

DESCRIPTION

AIR CONDITIONING APPRATUS

TECHNICAL FIELD

The present invention relates to an air conditioning apparatus, in particular, an air conditioning apparatus that is configured by connecting a plurality of indoor units and an outdoor unit having a compressor and performs air conditioning operations so that an indoor temperature at each indoor unit arrives at a target indoor temperature at each indoor unit.

BACKGROUND ART

There have conventionally been air conditioning apparatuses that are configured by connecting a plurality of indoor units and an outdoor unit having a compressor. In a certain variety of such air conditioning apparatuses, air conditioning operations (air-cooling operation and air-warming operation) are performed so that the indoor temperature at each indoor unit arrives at a target temperature in each indoor unit. During such air conditioning operations, when the indoor temperature at each indoor unit reaches the target indoor temperature and air conditioning operations are no longer necessary, indoor thermo-off to suspend air conditioning operation at the indoor units is performed and outdoor thermo-off to stop the compressor is performed when all of the indoor units assume the indoor thermo-off state. When the indoor temperature deviates from the target temperature after outdoor thermo-off and air conditioning operations are needed, an outdoor thermo-on to restart the compressor is performed and an indoor thermo-on to restart the air conditioning operations of the indoor units is performed. Therefore, thermo-start/stop, in which outdoor thermo-off and outdoor thermo-on are repeated, is likely to occur when the air conditioning operations are performed with the air conditioning capacity requested by each indoor unit being low and the indoor temperature being close to the target indoor temperature.

In response to this problem, there are air conditioning apparatuses configured so as to set a time in which stopping of the compressor (i.e., outdoor thermo-off) is prohibited in order to reduce the frequency of thermo-start/stop, as in Patent Literature 1 (Japanese Laid-open Patent Application No. 4-93558).

SUMMARY OF THE INVENTION

In the method of thermo-start/stop reduction in Patent Literature 1, a time in which stopping of the compressor (i.e., outdoor thermo-off) is prohibited is set whereby the occurrence of outdoor thermo-off is suppressed and the frequency of thermo-start/stop can be reduced.

However, with such a method of setting a time in which outdoor thermo-off is

prohibited, when the prohibiting time is increased, the compressor might not be stopped even when the air conditioning capacity requested by each indoor unit decreases and the indoor temperature becomes a temperature not wanted for air conditioning operations, and air conditioning operation in a state of excess air conditioning capacity might be continued.

- 5 When the prohibiting time is set short, it might not be possible to suppress the occurrence of outdoor thermo-off and it might not be possible to sufficiently reduce the frequency of thermo-start/stop. Thus, by the method of setting a time in which outdoor thermo-off is prohibited, it is difficult to have the frequency of thermo-start/stop be reduced sufficiently while suppressing air conditioning operations in a state of excess air conditioning capacity.
- 10 Air conditioning operations in a state of excess air conditioning capacity and/or an increase in the frequency of thermo-start/stop may cause increased power consumption or lowered operating efficiency of the compressor, and therefore such circumstances should be remedied to the extent possible.

An object of the present invention is to provide an air conditioning apparatus that is
15 configured by connecting a plurality of indoor units and an outdoor unit having a compressor, and that performs air conditioning operations so that an indoor temperature at each indoor unit arrives at a target indoor temperature at each indoor unit, wherein the frequency of thermo-start/stop can be sufficiently reduced while suppressing air conditioning operations in a state of excess air conditioning capacity.

20 The air conditioning apparatus according to a first aspect is configured by connecting a plurality of indoor units and an outdoor unit having a compressor, and performs air conditioning operation so that an indoor temperature at each indoor unit arrives at a target indoor temperature at each indoor unit. The air conditioning apparatus has a controller to control a rotation speed of the compressor on the basis of a request value concerning air
25 conditioning capacity at each indoor unit during the air conditioning operation. The controller performs a start/stop frequency-reducing rotation speed control in which the rotation speed of the compressor is controlled on the basis of the request values from the indoor units requesting a decrease in air conditioning capacity, disregarding the request values from the indoor units requesting an increase in air conditioning capacity, when each indoor
30 temperature at all indoor units performing the air conditioning operation is within a scope of a prescribed threshold temperature range surrounding the target indoor temperature at each indoor unit performing the air conditioning operation.

According to the aspect described above, by performing start/stop frequency-reducing rotation speed control as described above, the rotation speed of the compressor is

kept low and the occurrence of stopping of the compressor; i.e., outdoor thermo-off, can be suppressed while reducing the air conditioning capacity. Therefore, when air conditioning operations are performed with conditions in which the air conditioning capacity requested by each indoor unit is small and the indoor temperature is close to the target indoor temperature, the operation of the compressor can be continued to the extent possible while reducing the air conditioning capacity. As a consequence thereof, in this example, the frequency of thermo-start/stop can be sufficiently reduced while suppressing air conditioning operations in a state of excess air conditioning capacity.

The air conditioning apparatus according to a second aspect is the air conditioning apparatus according to the first aspect, wherein the start/stop frequency-reducing rotation speed control is to control the rotation speed of the compressor on the basis of the request value for which the extent of decrease in air conditioning capacity is smallest among the request values from the indoor units requesting a decrease in air conditioning capacity.

When performing start/stop frequency-reducing rotation speed control, the extent of reduction of the frequency of thermo-start/stop, or the like, comes to vary depending on how the request values from the indoor units requesting a decrease in air conditioning capacity are used. Here, the extent of reduction of the frequency of thermo-start/stop is improved when the rotation speed of the compressor is kept low, but there appears a tendency for the air conditioning capacity to become insufficient at indoor units requesting an increase in air conditioning capacity, and indoor temperatures having come close to the target indoor temperature up to within the scope of the threshold temperature range might deviate from the target indoor temperature and go beyond the scope of the threshold temperature range.

Therefore, in the aspect described above, a configuration is adopted to use the request value for which the extent of decrease in air conditioning capacity is smallest among the request values from the indoor units requesting a decrease in air conditioning capacity as described above. Therefore, the rotation speed of the compressor can be kept low, and the tendency for the air conditioning capacity to become insufficient at indoor units requesting an increase in air conditioning capacity can be suppressed as much as possible.

As for how to use the request values from indoor units requesting a decrease in air conditioning capacity, it may also be considered to use the request value for which the extent of decrease in air conditioning capacity is greatest among the request values from indoor units requesting a decrease in air conditioning capacity, but in this case, although the rotation speed of the compressor can be kept very low, it becomes difficult to suppress the tendency for the air conditioning capacity to become insufficient at indoor units requesting an increase

in air conditioning capacity. It may also be considered to use the average value of the request values from indoor units requesting a decrease in air conditioning capacity, but in this case, the extent of keeping down the rotation speed of the compressor or the extent of suppressing the tendency for the air conditioning capacity to become insufficient at indoor units requesting an increase in air conditioning capacity comes to an intermediate extent between that of the case when using the request value for which the extent of decrease in air conditioning capacity is smallest and that of the case when using the request value for which the extent of decrease is greatest. Thus, when performing start/stop frequency-reducing rotation speed control, the extent of reduction of the frequency of thermo-start/stop, or the like, comes to vary depending on how the request values from indoor units requesting a decrease in air conditioning capacity are used. In this embodiment, emphasis is placed on the extent of suppressing the tendency for the air conditioning capacity to become insufficient at indoor units requesting an increase in air conditioning capacity, and it is arranged to use the request value for which the extent of decrease in air conditioning capacity is smallest among the request values from indoor units requesting a decrease in air conditioning capacity.

