are set to predetermined target values, respectively, when adjustment of all the first and second compressors (21a, 21b), the first and second indoor expansion valves (26a, 26b), and the outdoor expansion valve (24) is done.

[0157] For example, as shown in FIG. 11, the disclosed technique may be applied to a multi-type air conditioner (510) which performs a two-stage compression refrigeration cycle, and includes an internal heat exchanger (51) between the outdoor heat exchanger (23) and the outdoor expansion valve (24), and a plurality of indoor units.

[0158] Specifically, the air conditioner (510) includes a bypass pipe (53) branched from a connection pipe (52) connecting the outdoor heat exchanger (23) and the receiver (25), and is connected to a pipe connecting the first compressor (21a) and the second compressor (21b). A bypass expansion valve (54) is provided in the bypass pipe (53). The refrigerant flowing in the bypass pipe (53) decreases in pressure as it passes through the bypass expansion valve (54), and becomes an intermediate pressure refrigerant.

[0159] Further, an outdoor expansion valve (24) is provided in the connection pipe (52) to be positioned closer to the receiver (25) than to the junction with the bypass pipe (53).

[0160] The internal heat exchanger (51) is provided on the connection pipe (52) between the junction with the bypass pipe (53) and the outdoor expansion valve (24), and on the bypass pipe (53) downstream of the bypass expansion valve (54), thereby performing heat exchange between the refrigerants flowing the pipes, respectively. Specifically, in the cooling operation, the refrigerant flowing in the bypass pipe (53) decreases in pressure as it passes through the bypass expansion valve (54) to become an intermediate pressure liquid or an intermediate pressure gas-liquid two-phase refrigerant. Then, the refrigerant passes through the internal heat exchanger (51), absorbs heat from the refrigerant flowing in the connection pipe (52) to become a superheated gaseous refrigerant, and flows into the suction side of the second compressor (21b). The refrigerant flowing in the connection pipe (52) exits from the outdoor heat exchanger (23), flows into the internal heat exchanger (51), and dissipates heat to the refrigerant flowing in the bypass pipe (53) to become a supercooled refrigerant. Then, the refrigerant decreases in pressure in the outdoor expansion valve (24) to become an intermediate pressure refrigerant, and flows into the receiver (25).

[0161] A receiver pressure saturation temperature sensor (55) is arranged at the connection pipe (52) closer to the receiver (25) than to the outdoor expansion valve (24). An intermediate pressure saturation temperature sensor (36) is arranged at the bypass pipe (53) downstream of the internal heat exchanger (51).

[0162] In the air conditioner (510) configured in this manner, for example, the high pressure, the low pressure, the first evaporator outlet temperature, the second evaporator outlet temperature, the intermediate pressure saturation temperature, and an internal pressure of the receiver sensed by the receiver pressure saturation temperature sensor (55) are input, and these physical values are associated with each other to generate control signals for controlling the first and second compressors (21a, 21 b), the first and second indoor expansion valves (26a, 26b), the outdoor expansion valve (24), and the bypass expansion valve (54), respectively. As a result, the control signals for the first and second compressors (21 a, 21 b), the first and second indoor expansion valves (26a, 26b), the outdoor expansion valve (24), and the bypass expansion valve (54), respectively, are generated, i.e., the first and second compressors (21a, 21b), the first and second indoor expansion valves (26a, 26b), the outdoor expansion valve (24), and the bypass expansion valve (54) are controlled in such a manner that the high pressure, the low pressure, the first evaporator outlet temperature, the second evaporator outlet temperature, the intermediate pressure saturation temperature, and the internal pressure of the receiver are set to the predetermined target values, respectively, when adjustment of all the first and second compressors (21 a, 21b), the first and second indoor expansion valves (26a, 26b), the outdoor expansion valve (24), and the bypass expansion valve (54) is done.

[0163] Further, in the second embodiment, two compressors (21a, 21b), and two expansion valves (24, 26) are provided to perform a two-stage compression refrigeration cycle. However, a single compressor may be provided, and gas injection may be performed during the compression in the compressor. In this case, the number of objects of control is three including the single compressor and the two expansion valves (24, 26). Therefore, the number of physical values to be controlled is preferably three in total (including at least the high pressure of the refrigeration cycle.)

[0164] In the above embodiments, a plurality of physical values is input, and outputs generated by multiplying the input physical values by control parameters, respectively, are added to generate a control signal for one object of control. However, the disclosed technique is not limited to this configuration. For example, a plurality of physical values may be input, and they may be multiplied by a matrix constituted of the control parameters, to calculate a plurality of control signals as outputs based on a dynamic model of the refrigeration cycle in each of the refrigerant circuits. Even in this configuration, the input physical values are associated with each other to generate the control signal for the objects of control. Thus, concurrent control of the plurality of objects of control allows for concurrent control of the plurality of physical values, thereby allowing for an improved convergence rate of the control of each of the physical values.

[0165] In the above embodiments, the expansion valve is employed as the expansion mechanism. However, the disclosed technique is not limited thereto, and an expansion unit may be used.

[0166] In the first embodiment only, the outdoor fan (28) is controlled as the object of control. However, in the other embodiments, the outdoor fan (28) may be used in combination to perform control of the high pressure and the capability of the apparatus.

[0167] The above embodiments are merely preferred embodiments in nature, and are not intended to limit the scope, applications and use of the disclosed technique.

INDUSTRIAL APPLICABILITY

[0168] As described above, the present disclosure is useful for a refrigeration apparatus including a refrigerant circuit for performing a supercritical refrigeration cycle.

DESCRIPTION OF REFERENCE CHARACTERS

[0169]

20	Refrigerant circuit
21	Compressor (compression mechanism)
21a a	First compressor (compressor mechanism)
21b	Second compressor (compressor mechanism)
23	Outdoor heat exchanger (heat source side heat exchanger)
24	Outdoor expansion valve (expansion mechanism, first expansion mechanism, heat source side expansion mechanism)
26	Indoor expansion valve (expansion mechanism, second expansion mechanism)
26a	First indoor expansion valve (utilization side expansion mechanism)
26b	Second indoor expansion valve (utilization side expansion mechanism)
27	Indoor heat exchanger (utilization side heat exchanger)
27a	First indoor heat exchanger (utilization side heat exchanger)
27b	Second indoor heat exchanger (utilization side heat exchanger)
28	Outdoor fan (heat source side fan)
40, 240, 340	Controller (control section)

Claims

1. A refrigeration apparatus comprising:

a refrigerant circuit (20) sequentially connecting a compression mechanism (21), a heat source side heat exchanger (23), an expansion mechanism (24), and a utilization side heat exchanger (27), and performing a supercritical refrigeration cycle in which a high pressure is a supercritical pressure of a refrigerant or higher; and
a control section (40) for controlling a plurality

of objects of control including at least the compression mechanism (21) and the expansion mechanism (24), wherein
the control section (40) concurrently controls the plurality of objects of control, thereby concurrently controlling a predetermined physical value as an index of a capability of the refrigeration apparatus, and the high pressure of the refrigeration cycle.

2. The refrigeration apparatus of claim 1, wherein
the control section (40) receives the predetermined physical value, and the high pressure of the refrigeration cycle as inputs, generates control signals each corresponding to the plurality of objects of control by associating the physical value and the high pressure with each other, and outputs the control signals to the corresponding objects of control, respectively, thereby concurrently controlling the predetermined physical value, and the high pressure of the refrigeration cycle.

3. The refrigeration apparatus of claim 1, further comprising:

a heat source side fan (28) for feeding air to the heat source side heat exchanger (23) in which the refrigerant exchanges heat with the air, wherein
in cooling operation,
the predetermined physical value includes, an evaporating temperature of the refrigerant in the utilization side heat exchanger (27), and a degree of superheat of the refrigerant at an outlet of the utilization side heat exchanger (27),
the objects of control further include the heat source side fan (28), and
the control section (40) receives the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, and the high pressure of the refrigeration cycle as inputs, and concurrently controls the compression mechanism (21), the expansion mechanism (24), and the heat source side fan (28), thereby concurrently controlling the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, and the high pressure of the refrigeration cycle.