The air conditioning apparatus according to a third aspect is the air conditioning apparatus according to the first or second aspect, wherein the threshold temperature range is a thermo temperature range that specifies a timing of indoor thermo-off, which suspends the air conditioning operations of the indoor units performing the air conditioning operations and indoor thermo-on, which restarts the air conditioning operations of the indoor units in the indoor thermo-off state.

According to the aspect described above, by making the threshold temperature range coincide with the thermo temperature range, the rotation speed of the compressor can be kept low until all of the indoor units come to indoor thermo-off, and the occurrence of stopping of the compressor; i.e., outdoor thermo-off can be suppressed while reducing the air conditioning capacity.

The air conditioning apparatus according to a fourth aspect is the air conditioning apparatus according to any one of the first to third aspects, wherein the controller performs a normal rotation speed control in which the rotation speed of the compressor is controlled on the basis of the request value for which the extent of increase in air conditioning capacity is greatest among the request values from the indoor units requesting an increase in air conditioning capacity, when there are indoor units for which the indoor temperature is beyond the scope of the threshold temperature range and increase in air conditioning capacity is being requested among the indoor units performing the air conditioning operations.

According to the aspect described above, the normal rotation speed control and the start/stop frequency-reducing rotation speed control as described above come to be switched in accordance with the indoor temperatures at the indoor units performing air conditioning operations. In other words, when there are indoor units for which the indoor temperature is beyond the scope of the threshold temperature range and air conditioning capacity is being requested, the rotation speed of the compressor is controlled on the basis of the request value for which the extent of increase in air conditioning capacity is greatest, so that the indoor temperatures are quickly brought closer to the target indoor temperature. When the indoor temperatures at all indoor units performing air conditioning operations are within the scope of the threshold temperature range and the air conditioning capacity requested by each indoor unit has become small, the rotation speed of the compressor is controlled on the basis of the request value from the indoor unit requesting a decrease in air conditioning capacity, so that the operation of the compressor can be continued to the extent possible while reducing the air conditioning capacity. As a consequence thereof, in the aspect described above, the indoor temperatures can be quickly brought closer to the target indoor temperature during air conditioning operations, and air conditioning operations in a state of excess air conditioning capacity can be suppressed and the frequency of thermo-start/stop can be reduced thereafter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic structural diagram of the air conditioning apparatus according to an embodiment of the present invention.

FIG. 2 is a control block diagram of the air conditioning apparatus.

FIG. 3 is a diagram illustrating the relationship between a target indoor temperature and an indoor temperature at each indoor unit performing air conditioning operations (when the indoor temperature greatly deviates from the target indoor temperature).

FIG. 4 is a diagram illustrating the relationship between the target indoor temperature and the indoor temperature at each indoor unit performing air conditioning operations (when there is an indoor unit within a thermo temperature range).

FIG. 5 is a diagram illustrating the relationship between the target indoor temperature and the indoor temperature at each indoor unit performing air conditioning operations (when all indoor units have assumed the thermo-off state).

FIG. 6 is a diagram illustrating the relationship between the target indoor temperature and the indoor temperature at each indoor unit performing air conditioning operations (when the indoor temperatures of all indoor units are within the thermo temperature range).

FIG. 7 is a flow chart illustrating rotation speed control of a compressor including start/stop frequency-reducing rotation speed control.

FIG. 8 is a diagram illustrating the relationship between the target indoor temperature and the indoor temperature at each indoor unit performing air conditioning operations (when performing start/stop frequency-reducing rotation speed control).

DESCRIPTION OF EMBODIMENTS

An embodiment of the air conditioning apparatus according to the present invention is described below with reference to the drawings. The specific configuration of the embodiments of the air conditioning apparatus according to the present invention is not limited to the embodiment thereof described below, and modifications are possible within a range that does not depart from the scope of the invention.

(1) Basic configuration of the air conditioning apparatus

FIG. 1 is a schematic structural diagram of the air conditioning apparatus 1 according to an embodiment of the present invention. The air conditioning apparatus 1 is used for air conditioning a building or other indoor space by a vapor compression-type refrigerant cycle operation. The air conditioning apparatus 1 is mainly composed of an outdoor unit 2 and a plurality of (three, in this example) indoor units 4a, 4b, 4c that are connected to each other. In this embodiment, the outdoor unit 2 and the plurality of indoor units 4a, 4b, 4c are connected to each other via a liquid refrigerant communication pipe 6 and a gas refrigerant communication pipe 7. In other words, a vapor compression-type refrigerant circuit 10 of the air conditioning apparatus 1 is configured by the outdoor unit 2 and the plurality of indoor units 4a, 4b, 4c being connected to each other via the refrigerant communication pipes 6, 7. The number of indoor units is not limited to three and may be more than three or less than three.

<Indoor Unit>

The indoor units 4a, 4b, 4c are installed indoors. The indoor units 4a, 4b, 4c are connected to the outdoor unit 2 via the refrigerant communication pipes 6, 7, and constitute a portion of the refrigerant circuit 10.

Next, the configuration of the indoor units 4a, 4b, 4c shall be described. Because the indoor unit 4b and the indoor unit 4c have the same configuration as that of the indoor unit 4a, only the configuration of the indoor unit 4a is described in the present embodiment, and for the configurations of the indoor units 4b, 4c, the subscripts b and c are assigned instead of the subscript a which indicates the parts of the indoor unit 4a, and descriptions of the indoor units 4b, 4c is omitted.

The indoor unit 4a mainly has an indoor-side refrigerant circuit 10a (indoor-side refrigerant circuit 10b, 10c in the indoor unit 4b, 4c) constituting a portion of the refrigerant circuit 10. The indoor-side refrigerant circuit 10a mainly has an indoor expansion valve 41a and an indoor heat exchanger 42a.

5 The indoor expansion valve 41a is a valve for decompressing refrigerant flowing through the indoor-side refrigerant circuit 10a to regulate the flow rate of the refrigerant. The indoor expansion valve 41a is an electric expansion valve connected to the liquid side of the indoor heat exchanger 42a.

10 The indoor heat exchanger 42a is a heat exchanger that functions as a refrigerant evaporator or refrigerant radiator, and is configured from a plurality of heat transfer tubes and a plurality of fins. An indoor fan 43a for sending indoor air to the indoor heat exchanger 42a is provided close to the indoor heat exchanger 42a. Indoor air is blown onto the indoor heat exchanger 42a by the indoor fan 43a, whereby heat exchange is brought about between the refrigerant and the indoor air in the indoor heat exchanger 42a. The indoor fan 43a is
15 rotatably driven by an indoor fan motor 44a.

 Various sensors are provided to the indoor unit 4a. A liquid-side temperature sensor 45a for detecting the temperature $Tr1a$ of refrigerant in a liquid state or in a gas-liquid two-phase state is provided to the liquid side of the indoor heat exchanger 42a. On the gas side of the indoor heat exchanger 42a, a gas-side temperature sensor 46a is provided for detecting the
20 temperature $Trga$ of the gas-state refrigerant. On the indoor air intake port side of the indoor unit 4a, there is provided an indoor temperature sensor 47a for detecting the air temperature in the air-conditioned space cooled or heated by the indoor heat exchanger 42a of the indoor unit 4a; i.e., the temperature (indoor temperature Tra) of the indoor air in the indoor unit 4. The indoor unit 4a has an indoor-side controller 48a to control the actions of the components
25 constituting the indoor unit 4a. The indoor-side control controller 48a has a microcomputer, memory, and the like provided to control the indoor unit 4a, and is capable of exchanging control signals and the like with the remote control 49a for individually operating the indoor unit 4a and exchanging control signals or the like with the outdoor unit 2. The remote control 49a is a device for the user to perform various settings concerning air conditioning operations
30 or to send operate/stop commands. The indoor temperature sensor 47a may be provided in the remote control 49a rather than in the indoor unit 4a.

<Outdoor Unit>

The outdoor unit 2 is installed outdoors. The outdoor unit 2 is connected to the indoor units 4a, 4b, 4c via the refrigerant communication pipes 6, 7 and constitutes a portion

of the refrigerant circuit 10.

Next, the configuration of the outdoor unit 2 shall be described.

The outdoor unit 2 mainly has an outdoor-side refrigerant circuit 10d constituting a portion of the refrigerant circuit 10. The outdoor-side refrigerant circuit 10d mainly has a
5 compressor 21, a four-way switching valve 22, an outdoor heat exchanger 23, an outdoor expansion valve 25, a liquid-side shutoff valve 26, and a gas-side shutoff valve 27.

The compressor 21 is a hermetic compressor in which a compression element (not shown) and a compressor motor 21a for rotatably driving the compression element are accommodated in a casing. The compressor motor 21a is designed so that electric power is
10 supplied via an inverter device (not shown), and the operating capacity can be varied by changing the output frequency (i.e., the rotational speed) of the inverter device.

The four-way switching valve 22 is a valve for switching the direction of the flow of the refrigerant. The four-way switching valve 22 is capable of connecting the discharge side of the compressor 21 with the gas side of the outdoor heat exchanger 23 and connecting the
15 intake side of the compressor 21 with the gas refrigerant communication pipe 7 (see the solid line of the four-way switching valve 22 in FIG. 1) to enable the outdoor heat exchanger 23 to function as a radiator of refrigerant compressed in the compressor 21 and to enable the indoor heat exchangers 42a, 42b, 42c to function as evaporators of refrigerant radiated in the outdoor heat exchanger 23 during an air-cooling operation as one of the air conditioning operations.
20 The four-way switching valve 22 is capable of connecting the discharge side of the compressor 21 with the gas refrigerant communication pipe 7 and connecting the intake side of the compressor 21 with the gas side of the outdoor heat exchanger 23 (see the broken line of the four-way switching valve 22 in FIG. 1) to enable the indoor heat exchangers 42a, 42b, 42c to function as radiators of refrigerant compressed in the compressor 21 and to enable the
25 outdoor heat exchanger 23 to function as an evaporator of refrigerant radiated in the indoor heat exchangers 42a, 42b, 42c during an air-warming operation as another of the air cooling operations.

The outdoor heat exchanger 23 is a heat exchanger that functions as a refrigerant radiator or a refrigerant evaporator, and is configured with a plurality of heat transfer tubes and a plurality of fins. Provided in proximity to the outdoor heat exchanger 23 is an outdoor
30 fan 28 for sending outdoor air to the outdoor heat exchanger 23. Outdoor air is blown onto the outdoor heat exchanger 23 by the outdoor fan 28, whereby heat exchange is brought about between the refrigerant and the outdoor air in the outdoor heat exchanger 23. The outdoor fan 28 is rotatably driven by an outdoor fan motor 28a.

The outdoor expansion valve 25 decompresses refrigerant flowing through the outdoor-side refrigerant circuit 10d. The outdoor expansion valve 25 is an electric expansion valve connected to the liquid side of the outdoor heat exchanger 23.

The liquid-side shutoff valve 26 and the gas-side shutoff valve 27 are provided to the connection ports of the exterior devices and pipes (specifically, the liquid refrigerant communication pipe 6 and the gas refrigerant communication pipe 7). The liquid-side shutoff valve 26 is connected to the outdoor expansion valve 25. The gas-side shutoff valve 27 is connected to the four-way switching valve 22.

Various sensors are provided to the outdoor unit 2. The outdoor unit 2 is provided with an intake pressure sensor 29 for detecting the intake pressure P_s of the compressor 21, a discharge pressure sensor 30 for detecting the discharge pressure P_d of the compressor 21, an intake temperature sensor 31 for detecting the intake temperature T_s of the compressor 21, and a discharge temperature sensor 32 for detecting the discharge temperature T_d of the compressor 21. The intake temperature sensor 31 is provided on the intake side of the compressor 21. A liquid-side temperature sensor 33 for detecting the temperature T_{ol} of refrigerant in a liquid state or in a gas-liquid two-phase state is provided to the liquid side of the outdoor heat exchanger 23. On the outdoor air intake port side of the outdoor unit 2, there is provided an outside air temperature sensor 34 for detecting the temperature (outside air temperature T_a) of the outdoor air in the outdoor unit 2. The outdoor unit 2 has an outdoor-side controller 35 to control the actions of the components constituting the outdoor unit 2. The outdoor-side controller 35 has a microcomputer, memory, an inverter circuit to control the compressor motor 21a and the like provided to control the outdoor unit 2, and is capable of exchanging control signals and the like with the indoor-side controllers 48a, 48b, 48c of the indoor units 4a, 4b, 4c.

<Refrigerant Communication Pipes>

The refrigerant communication pipes 6, 7 are refrigerant pipes constructed on-site when the air conditioning apparatus 1 is installed. The liquid refrigerant communication pipe 6 extends from a liquid-side connection port (in this example, the liquid-side shutoff valve 26) of the outdoor unit 2, branches partway therealong to the plurality of (in the present embodiment, three) indoor units 4a, 4b, 4c, and extends to liquid-side connection ports (in the present embodiment, refrigerant pipes connected to the indoor expansion valves 41a, 41b, 41c) of the indoor units 4a, 4b, 4c. The gas refrigerant communication pipe 7 extends from a gas-side connection port (in the present embodiment, the gas-side shutoff valve 27) of the outdoor unit 2, branches partway therealong to a plurality of (in the present embodiment,

three) indoor units 4a, 4b, 4c, and extends to gas-side connection ports (in the present embodiment, refrigerant pipes connected to the gas sides of the indoor heat exchangers 42a, 42b, 42c) of the indoor units 4a, 4b, 4c. The refrigerant communication pipes 6, 7 having various lengths or pipe diameters are used in accordance with the conditions of setup of the outdoor unit 2 and the indoor units 4a, 4b, 4c.