4. The refrigeration apparatus of claim 1, wherein
in heating operation,
the predetermined physical value includes a degree of superheat of the refrigerant at an outlet of the heat source side heat exchanger (23), and
the control section (40) receives the degree of superheat of the refrigerant, and the high pressure of the refrigeration cycle as inputs, and concurrently controls the compression mechanism (21) and the expansion mechanism (24), thereby concurrently controlling the degree of superheat of the refrigerant, and the high pressure of the refrigeration cycle.

5. The refrigeration apparatus of claim 1, wherein
the compression mechanism includes a first compressor (21a) for sucking and compressing a low pressure refrigerant, and a second compressor (21b) for further compressing and discharging the refrigerant discharged from the first compressor (2 1 a),
the expansion mechanism includes a first expansion mechanism (24) for expanding a high pressure refrigerant, and a second expansion mechanism (26) for further expanding the refrigerant expanded to an intermediate pressure refrigerant in the first expansion mechanism (24),
in cooling operation,
the predetermined physical value includes an evaporating temperature of the refrigerant in the utilization side heat exchanger (27), a degree of superheat of the refrigerant at an outlet of the utilization side heat exchanger (27), and an intermediate pressure of the refrigeration cycle, and
the control section (240) receives the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, the intermediate pressure of the refrigeration cycle, and the high pressure of the refrigeration cycle as inputs, and concurrently controls the first and second compressors (21 a, 21 b), and the first and second expansion mechanisms (24, 26), thereby concurrently controlling the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, the intermediate pressure of the refrigeration cycle, and the high pressure of the refrigeration cycle.

6. The refrigeration apparatus of claim 1, wherein
the compression mechanism includes a first compressor (21a) for sucking and compressing a low pressure refrigerant, and a second compressor (21b) for further compressing and discharging the refrigerant discharged from the first compressor (21 a),
the expansion mechanism includes a first expansion mechanism (24) for expanding a high pressure refrigerant, and a second expansion mechanism (26) for further expanding the refrigerant expanded to an intermediate pressure refrigerant in the first expansion mechanism (24),
in heating operation,
the predetermined physical value includes, an evaporating temperature of the refrigerant in the heat source side heat exchanger (23), a degree of superheat of the refrigerant at an outlet of the heat source side heat exchanger (23), and a gas cooler outlet temperature which is a temperature of the refrigerant at an outlet of the utilization side heat exchanger

(27), and
the control section (240) receives the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, the gas cooler outlet temperature of the refrigerant, and the high pressure of the refrigeration cycle as inputs, and concurrently controls the first and second compressors (21 a, 21b), and the first and second expansion mechanisms (24, 26), thereby concurrently controlling the evaporating temperature of the refrigerant, the degree of superheat of the refrigerant, the gas cooler outlet temperature of the refrigerant, and the high pressure of the refrigeration cycle.

7. The refrigeration apparatus of claim 1, wherein
a plurality ones of the utilization side heat exchanger (27a, 27b) are connected in parallel with each other,
the expansion mechanism includes a plurality of utilization side expansion mechanisms (26a, 26b) each corresponding to the utilization side heat exchangers (27a, 27b), and a heat source side expansion mechanism (24) provided between the utilization side heat exchangers (27a, 27b) and expansion mechanisms (26a, 26b), and the heat source side heat exchanger (23),
in cooling operation,
the predetermined physical value includes evaporating temperatures of the refrigerant in the utilization side heat exchangers (27a, 27b), and degrees of superheat of the refrigerant at the outlets of the utilization side heat exchangers (27a, 27b), and
the control section (340) receives the evaporating temperatures of the refrigerant, the degrees of superheat of the refrigerant in the utilization side heat exchangers (27a, 27b), and the high pressure of the refrigeration cycle as inputs, and concurrently controls the compression mechanism (21), the plurality of utilization side heat expansion mechanisms (26a, 26b), and the heat source side expansion mechanism (24), thereby concurrently controlling the evaporating temperatures of the refrigerant, and the degrees of superheat of the refrigerant in the utilization side heat exchangers (27a, 27b), and the high pressure of the refrigeration cycle.

8. The refrigeration apparatus of claim 1, wherein
a plurality ones of the utilization side heat exchanger (27a, 27b) are connected in parallel with each other,
the expansion mechanism includes a plurality of utilization side expansion mechanisms (26a, 26b) each corresponding to the utilization side heat exchangers (27a, 27b), and a heat source side expansion mechanism (24) provided between the utilization side heat exchangers (27a, 27b) and expansion mechanisms (26a, 26b), and the heat source side heat exchanger (23),
in heating operation,
the predetermined physical value includes a degree of superheat of the refrigerant at an outlet of the heat source side heat exchanger (23), and gas cooler outlet temperatures of the refrigerant which are temperatures of the refrigerant at outlets of the utilization side heat exchangers (27a, 27b), and
the control section (340) receives the degree of superheat of the refrigerant, the gas cooler outlet temperatures of the refrigerant in the utilization side heat exchangers (27a, 27b), and the high pressure of the refrigeration cycle as inputs, and concurrently controls the compression mechanism (21), the plurality of utilization side expansion mechanisms (26a, 26b), and the heat source side expansion mechanism (24), thereby concurrently controlling the degree of superheat of the refrigerant, the gas cooler outlet temperatures of the refrigerant in the utilization side heat exchangers (27a, 27b), and the high pressure of the refrigeration cycle.

FIG.1

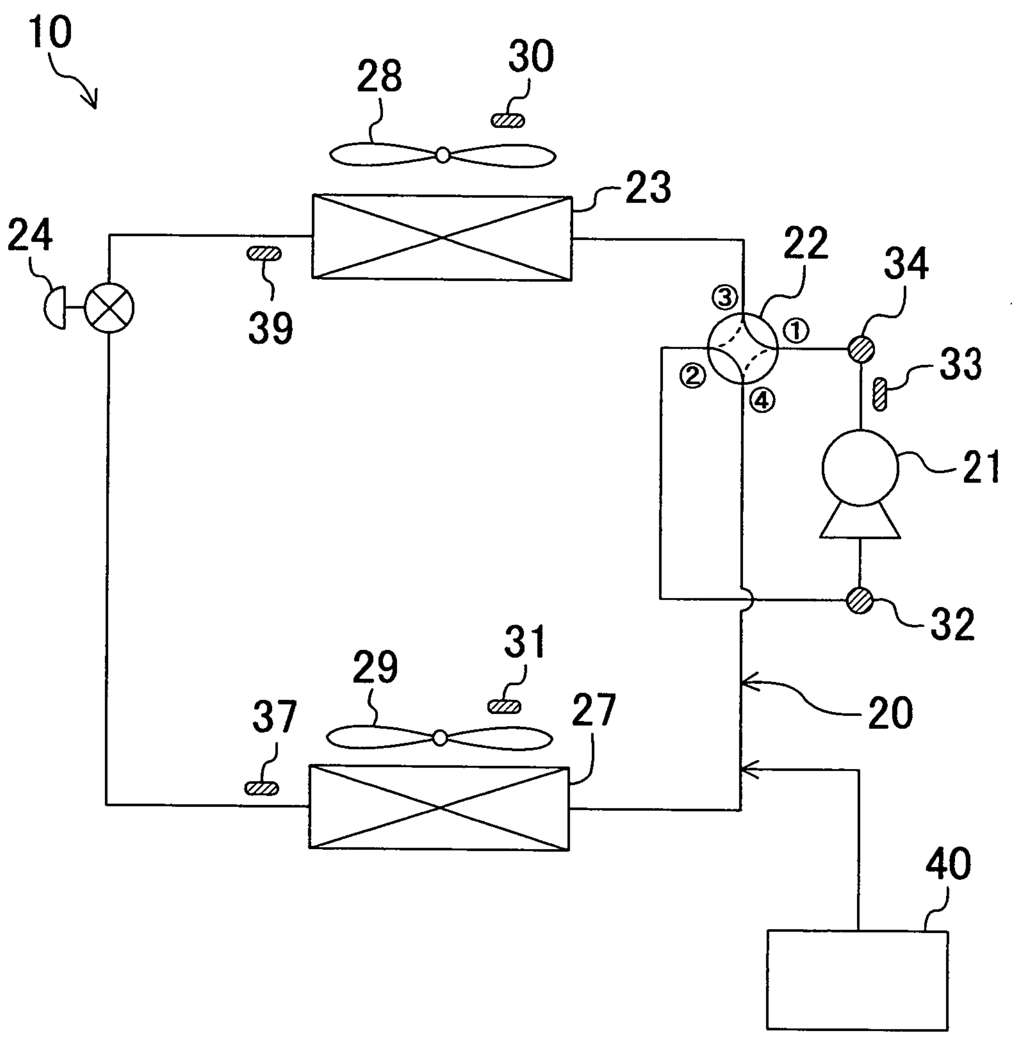


FIG.2

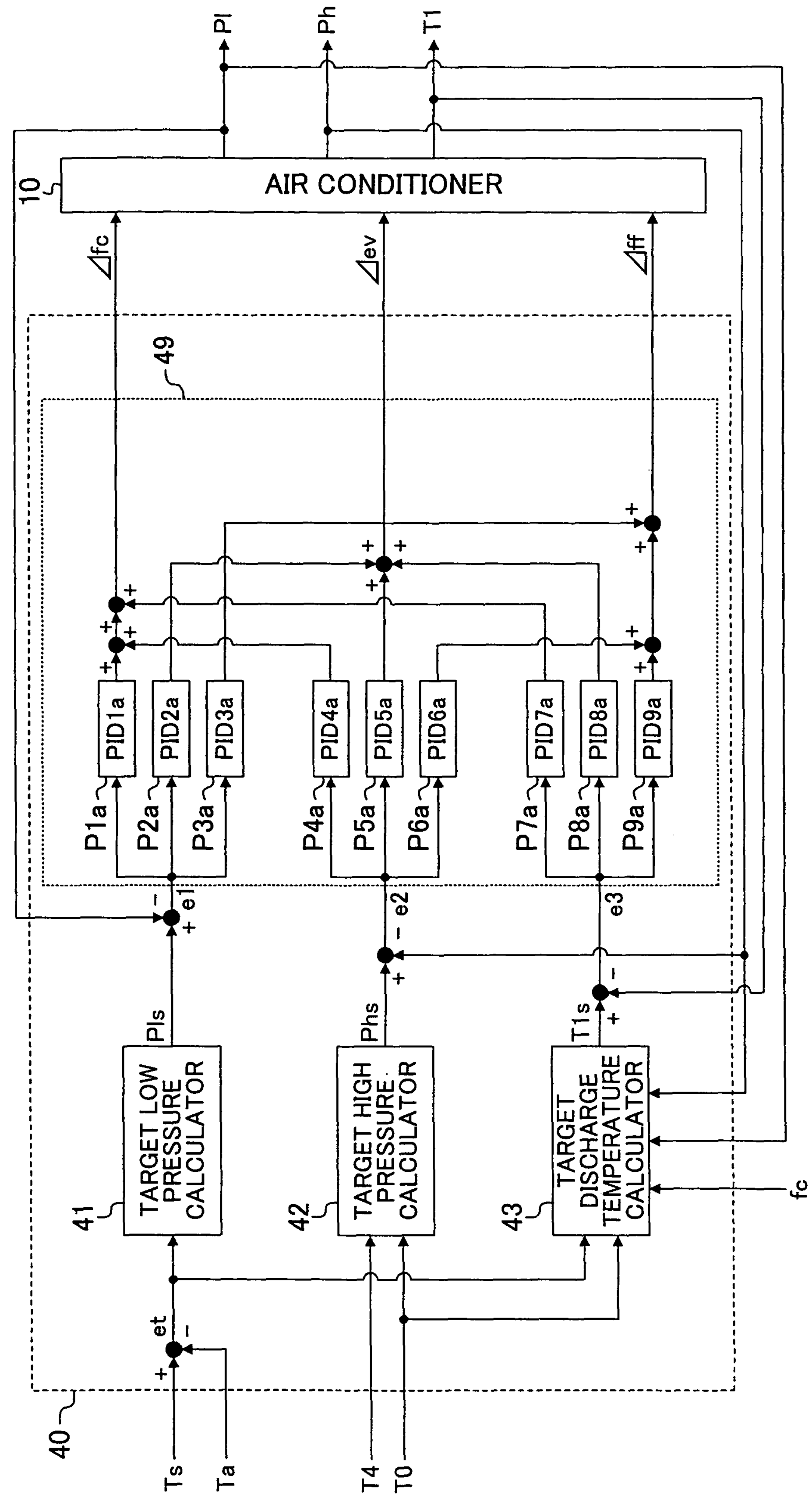

Pl
Ph
T1
10
AIR CONDITIONER
⊿fc
⊿ev
⊿ff
49
PID1a
PID2a
PID3a
PID4a
PID5a
PID6a
PID7a
PID8a
PID9a
P1a
P2a
P3a
P4a
P5a
P6a
P7a
P8a
P9a
e1
e2
e3
Pls
Phs
T1s
TARGET LOW PRESSURE CALCULATOR
TARGET HIGH PRESSURE CALCULATOR
TARGET DISCHARGE TEMPERATURE CALCULATOR
41
42
43
fc
et
40
Ts
Ta
T4
T0