<Controller>

Remote controls 49a, 49b, 49c for individually operating the indoor units 4a, 4b, 4c, the indoor-side controllers 48a, 48b, 48c of the indoor units 4a, 4b, 4c, and the outdoor-side controller 35 of the outdoor unit 2 compose of a controller 8 to control the overall operation of the air conditioning apparatus 1. The controller 8 is connected so as to be able to receive detection signals from the various sensors 29 to 34, 45a to 45c, 46a to 46c, 47a to 47c, and the like, as shown in FIG. 2. The controller 8 is configured so as to be able to carry out air conditioning operations (air-cooling operation and air-warming operation) by controlling the various devices and valves 21a, 22, 25, 28a, 41a to 41c, 44a to 44c on the basis of these detection signals or the like. FIG. 2 is a control block diagram of the air-conditioning apparatus 1.

As above, the air conditioning apparatus 1 is configured by connecting the plurality of (in the present embodiment, three) indoor units 4a, 4b, 4c with the outdoor unit 2 having the compressor 21, and performs air conditioning operations so that an indoor temperature T_{ra} , T_{rb} , T_{rc} at each indoor unit 4a, 4b, 4c arrives at a target indoor temperature T_{ras} , T_{rbs} , T_{rcs} at each indoor unit 4a, 4b, 4c. Setting of these target indoor temperatures T_{ras} , T_{rbs} , T_{rcs} is performed by users using the remote controls 49a, 49b, 49c.

(2) Basic actuation and basic control of the air conditioning apparatus

<Basic actuation>

The basic actuation of the air-conditioning operation (air-cooling operation and air-warming operation) of the air conditioning apparatus 1 is next described with reference to FIG. 1.

-Air-cooling operation-

When commands for the air-cooling operation are given from the remote controls 49a, 49b, 49c, the four-way switching valve 22 is switched to the air-cooling operation state (state indicated by the solid line of the four-way switching valve 22 in FIG. 1), and the compressor 21, outdoor fan 28, and indoor fans 43a, 43b, 43c are started up.

At this time, the low-pressure gas refrigerant in the refrigerant circuit 10 is taken into the compressor 21 and compressed to become a high-pressure gas refrigerant. This high-

pressure gas refrigerant is fed to the outdoor heat exchanger 23 through the four-way switching valve 22. The high-pressure gas refrigerant sent to the outdoor heat exchanger 23 is condensed by undergoing heat exchange with outdoor air fed by the outdoor fan 28 and being cooled to become high-pressure liquid refrigerant in the outdoor heat exchanger 21, which
5 functions as a radiator for the refrigerant. The high-pressure liquid refrigerant is sent from the outdoor unit 2 to the indoor units 4a, 4b, 4c via the outdoor expansion valve 25, the liquid-side shutoff valve 26 and the liquid refrigerant communication pipe 6.

The high-pressure liquid refrigerant sent to the indoor units 4a, 4b, 4c is decompressed by the indoor expansion valves 41a, 41b, 41c to become low-pressure
10 refrigerant in gas-liquid two-phase state. The low-pressure refrigerant in a gas-liquid two-phase state is sent to the indoor heat exchangers 42a, 42b, 42c. The low-pressure refrigerant in a gas-liquid two-phase state sent to the indoor heat exchangers 42a, 42b, 42c is evaporated by undergoing heat exchange with indoor air fed by the indoor fans 43a, 43b, 43c and being heated to become low-pressure gas refrigerant in the indoor heat exchangers 42a, 42b, 42c,
15 which function as evaporators for the refrigerant. The low-pressure gas refrigerant is sent from the indoor units 4a, 4b, 4c to the outdoor unit 2 via the gas refrigerant communication pipe 7.

The low-pressure gas refrigerant sent to the outdoor unit 2 is again taken into the compressor 21 via the gas-side shutoff valve 27 and the four-way switching valve 22.

20 -Air-warming operation-

When commands for the air-warming operation are given from the remote controls 49a, 49b, 49c, the four-way switching valve 22 is switched to the air-warming operation state (state indicated by the broken line of the four-way switching valve 22 in FIG. 1), and the compressor 21, outdoor fan 28, and indoor fans 43a, 43b, 43c are started up.

25 At this time, the low-pressure gas refrigerant in the refrigerant circuit 10 is taken into the compressor 21 and compressed to become a high-pressure gas refrigerant. The high-pressure gas refrigerant is sent from the outdoor unit 2 to the indoor units 4a, 4b, 4c via the four-way switching valve 22, the gas-side shutoff valve 27 and the gas refrigerant communication pipe 7.

30 The high-pressure gas refrigerant sent to the indoor units 4a, 4b, 4c is sent to the indoor heat exchangers 42a, 42b, 42c. The high-pressure gas refrigerant sent to the indoor heat exchangers 42a, 42b, 42c is condensed by undergoing heat exchange with indoor air fed by the indoor fans 43a, 43b, 43c and being cooled to become high-pressure liquid refrigerant in the indoor heat exchangers 42a, 42b, 42c, which function as radiators for the refrigerant.

The high-pressure liquid refrigerant is decompressed by the indoor expansion valves 41a, 41b, 41c. The refrigerant decompressed by the indoor expansion valves 41a, 41b, 41c is sent from the indoor units 4a, 4b, 4c to the outdoor unit 2 via the gas refrigerant communication pipe 7.

5 The refrigerant sent to the outdoor unit 2 is sent to the outdoor expansion valve 25 via the gas-side shutoff valve 27 and decompressed by the outdoor expansion valve 25 to become low-pressure refrigerant in a gas-liquid two-phase state. The low-pressure refrigerant in a gas-liquid two-phase state is sent to the outdoor heat exchanger 23. The low-pressure refrigerant in a gas-liquid two-phase state sent to the outdoor heat exchanger 23 is evaporated by undergoing heat exchange with outdoor air fed by the outdoor fan 28 and being heated to
10 become low-pressure gas refrigerant in the outdoor heat exchanger 23, which functions as an evaporator for the refrigerant. The low-pressure refrigerant in a gas state is again taken into the compressor 21 by way of the four-way switching valve 22.

<Basic control>

15 In the above air conditioning operations (air-cooling operation and air-warming operation), the air conditioning capacities (air-cooling capacity and air-warming capacity) as below are controlled so that the indoor temperature T_{ra} , T_{rb} , T_{rc} at each indoor unit 4a, 4b, 4c is brought to the target indoor temperature T_{ras} , T_{rbs} , T_{rcs} at each indoor unit 4a, 4b, 4c.

-During air-cooling operation-

20 When the air conditioning operation is the air-cooling operation, the controller 8 controls the capacity of the compressor 21 on the basis of a target evaporation temperature T_{es} .

Capacity control of the compressor 21 is accomplished by controlling the rotation speed (operating frequency) of the compressor 21 (more specifically, the compressor motor 21a). Specifically, the rotation speed of the compressor 21 is controlled so that an evaporation
25 temperature T_e of the refrigerant equivalent to a low pressure P_e of the refrigerant circuit 10 arrives at the target evaporation temperature T_{es} . Here, low pressure P_e signifies the pressure representative of low-pressure refrigerant flowing from outlets of the indoor expansion valves 41a, 41b, 41c through the indoor heat exchangers 42a, 42b, 42c to the intake side of the compressor 21 during the air-cooling operation. In this embodiment, an intake pressure P_s ,
30 which is the refrigerant pressure detected by the intake pressure sensor 29, is used as the low pressure P_e , and a value obtained by converting the intake pressure P_s to the saturation temperature of the refrigerant is the evaporation temperature T_e of the refrigerant.