FIG.3

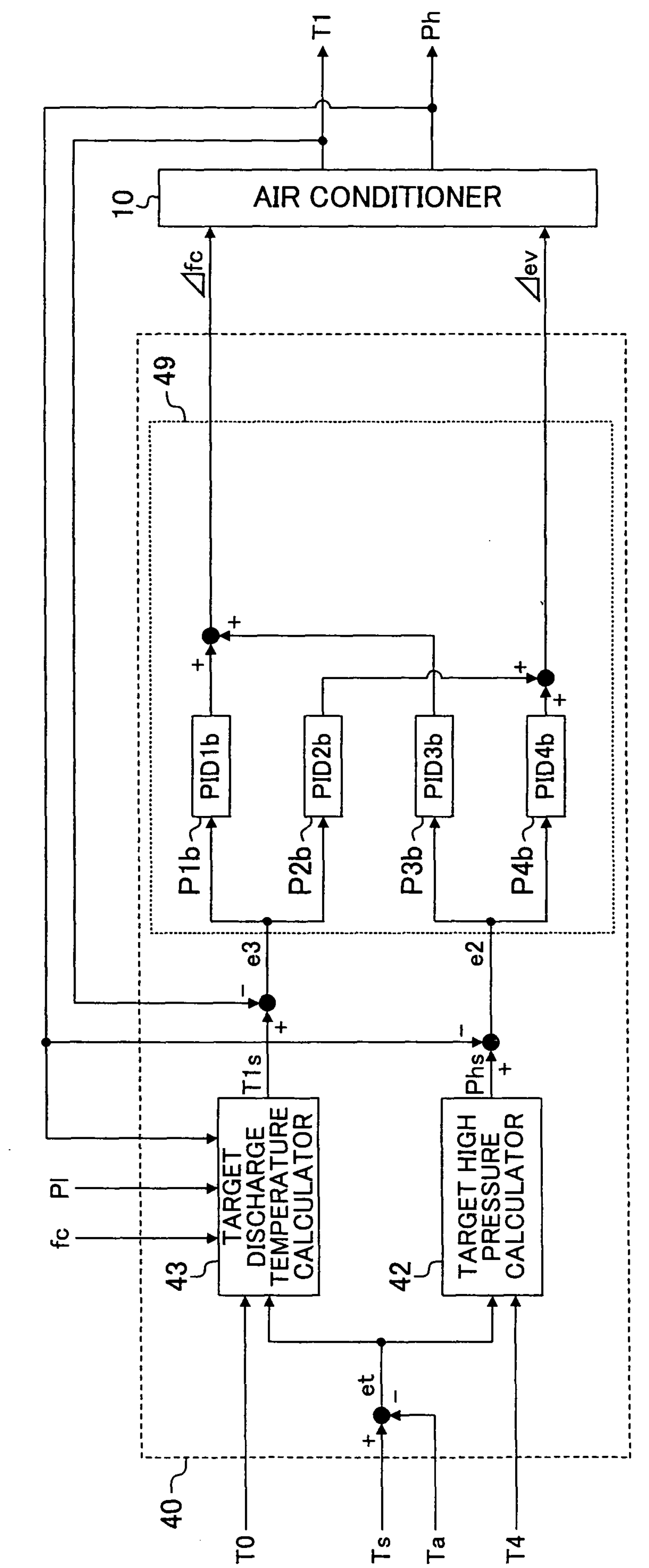

T1
Ph
10
AIR CONDITIONER
⊿fc
⊿ev
49
PID1b
PID2b
PID3b
PID4b
P1b
P2b
P3b
P4b
e3
e2
T1s
Phs
43
TARGET DISCHARGE TEMPERATURE CALCULATOR
42
TARGET HIGH PRESSURE CALCULATOR
fc
Pl
et
40
T0
Ts
Ta
T4

FIG.4

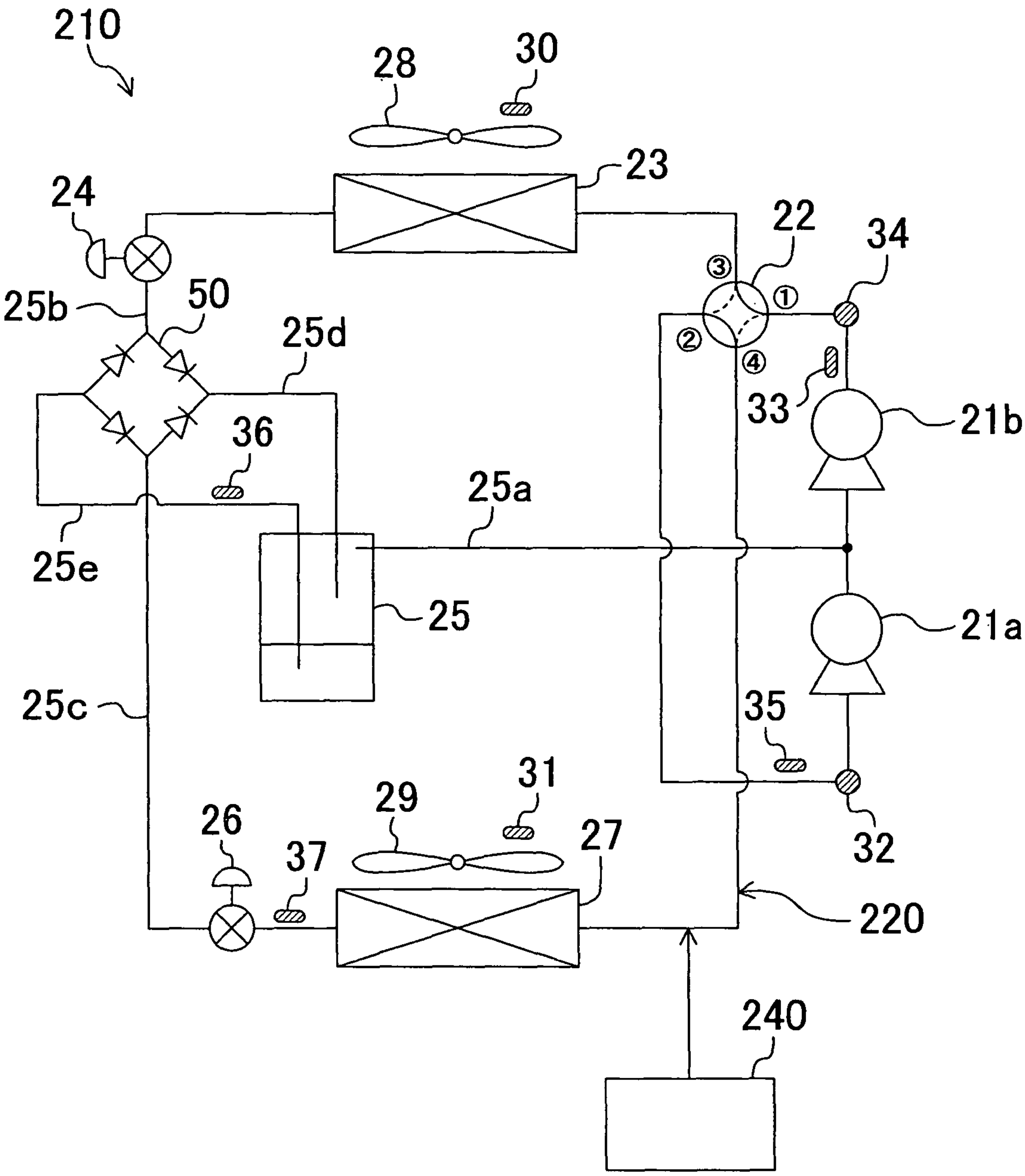

210
28
30
23
24
22
34
③
①
25b
50
②
④
25d
33
21b
36
25a
25e
25
21a
25c
35
32
31
29
26
37
27
220
240