The target evaporation temperature T_{es} in capacity control (rotation speed control) of the compressor 21 is decided in the controller 8 on the basis of request values ΔQCa ,

ΔQCb , ΔQCc concerning the air-cooling capacity at each indoor unit 4a, 4b, 4c performing the air-cooling operation.

Specifically, first, each temperature difference $\Delta TCra$, $\Delta TCrb$, $\Delta TCrc$ is obtained by subtracting each target indoor temperature $Tras$, $Trbs$, $Trcs$ from each indoor temperature Tra , Trb , Trc at each indoor unit 4a, 4b, 4c performing the air-cooling operation. The request values ΔQCa , ΔQCb , ΔQCc concerning the air-cooling capacity at each indoor unit 4a, 4b, 4c performing the air-cooling operation are calculated on the basis of these temperature differences $\Delta TCra$, $\Delta TCrb$, $\Delta TCrc$. Here, when the temperature differences $\Delta TCra$, $\Delta TCrb$, $\Delta TCrc$ are positive values; i.e., when the indoor temperatures Tra , Trb , Trc have not reached the target indoor temperatures $Tras$, $Trbs$, $Trcs$, it signifies that an increase in air-cooling capacity is requested, and the extent of the request for increase in air-cooling capacity is greater as the absolute values of these are greater. Meanwhile, when the temperature differences $\Delta TCra$, $\Delta TCrb$, $\Delta TCrc$ are negative values; i.e., when the indoor temperatures Tra , Trb , Trc have reached the target indoor temperatures $Tras$, $Trbs$, $Trcs$, this signifies that a decrease in air-cooling capacity is requested, and the extent of the request for decrease in air-cooling capacity is greater as the absolute values of these are greater. Therefore, as with the temperature differences $\Delta TCra$, $\Delta TCrb$, $\Delta TCrc$, the request values ΔQCa , ΔQCb , ΔQCc concerning the air-cooling capacity are also values signifying the direction and extent of increase or decrease in air-cooling capacity.

When an increase in air-cooling capacity is requested; i.e., when the request values ΔQCa , ΔQCb , ΔQCc concerning the air-cooling capacity are positive values, the target evaporation temperature Tes is decided to be lower than the current value in accordance with the extent of increase (absolute value of the request value), whereby the rotation speed of the compressor 21 is increased and the air-cooling capacity is increased. Meanwhile, when a decrease in the air-cooling capacity is requested; i.e., when the request values ΔQCa , ΔQCb , ΔQCc concerning the air-cooling capacity are negative values, the target evaporation temperature Tes is decided to be higher than the current value in accordance with the extent of decrease (absolute value of the request value), whereby the rotation speed of the compressor 21 is decreased and the air-cooling capacity is decreased.

Here, at each indoor unit 4a, 4b, 4c performing the air-cooling operation, various requests for increase or decrease in air-cooling capacity (request values ΔQCa , ΔQCb , ΔQCc) are made in accordance with each temperature difference $\Delta TCra$, $\Delta TCrb$, $\Delta TCrc$. However, the target evaporation temperature Tes is a target value that is common to all indoor units 4a, 4b, 4c. Therefore, the target evaporation temperature Tes must be set to a value representative

of the requests for increase or decrease in air-cooling capacity at all indoor units 4a, 4b, 4c. Therefore, the target evaporation temperature T_{es} is decided on the basis of the request value for which the target evaporation temperature T_{es} is lowest among the request values ΔQCa , ΔQCb , ΔQCc concerning the air-cooling capacity. For example, when the request values ΔQCa , ΔQCb , ΔQCc concerning the air-cooling capacity are evaporation temperatures requested at the indoor units 4a, 4b, 4c, the lowest request value of these is selected as the target evaporation temperature T_{es} . Specifically, when the request value ΔQCa as the evaporation temperature requested at the indoor unit 4a is 5°C, the request value ΔQCb as the evaporation temperature requested at the indoor unit 4b is 7°C, and the request value ΔQCc as the evaporation temperature requested at the indoor unit 4c is 10°C, then 5°C being the request value ΔQCa that is the lowest request value of these is selected as the target evaporation temperature T_{es} . When the request values ΔQCa , ΔQCb , ΔQCc concerning the air-cooling capacity are values indicating the extent of increase or decrease of evaporation temperature requested at the indoor units 4a, 4b, 4c, the target evaporation temperature T_{es} is decided on the basis of the request value for which the air-cooling capacity is greatest of these. Specifically, if the current target evaporation temperature T_{es} is 12°C and the request values ΔQCa , ΔQCb , ΔQCc concerning the air-cooling capacity indicate how low to set the evaporation temperature, and when the request value ΔQCa requested at the indoor unit 4a is 7°C, the request value ΔQCb requested at the indoor unit 4b is 5°C, and the request value ΔQCc requested at the indoor unit 4c is 2°C, then 7°C being the request value ΔQCa that is the greatest request value of these is adopted, and the temperature (5°C) obtained by subtracting from the current target evaporation temperature T_{es} (12°C) is set as the target evaporation temperature T_{es} .

In this embodiment, the rotation speed of the compressor 21 is controlled so that the evaporation temperature T_e of the refrigerant arrives at the target evaporation temperature T_{es} , but instead of this, the rotation speed of the compressor 21 may be controlled so that the low pressure P_e (intake pressure P_s) equivalent to the evaporation temperature T_e of the refrigerant arrives at the target low pressure P_{es} . In this case, the request values ΔQCa , ΔQCb , ΔQCc used also become values corresponding to the low pressure P_e or the target low pressure P_{es} .

Thermo control, as described below, is performed by the controller 8 when the indoor temperatures T_{ra} , T_{rb} , T_{rc} at the indoor units 4a, 4b, 4c reach the target indoor temperatures T_{ras} , T_{rbs} , T_{rcs} at the indoor units 4a, 4b, 4c by control of the air-cooling capacity as described above.

Thermo control is a control to set a thermo temperature range for the target indoor temperatures T_{ras} , T_{rbs} , T_{rcs} at the indoor units 4a, 4b, 4c, and perform indoor thermo-off, indoor thermo-on, outdoor thermo-off, and outdoor thermo-on. Here, indoor thermo-off is to suspend the air conditioning operation of the indoor unit performing air conditioning operation within the scope of the thermo temperature range when the indoor temperature at the indoor unit deviates from the thermo temperature range. Indoor thermo-on is to restart the air conditioning operation of the indoor unit in the indoor thermo-off state when the indoor temperature at the indoor unit in the indoor thermo-off state deviates from the thermo temperature range. Outdoor thermo-off is to stop the compressor 21 when all indoor units performing air conditioning operations have assumed the indoor thermo-off state. Outdoor thermo-on is to restart the compressor 21 when at least one indoor unit assumes the indoor thermo-on state during the outdoor thermo-off state. In this embodiment, upper limit values T_{rax} , T_{rbx} , T_{rcx} of the thermo temperature range at the indoor units 4a, 4b, 4c are values obtained by adding upper limit ranges ΔT_{ax} , ΔT_{bx} , ΔT_{cx} to the target indoor temperature T_{ras} , T_{rbs} , T_{rcs} . Lower limit values T_{ran} , T_{rbn} , T_{rcn} of the thermo temperature range at the indoor units 4a, 4b, 4c are values obtained by subtracting lower limit ranges ΔT_{an} , ΔT_{bn} , ΔT_{cn} from the target indoor temperatures T_{ras} , T_{rbs} , T_{rcs} .