FIG.5

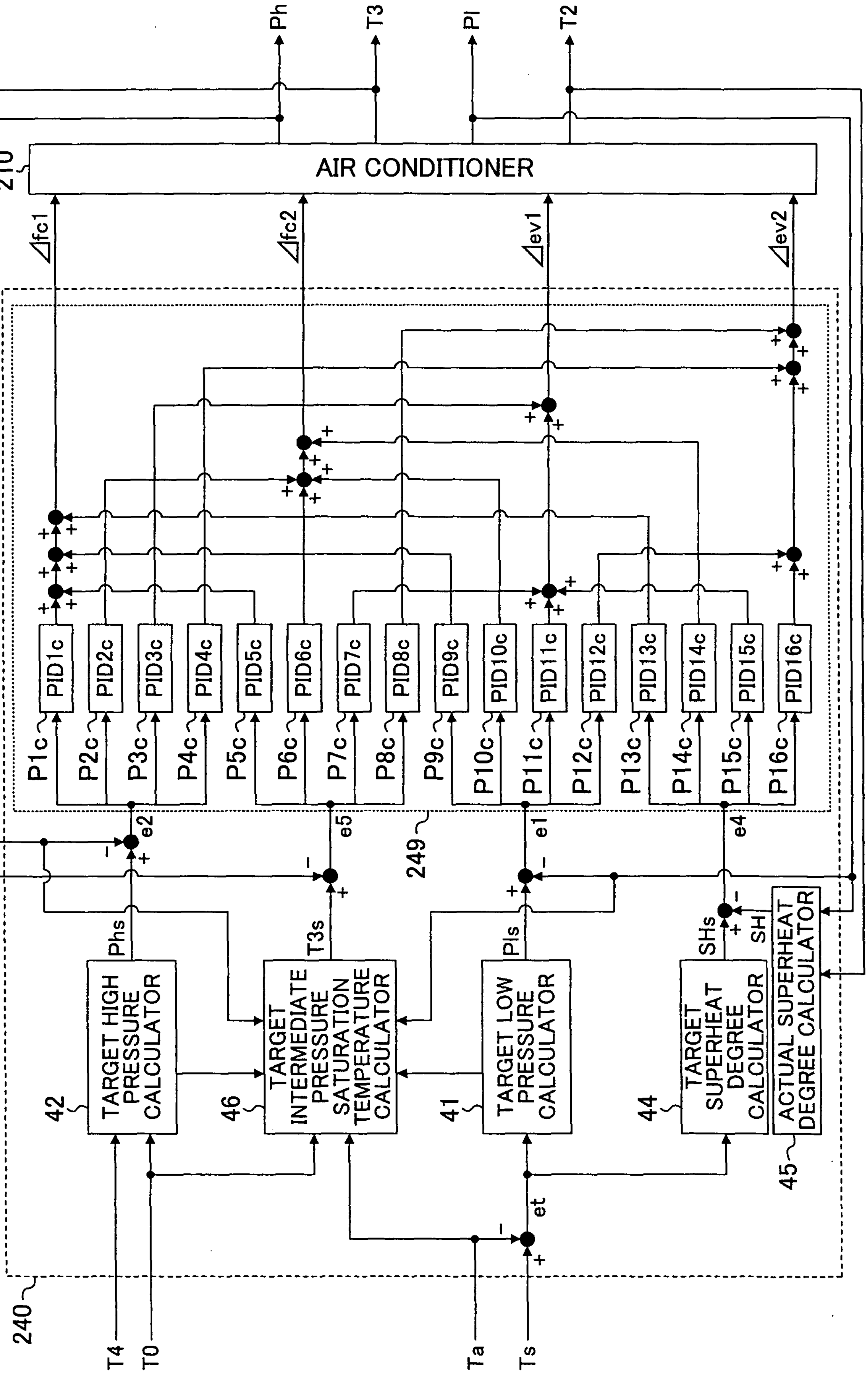
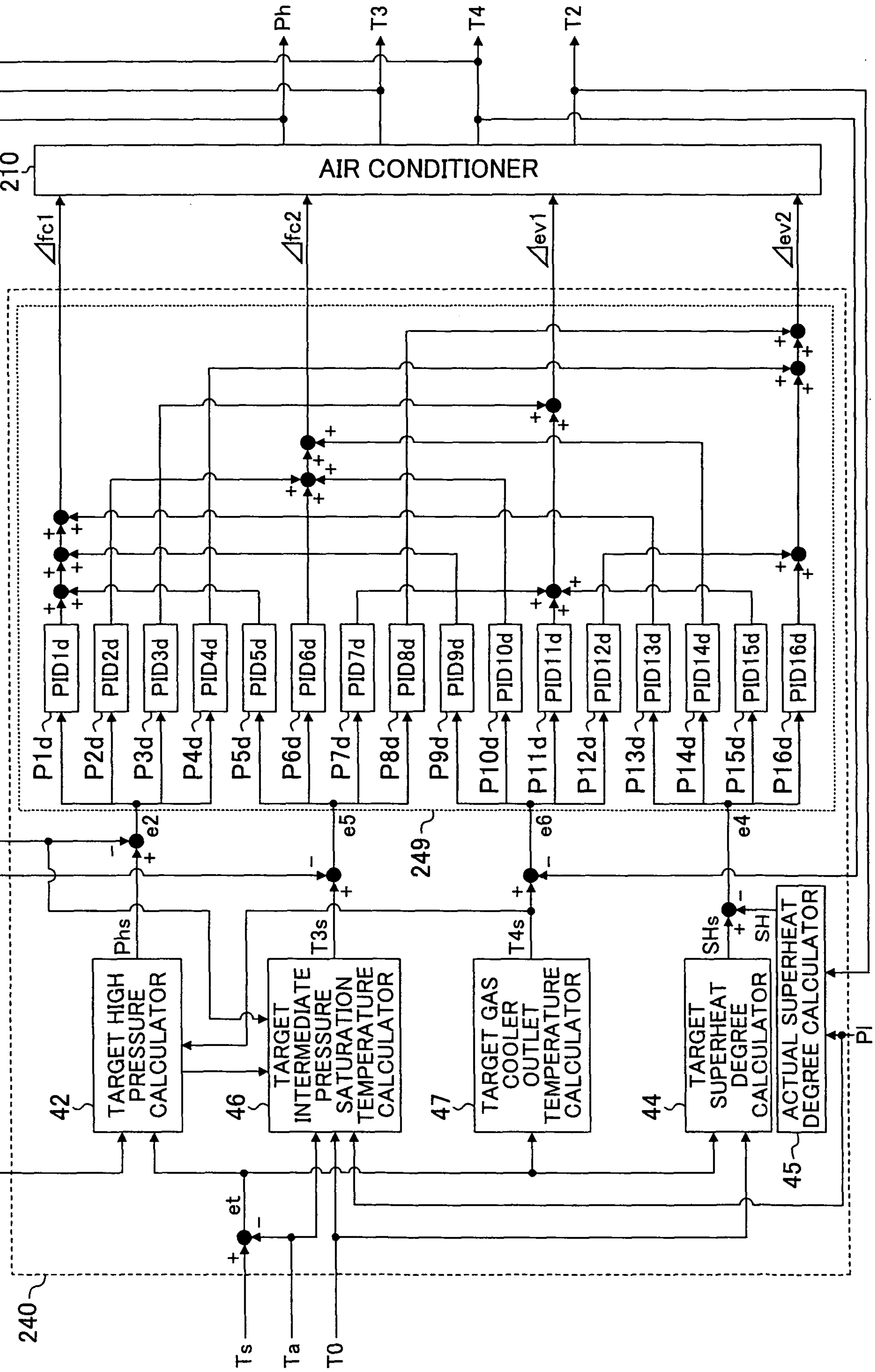

Ph
T3
Pl
T2
210
AIR CONDITIONER
⊿fc1
⊿fc2
⊿ev1
⊿ev2
PID1c
PID2c
PID3c
PID4c
PID5c
PID6c
PID7c
PID8c
PID9c
PID10c
PID11c
PID12c
PID13c
PID14c
PID15c
PID16c
P1c
P2c
P3c
P4c
P5c
P6c
P7c
P8c
P9c
P10c
P11c
P12c
P13c
P14c
P15c
P16c
e2
e5
249
e1
e4
Phs
T3s
Pls
SHs
SH
42
TARGET HIGH PRESSURE CALCULATOR
46
TARGET INTERMEDIATE PRESSURE SATURATION TEMPERATURE CALCULATOR
41
TARGET LOW PRESSURE CALCULATOR
44
TARGET SUPERHEAT DEGREE CALCULATOR
ACTUAL SUPERHEAT DEGREE CALCULATOR
45
et
240
T4
T0
Ta
Ts

FIG.6



AIR CONDITIONER
210
240
249
42
TARGET HIGH PRESSURE CALCULATOR
46
TARGET INTERMEDIATE PRESSURE SATURATION TEMPERATURE CALCULATOR
47
TARGET GAS COOLER OUTLET TEMPERATURE CALCULATOR
44
TARGET SUPERHEAT DEGREE CALCULATOR
45
ACTUAL SUPERHEAT DEGREE CALCULATOR
PID1d
PID2d
PID3d
PID4d
PID5d
PID6d
PID7d
PID8d
PID9d
PID10d
PID11d
PID12d
PID13d
PID14d
PID15d
PID16d
P1d
P2d
P3d
P4d
P5d
P6d
P7d
P8d
P9d
P10d
P11d
P12d
P13d
P14d
P15d
P16d
Ph
T3
T4
T2
⊿fc1
⊿fc2
⊿ev1
⊿ev2
Phs
T3s
T4s
SHs
SH
e2
e5
e6
e4
et
Ts
Ta
T0
Pl

FIG.7

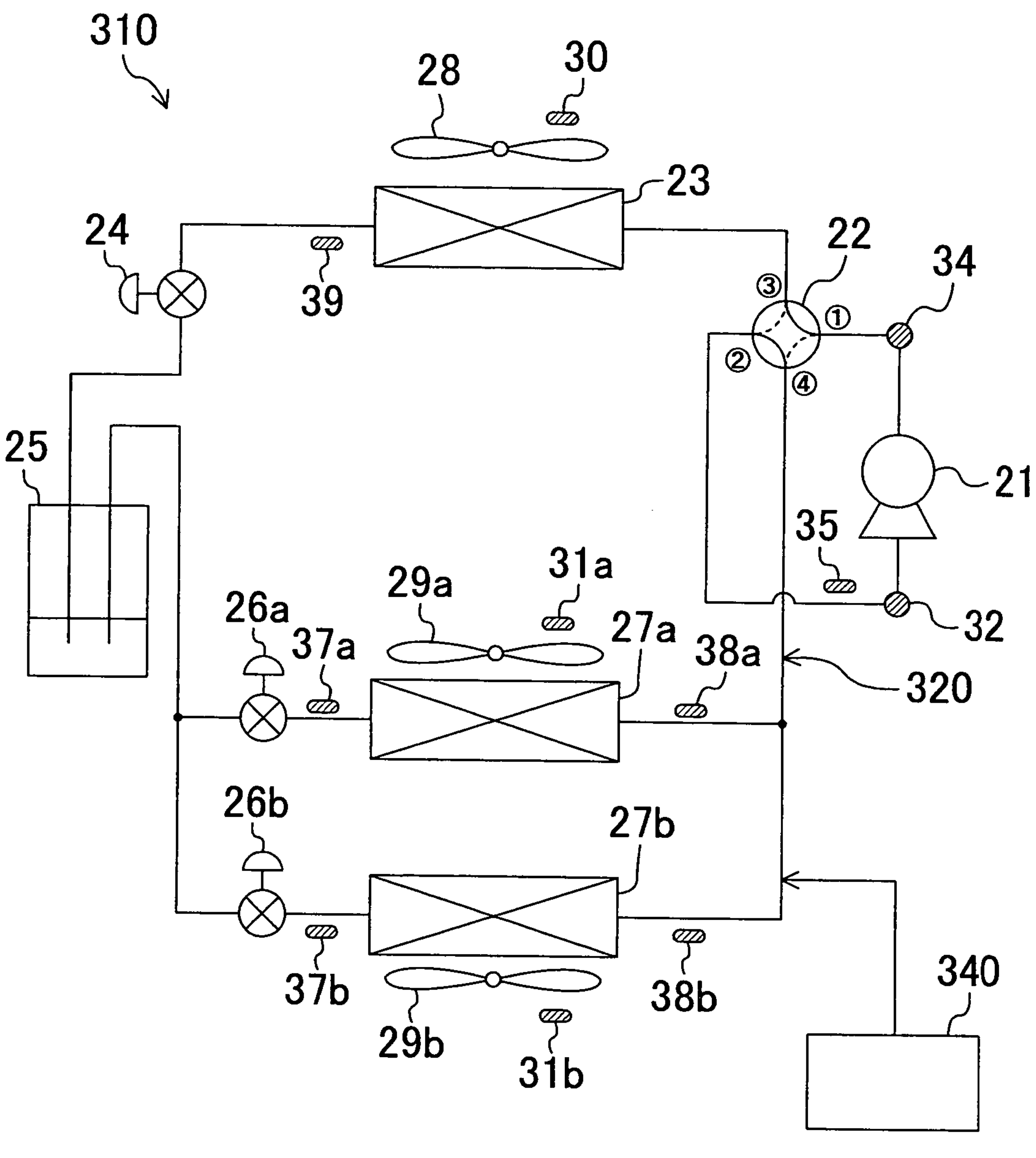
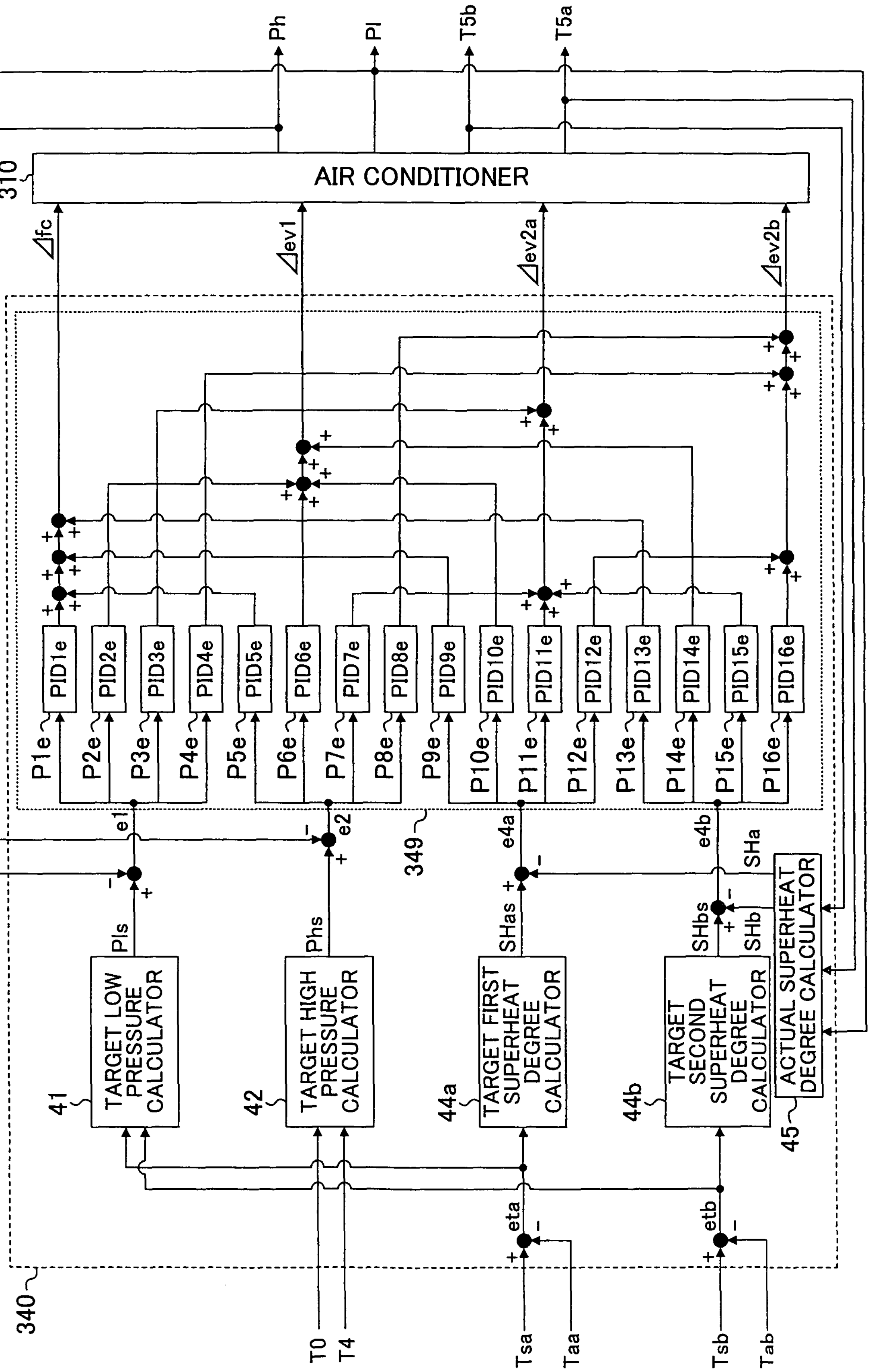
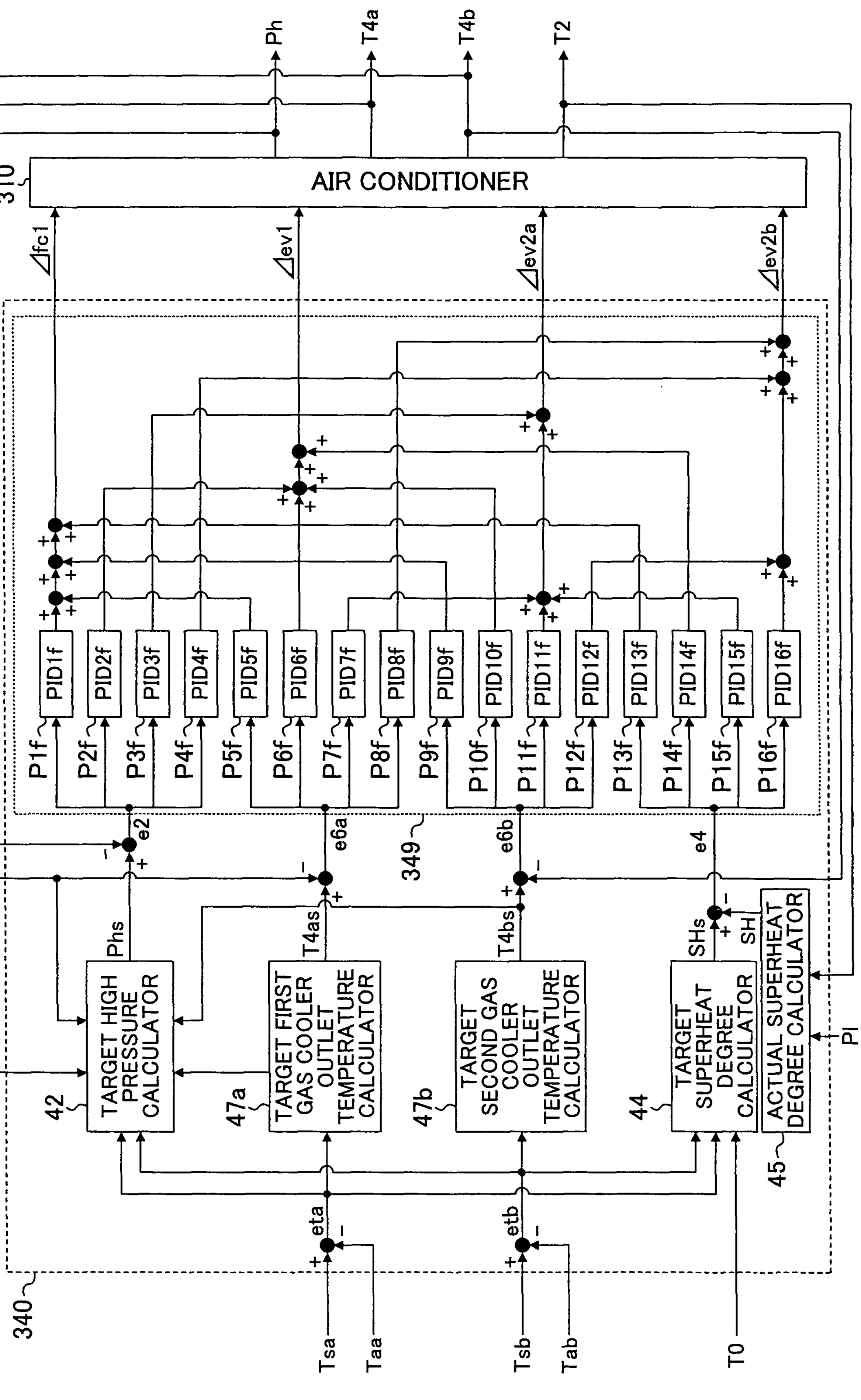