For example, if the indoor unit 4a is an indoor unit performing the air-cooling operation, the controller 8 suspends the air-cooling operation of the indoor unit 4a when the indoor temperature T_{ra} at the indoor unit 4a deviates from the thermo temperature range by control of the above air-cooling capacity. More specifically, the controller 8 closes the indoor expansion valve 41a of the indoor unit 4a so that the refrigerant does not flow to the indoor heat exchanger 42a when the indoor temperature T_{ra} drops to the lower limit value T_{ran} by the air-cooling operation. As a consequence thereof, the indoor unit 4a assumes the indoor thermo-off state in which heat exchange between the refrigerant and the indoor air is not performed. Also, the controller 8 closes the indoor expansion valves 41b, 41c of the indoor units 4b, 4c and puts the indoor units 4b, 4c into the indoor thermo-off state, just as with the indoor unit 4a, when the indoor temperatures T_{rb} , T_{rc} drop to the lower limit values T_{rbn} , T_{rcn} .

Next, for example, if the indoor unit 4a is an indoor unit in the indoor thermo-off state, the controller 8 restarts the air-cooling operation of the indoor unit 4a when the indoor temperature T_{ra} at the indoor unit 4a deviates from the thermo temperature range. More specifically, the controller 8 opens the indoor expansion valve 41a of the indoor unit 4a so that the refrigerant flows to the indoor heat exchanger 42a when the indoor temperature T_{ra}

risers to the upper limit value Tr_{ax} by suspension of the air-cooling operation. As a consequence thereof, the indoor unit 4a assumes the indoor thermo-on state in which heat exchange between the refrigerant and the indoor air is performed. Also, the controller 8 opens the indoor expansion valves 41b, 41c of the indoor units 4b, 4c and puts the indoor units 4b, 4c into the indoor thermo-on state, just as with the indoor unit 4a, when the indoor temperatures Tr_b , Tr_c of the indoor units 4b, 4c in the indoor thermo-off state rise to the upper limit values Tr_{bx} , Tr_{cx} .

For example, if the indoor units 4a, 4b, 4c are indoor units performing the air-cooling operation and when all of the indoor units 4a, 4b, 4c have assumed the indoor thermo-off state, the controller 8 stops the compressor 21 and stops the flow of refrigerant in the refrigerant circuit 10. As a consequence thereof, the air conditioning apparatus 1 substantially assumes a state in which all air-cooling operations are stopped even though operating commands for the air-cooling operations have been given.

Next, for example, in the outdoor thermo-off state, if the indoor unit 4a is an indoor unit having assumed the indoor thermo-on state, the controller 8 restarts the compressor 21 when the indoor unit 4a assumes the indoor thermo-on state. More specifically, the controller 8 opens the indoor expansion valve 41a of the indoor unit 4a and restarts the compressor 21 so that the refrigerant flows in the refrigerant circuit 10 and to the indoor heat exchanger 42a when the indoor temperature Tr_a rises to the upper limit value Tr_{ax} by suspension of the air-cooling operation and stopping of the compressor 21. As a consequence thereof, the air conditioning apparatus 1 assumes the outdoor thermo-on state, and the indoor unit 4a assumes the indoor thermo-on state. Also, the controller 8 opens the indoor expansion valves 41b, 41c of the indoor units 4b, 4c and restarts the compressor 21, putting the air conditioning apparatus 1 into outdoor thermo-on state and putting the indoor units 4b, 4c into the indoor thermo-on state, just as with the indoor unit 4a, when the indoor temperatures Tr_b , Tr_c rise to the upper limit values Tr_{bx} , Tr_{cx} .

-During air-warming operation-

When the air conditioning operation is the air-warming operation, the controller 8 controls the capacity of the compressor 21 on the basis of a target condensation temperature T_{cs} .

Capacity control of the compressor 21 is accomplished by controlling the rotation speed (operating frequency) of the compressor 21 (more specifically, the compressor motor 21a). Specifically, the rotation speed of the compressor 21 is controlled so that condensation temperature T_c of the refrigerant equivalent to a high pressure P_c of the refrigerant circuit 10

arrives at the target condensation temperature T_{cs} . Here, high pressure P_c signifies the pressure representative of high-pressure refrigerant flowing from the discharge side of the compressor 21 through the indoor heat exchangers 42a, 42b, 42c the inlets of the indoor expansion valves 41a, 41b, 41c during the air-warming operation. In this embodiment, a
5 discharge pressure P_d being the refrigerant pressure detected by the discharge pressure sensor 30 is used as the high pressure P_c , and a value obtained by converting the discharge pressure P_d to the saturation temperature of the refrigerant is the condensation temperature T_c of the refrigerant.

The target condensation temperature T_{cs} in capacity control (rotation speed control)
10 of the compressor 21 is decided in the controller 8 on the basis of request values ΔQ_{Ha} , ΔQ_{Hb} , ΔQ_{Hc} concerning the air-warming capacity at each indoor unit 4a, 4b, 4c performing the air-warming operation.

Specifically, first, each temperature difference ΔTH_{ra} , ΔTH_{rb} , ΔTH_{rc} is obtained by subtracting each indoor temperature T_{ra} , T_{rb} , T_{rc} from each target indoor temperature T_{ras} ,
15 T_{rbs} , T_{rcs} at each indoor unit 4a, 4b, 4c performing the air-warming operation. The request values ΔQ_{Ha} , ΔQ_{Hb} , ΔQ_{Hc} concerning the air-warming capacity at each indoor unit 4a, 4b, 4c performing the air-warming operation are calculated on the basis of these temperature differences ΔTH_{ra} , ΔTH_{rb} , ΔTH_{rc} . Here, when the temperature differences ΔTH_{ra} , ΔTH_{rb} , ΔTH_{rc} are positive values; i.e., when the indoor temperatures T_{ra} , T_{rb} , T_{rc} have not reached
20 the target indoor temperatures T_{ras} , T_{rbs} , T_{rcs} , this signifies that an increase in air-warming capacity is requested, and the extent of the request for increase in air-warming capacity is greater as the absolute values of these are greater. Meanwhile, when the temperature differences ΔTH_{ra} , ΔTH_{rb} , ΔTH_{rc} are negative values; i.e., when the indoor temperatures T_{ra} , T_{rb} , T_{rc} have reached the target indoor temperatures T_{ras} , T_{rbs} , T_{rcs} , this signifies that a
25 decrease in air-warming capacity is requested, and the extent of the request for decrease in air-warming capacity is greater as the absolute values of these are greater. Therefore, the request values ΔQ_{Ha} , ΔQ_{Hb} , ΔQ_{Hc} concerning the air-warming capacity also, just as the temperature differences ΔTH_{ra} , ΔTH_{rb} , ΔTH_{rc} , are values signifying the direction and extent of increase or decrease in air-warming capacity.