310
28
30
23
24
39
22
34
③
①
②
④
25
21
35
31a
29a
26a
37a
27a
38a
32
320
26b
27b
37b
29b
31b
38b
340

FIG.8


340
AIR CONDITIONER
310
Ph
Pl
T5b
T5a
Δfc
Δev1
Δev2a
Δev2b
PID1e
PID2e
PID3e
PID4e
PID5e
PID6e
PID7e
PID8e
PID9e
PID10e
PID11e
PID12e
PID13e
PID14e
PID15e
PID16e
P1e
P2e
P3e
P4e
P5e
P6e
P7e
P8e
P9e
P10e
P11e
P12e
P13e
P14e
P15e
P16e
349
e1
e2
e4a
e4b
Pls
Phs
SHas
SHbs
SHa
SHb
41
TARGET LOW PRESSURE CALCULATOR
42
TARGET HIGH PRESSURE CALCULATOR
44a
TARGET FIRST SUPERHEAT DEGREE CALCULATOR
44b
TARGET SECOND SUPERHEAT DEGREE CALCULATOR
45
ACTUAL SUPERHEAT DEGREE CALCULATOR
eta
etb
T0
T4
Tsa
Taa
Tsb
Tab



AIR CONDITIONER
310
Ph
T4a
T4b
T2
⊿fc1
⊿ev1
⊿ev2a
⊿ev2b
PID1f
PID2f
PID3f
PID4f
PID5f
PID6f
PID7f
PID8f
PID9f
PID10f
PID11f
PID12f
PID13f
PID14f
PID15f
PID16f
P1f
P2f
P3f
P4f
P5f
P6f
P7f
P8f
P9f
P10f
P11f
P12f
P13f
P14f
P15f
P16f
e2
e6a
e6b
e4
349
Phs
T4as
T4bs
SHs
SH
TARGET HIGH PRESSURE CALCULATOR
TARGET FIRST GAS COOLER OUTLET TEMPERATURE CALCULATOR
TARGET SECOND GAS COOLER OUTLET TEMPERATURE CALCULATOR
TARGET SUPERHEAT DEGREE CALCULATOR
ACTUAL SUPERHEAT DEGREE CALCULATOR
PI
42
47a
47b
44
45
eta
etb
340
Tsa
Taa
Tsb
Tab
T0