30 When an increase in air-warming capacity is requested; i.e., when the request values ΔQ_{Ha} , ΔQ_{Hb} , ΔQ_{Hc} concerning the air-warming capacity are positive values, the target condensation temperature T_{cs} is decided to be higher than the current value in accordance with the extent of increase (absolute value of the request value), whereby the rotation speed of the compressor 21 is increased and the air-warming capacity is increased. Meanwhile,

when a decrease in air-warming capacity is requested; i.e., when the request values ΔQHa , ΔQHb , ΔQHc concerning the air-warming capacity are negative values, the target condensation temperature Tcs is decided to be lower than the current value in accordance with the extent of decrease (absolute value of the request value), whereby the rotation speed
5 of the compressor 21 is decreased and the air-warming capacity is decreased.

Here, at each indoor unit 4a, 4b, 4c performing the air-warming operation, various requests for increase or decrease in air-warming capacity (request values ΔQHa , ΔQHb , ΔQHc) are made in accordance with each temperature difference $\Delta THra$, $\Delta THrb$, $\Delta THrc$. However, the target condensation temperature Tcs is a target value that is common to all
10 indoor units 4a, 4b, 4c as with the target evaporation temperature Tes . Therefore, the target condensation temperature Tcs must be set to a value representative of the requests for increase or decrease in air-warming capacity at all indoor units 4a, 4b, 4c. Therefore, the target condensation temperature Tcs is decided on the basis of the request value for which the target condensation temperature Tcs is highest among the request values ΔQHa , ΔQHb , ΔQHc
15 concerning the air-warming capacity. For example, when the request values ΔQHa , ΔQHb , ΔQHc concerning the air-warming capacity are condensation temperatures requested at the indoor units 4a, 4b, 4c, the highest request value of these is selected as the target condensation temperature Tcs . Specifically, when the request value ΔQHa used as the condensation temperature requested at the indoor unit 4a is 45°C, the request value ΔQHb
20 used as the condensation temperature requested at the indoor unit 4b is 43°C, and the request value ΔQHc used as the condensation temperature requested at the indoor unit 4c is 40°C, then 45°C being the request value ΔQHa that is the highest request value of these is selected as the target condensation temperature Tcs . When the request values ΔQHa , ΔQHb , ΔQHc concerning the air-warming capacity are values indicating the extent of increase or decrease
25 of condensation temperature requested at the indoor units 4a, 4b, 4c, the target condensation temperature Tcs is decided on the basis of the request value for which the air-warming capacity is greatest among these. Specifically, if the current target condensation temperature Tcs is 38°C and the request values ΔQHa , ΔQHb , ΔQHc concerning the air-warming capacity indicate how high to set the condensation temperature, and when the request value ΔQHa
30 requested at the indoor unit 4a is 7°C, the request value ΔQHb requested at the indoor unit 4b is 5°C, and the request value ΔQHc requested at the indoor unit 4c is 2°C, then 7°C being the request value ΔQHa that is the greatest request value of these is adopted, and the temperature (45°C) obtained by adding to the current target condensation temperature Tcs (38°C) is set as the target condensation temperature Tcs .

In this embodiment, the rotation speed of the compressor 21 is controlled so that the condensation temperature T_c of the refrigerant arrives at the target condensation temperature T_{cs} , but instead of this, the rotation speed of the compressor 21 may be controlled so that the high pressure P_c (discharge pressure P_d) equivalent to the condensation temperature T_c of the refrigerant arrives at the target high pressure P_{cs} . In this case, the request values ΔQ_{Ha} , ΔQ_{Hb} , ΔQ_{Hc} used also become values corresponding to the high pressure P_c or the target high pressure P_{cs} .

Thermo control, as described below, is performed by the controller 8 when the indoor temperatures T_{ra} , T_{rb} , T_{rc} at the indoor units 4a, 4b, 4c reach the target indoor temperatures T_{ras} , T_{rbs} , T_{rcs} at the indoor units 4a, 4b, 4c by control of the air-warming capacity as described above.

This thermo control, as when the air-cooling operation is performed, is a control to set a thermo temperature range for the target indoor temperatures T_{ras} , T_{rbs} , T_{rcs} at the indoor units 4a, 4b, 4c, and perform indoor thermo-off, indoor thermo-on, outdoor thermo-off, and outdoor thermo-on.

For example, if the indoor unit 4a is an indoor unit performing the air-warming operation, the controller 8 suspends the air-warming operation of the indoor unit 4a when the indoor temperature T_{ra} at the indoor unit 4a deviates from the thermo temperature range by control of the air-warming capacity. More specifically, the controller 8 closes the indoor expansion valve 41a of the indoor unit 4a so that the refrigerant does not flow to the indoor heat exchanger 42a when the indoor temperature T_{ra} rises to the upper limit value T_{rax} by the air-warming operation. As a consequence thereof, the indoor unit 4a assumes the indoor thermo-off state in which heat exchange between the refrigerant and the indoor air is not performed. Also, the controller 8 closes the indoor expansion valves 41b, 41c of the indoor units 4b, 4c and puts the indoor units 4b, 4c into the indoor thermo-off state, just as with the indoor unit 4a, when the indoor temperatures T_{rb} , T_{rc} rise to the upper limit values T_{rbx} , T_{rcx} .

Next, for example, if the indoor unit 4a is an indoor unit in the indoor thermo-off state, the controller 8 restarts the air-warming operation of the indoor unit 4a when the indoor temperature T_{ra} at the indoor unit 4a deviates from the thermo temperature range. More specifically, the controller 8 opens the indoor expansion valve 41a of the indoor unit 4a so that the refrigerant flows to the indoor heat exchanger 42a when the indoor temperature T_{ra} drops to the lower limit value T_{ran} by suspension of the air-warming operation. As a consequence thereof, the indoor unit 4a assumes the indoor thermo-on state in which heat

exchange between the refrigerant and the indoor air is performed. Also, the controller 8 opens the indoor expansion valves 41b, 41c of the indoor units 4b, 4c and puts the indoor units 4b, 4c into the indoor thermo-on state, as with the indoor unit 4a, when the indoor temperatures Trb, Trc of the indoor units 4b, 4c in the indoor thermo-off state drop to the lower limit values Trbn, Trcn.

For example, if the indoor units 4a, 4b, 4c are indoor units performing the air-cooling operation and when all of the indoor units 4a, 4b, 4c have assumed the indoor thermo-off state, the controller 8 stops the compressor 21 and stops the flow of refrigerant in the refrigerant circuit 10. As a consequence thereof, the air conditioning apparatus 1 substantially assumes a state in which all air-warming operations are stopped even though operating commands for the air-warming operations have been given.