FIG.9

FIG.10

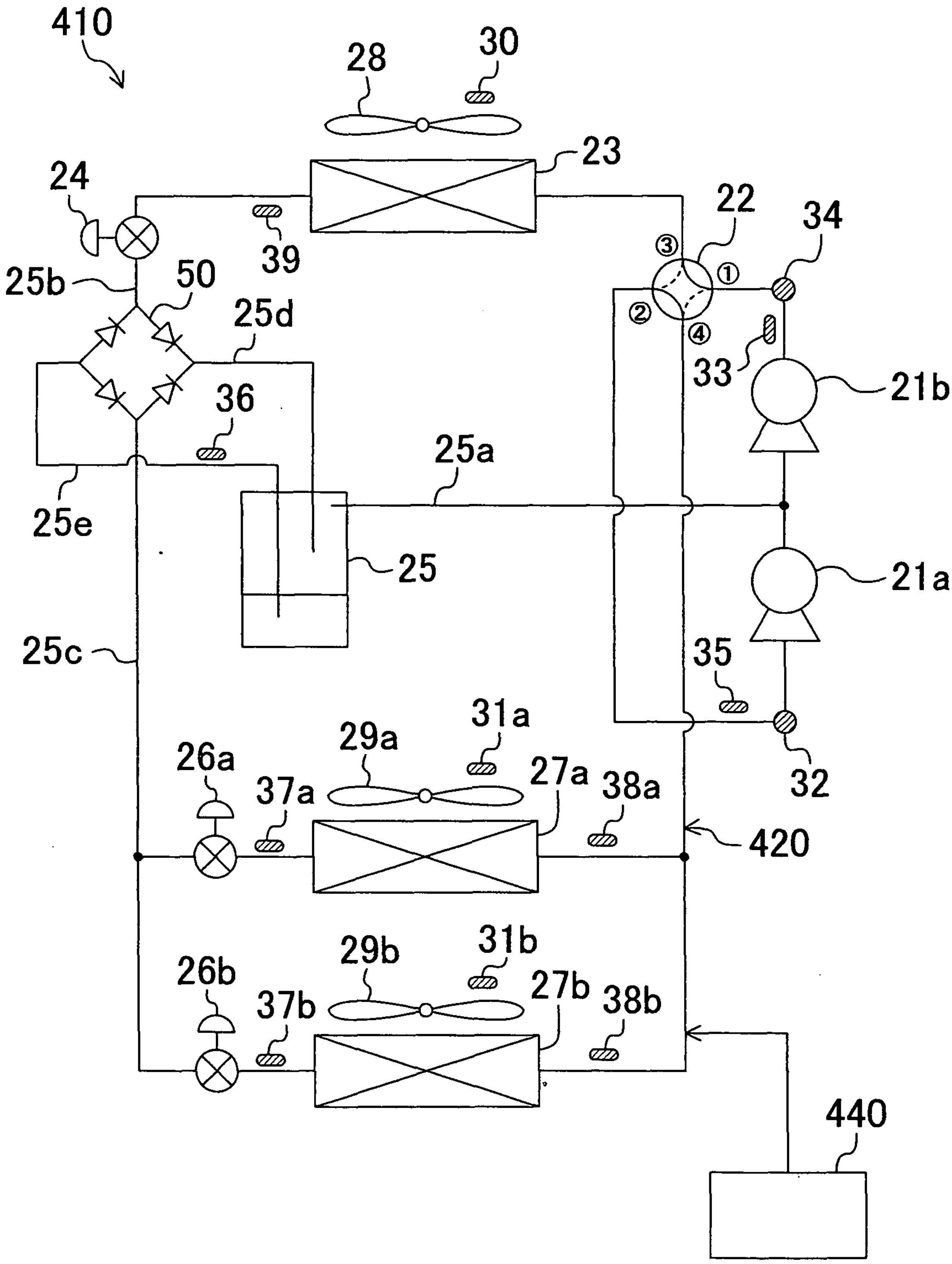
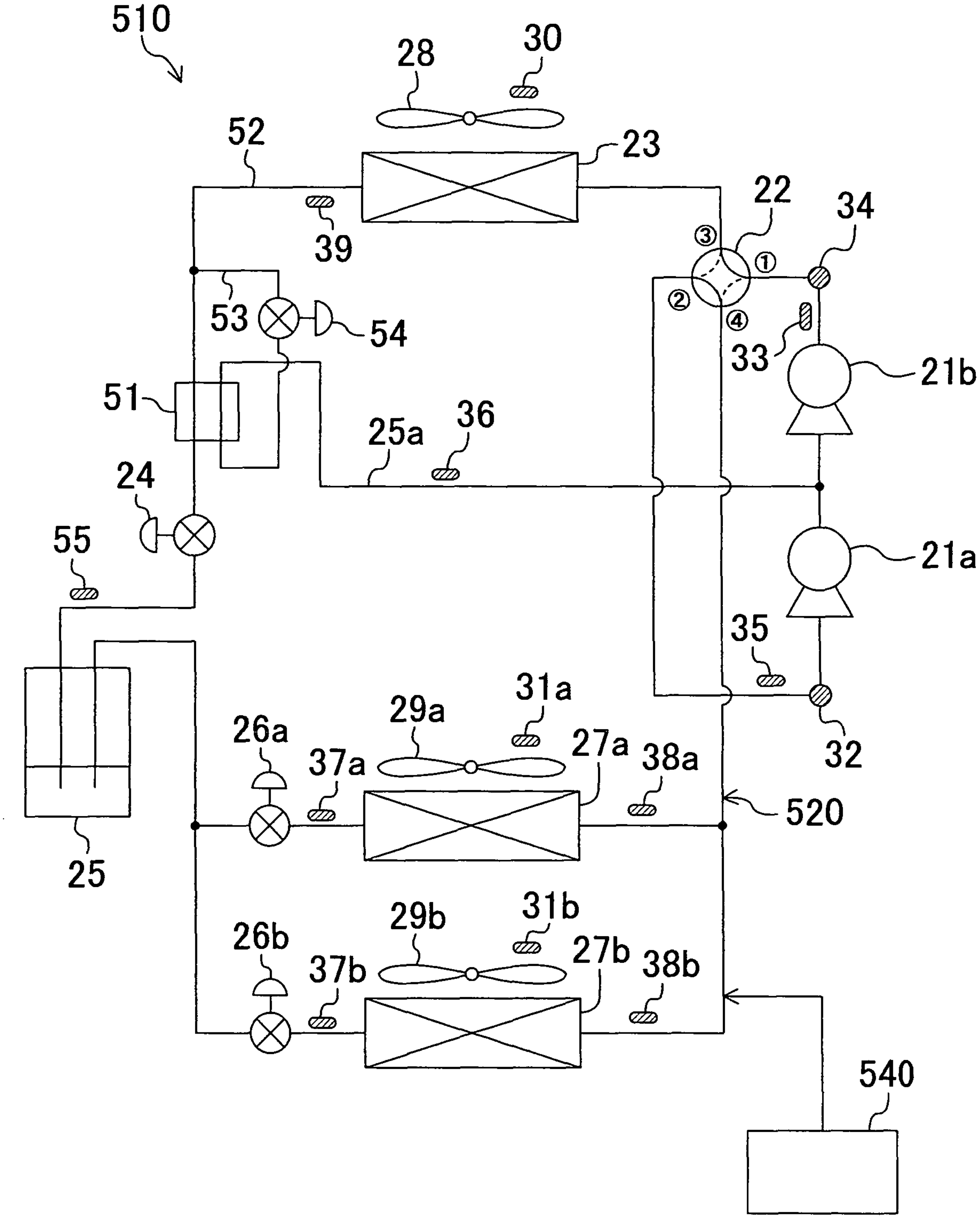

410
28
30
23
24
22
34
39
③
①
25b
50
25d
②
④
33
21b
36
25a
25e
25
21a
25c
35
31a
29a
32
26a
27a
38a
37a
420
31b
29b
26b
27b
38b
37b
440

FIG.11


510
28
30
52
23
22
34
39
③
①
②
④
53
54
33
21b
51
25a
36
24
21a
55
35
31a
29a
26a
27a
38a
32
37a
520
25
31b
29b
26b
27b
38b
37b
540

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/001493

A. CLASSIFICATION OF SUBJECT MATTER
F25B1/00(2006.01)i, *F25B1/10*(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)
F25B1/00, F25B1/10

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2008
Kokai Jitsuyo Shinan Koho	1971-2008	Toroku Jitsuyo Shinan Koho	1994-2008

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2000-297970 A (Yanmar Diesel Engine Co., Ltd.), 24 October, 2000 (24.10.00), Fig. 5 (Family: none)	1,2
X	JP 63-29155 A (Nippon Telegraph And Telephone Corp.), 06 February, 1988 (06.02.88), Fig. 2; Claims (Family: none)	1,2

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"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)
"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
"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
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 August, 2008 (26.08.08)	09 September, 2008 (09.09.08)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/001493

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See extra sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.: 1, 2

Remark on Protest the

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/001493

Continuation of Box No.III of continuation of first sheet(2)

The technical feature common to the inventions of claims 1, 2, claim 3, claim 4, claim 5, claim 6, claim 7, and claim 8 relates to the freezing device disclosed in claim 1.

However, the search has revealed that Document JP 2000-297970 A (Yanmar Diesel Engine Co., Ltd.) discloses an invention relating to that by controlling the compressor rpm and the expansion valve open degree (corresponding to "the control object" in the present application) in the freezing cycle, it is possible to control both of the discharge output (corresponding to "the high pressure" in the present application) and the overheat (corresponding to "the predetermined physical amount" in the present application).

Moreover, Document JP 63-29155 A (Nippon Telegraph And Telephone Corp.) also discloses an invention relating to that by controlling both of the compressor rpm and the expansion valve open degree (corresponding to "the control object" in the present application) in the freezing cycle, it is possible to control both of the chamber temperature and the overheat degree (corresponding to "the predetermined physical amount" in the present application).

The change of the control amount from "the chamber temperature" to "the high pressure" is merely a design change.

Moreover, in the technical field of the freezing cycle, the super-critical freezing cycle having a high pressure exceeding the critical pressure is a known technique.

As a result, the freezing device of claim 1 makes no contribution over the prior art. Accordingly, the common technical feature (the freezing device of claim 1) cannot be a special technical feature within the meaning of PCT Rule 13.2, second sentence.

Consequently, there exists no technical feature common to all the inventions of claims 1, 2, claim 3, claim 4, claim 5, claim 6, claim 7, and claim 8.

Since there exists no other common feature which can be considered as a special technical feature within the meaning of PCT Rule 13.2, second sentence, no technical relationship within the meaning of PCT Rule 13 between the different inventions can be seen.

As for the invention of claim 2, its examination is already complete. Accordingly, claim 2 is excluded from the requirement of unity of invention.

Therefore, it is obvious that the invention of claim 1 and the inventions of claim 3, claim 4, claim 5, claim 6, claim 7, and claim 8 do not satisfy the requirement of unity of invention.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2002022242 A **[0004]**