Next, for example, in the outdoor thermo-off state, if the indoor unit 4a is an indoor unit having become in the indoor thermo-on state, the controller 8 restarts the compressor 21 when the indoor unit 4a assumes the indoor thermo-on state. More specifically, the controller 8 opens the indoor expansion valve 41a of the indoor unit 4a and restarts the compressor 21 so that the refrigerant flows in the refrigerant circuit 10 and to the indoor heat exchanger 42a when the indoor temperature Tra drops to the lower limit value Tran by suspension of the air-warming operation and stopping of the compressor 21. As a consequence thereof, the air conditioning apparatus 1 assumes the outdoor thermo-on state, and the indoor unit 4a assumes the indoor thermo-on state. Also, the controller 8 opens the indoor expansion valves 41b, 41c of the indoor units 4b, 4c and restarts the compressor 21, putting the air conditioning apparatus 1 into outdoor thermo-on state and putting the indoor units 4b, 4c into the indoor thermo-on state, just as with the indoor unit 4a, when the indoor temperatures Trb, Trc drop to the lower limit values Trbn, Trcn.

Rotation speed control (hereinafter referred to as “normal rotation speed control”) of the compressor 21 and thermo control thus are performed as control of the air conditioning capacities in the air conditioning operations. In the air conditioning apparatus 1, the indoor temperatures Tra, Trb, Trc at the indoor units 4a, 4b, 4c performing air conditioning operations are brought to the target indoor temperatures Tras, Trbs, Trcs at the indoor units 4a, 4b, 4c by such control of the air conditioning capacity.

(3) Start/stop frequency-reducing rotation speed control

In this embodiment, the air conditioning capacities (air-cooling capacity and air-warming capacity) are controlled so that the indoor temperatures Tra, Trb, Trc at the indoor units 4a, 4b, 4c are brought to the target indoor temperatures Tras, Trbs, Trcs at the indoor

units 4a, 4b, 4c by the air conditioning operations (air-cooling operation and air-warming operation) including the above normal rotation speed control and thermo control.

For example, imagining the case when all of the indoor units 4a, 4b, 4c are performing air conditioning operations, when the air conditioning operations are performed with conditions in which the indoor temperatures T_{ra} , T_{rb} , T_{rc} greatly deviate from the target indoor temperatures T_{ras} , T_{rbs} , T_{rcs} , the rotation speed of the compressor 21 is controlled to high by normal rotation speed control on the basis of the request value (in the present embodiment, the request value ΔQCb , ΔQHb from the indoor unit 4b) for which the extent of increase in air conditioning capacity is greatest among the request values (ΔQCa , ΔQCb , ΔQCc during air-cooling operation, ΔQHa , ΔQHb , ΔQHc during air-warming operation) for air conditioning capacity requested by each indoor unit 4a, 4b, 4c (see FIG. 3). After that, because the request values for air conditioning capacity requested by each indoor unit 4a, 4b, 4c decrease as the indoor temperatures T_{ra} , T_{rb} , T_{rc} come closer to the target indoor temperatures T_{ras} , T_{rbs} , T_{rcs} , the rotation speed of the compressor 21 gradually decreases accordingly, and eventually there appears an indoor unit (in the present embodiment, indoor unit 4c) for which the indoor temperature T_{ra} , T_{rb} , T_{rc} comes within the scope of the thermo temperature range surrounding the target indoor temperature T_{ras} , T_{rbs} , T_{rcs} (see FIG. 4). When the indoor temperature at an indoor unit performing air conditioning operations within the scope of the thermo temperature range deviates from the thermo temperature range (i.e., when air conditioning operations are no longer necessary), indoor thermo-off to suspend the air conditioning operations of the indoor unit (in the present embodiment, indoor unit 4c) is performed by thermo control, and outdoor thermo-off to stop the compressor 21 is further performed when all of the indoor units 4a, 4b, 4c assume the indoor thermo-off state (see FIG. 5).

Here, there is a case where the indoor temperatures T_{ra} , T_{rb} , T_{rc} of all indoor units 4a, 4b, 4c performing air conditioning operations are within the scope of the thermo temperature range (see FIG. 6). In such case, air conditioning operations in a state of excess air conditioning capacity occurs, and thermo-start/stop, being the iteration of outdoor thermo-off and outdoor thermo-on, becomes likely to occur. In other words, when normal rotation speed control is performed even when the indoor temperatures T_{ra} , T_{rb} , T_{rc} at all indoor units 4a, 4b, 4c performing air conditioning operations are within the scope of the thermo temperature range, the rotation speed of the compressor 21 is controlled on the basis of the request value (in the present embodiment, the request value ΔQCb , ΔQHb from the indoor unit 4b) for which the extent of increase in air conditioning capacity is greatest among the

request values for air conditioning capacity requested by each indoor unit 4a, 4b, 4c. Therefore, air conditioning operations in a state of excess air conditioning capacity occur at the indoor units requesting a decrease in air conditioning capacity (i.e., the indoor units that are performing air conditioning operations within the scope of the thermo temperature range and are such that the indoor temperature has reached the target indoor temperature, in the present embodiment, indoor units 4a, 4b), the number of indoor units becoming in the indoor thermo-off state increases, and eventually the state where all of the indoor units become in the indoor thermo-off state and the outdoor thermo-off state is brought about. After that, the indoor thermo-on state and the outdoor thermo-on state are brought about when there arises an indoor unit for which the indoor temperature has deviated from the thermo temperature range, but because the indoor temperature at the indoor units performing air conditioning operations comes within the scope of the thermo temperature range as soon as the air conditioning operations are restarted, air conditioning operations in a state of excess air conditioning capacity again occur, and all of the indoor units assume the indoor thermo-off state and the outdoor thermo-off state.

Thus, air conditioning operations in a state of excess air conditioning capacity occur under conditions in which the indoor temperatures T_{ra} , T_{rb} , T_{rc} at all of the indoor units 4a, 4b, 4c performing air conditioning operations are within the scope of the thermo temperature range; i.e., the indoor temperatures T_{ra} , T_{rb} , T_{rc} are close to the target indoor temperatures T_{ras} , T_{rbs} , T_{rcs} , and thermo-start/stop becomes more likely to occur. Such air conditioning operations in a state of excess air conditioning capacity, or increase of frequency of thermo-start/stop may become a cause of increased power consumption or lowered operating efficiency of the compressor 21, and therefore the situation should be remedied to the extent possible.

Therefore, in the air conditioning apparatus 1, the controller 8 performs start/stop frequency-reducing rotation speed control during air conditioning operations (air-cooling operation and air-warming operation) including normal rotation speed control and thermo control. Here, start/stop frequency-reducing rotation speed control is to control the rotation speed of the compressor 21 on the basis of the request values from the indoor units requesting a decrease in air conditioning capacity, disregarding the request values from the indoor units requesting an increase in air conditioning capacity, when each indoor temperature T_{ra} , T_{rb} , T_{rc} at all indoor units 4a, 4b, 4c performing air conditioning operations is within the scope of a prescribed threshold temperature range surrounding a target indoor temperature T_{ras} , T_{rbs} , T_{rcs} at each indoor unit 4a, 4b, 4c performing air conditioning operations.

Next, rotation speed control of the compressor 21 including start/stop frequency-reducing rotation speed control shall be described using FIG. 3 to FIG. 8. FIG. 7 is a flow chart illustrating rotation speed control of compressor 21 including start/stop frequency-reducing rotation speed control. FIG. 8 is a diagram illustrating the relationship between the indoor temperature T_{ra} , T_{rb} , T_{rc} and the target indoor temperature T_{ras} , T_{rbs} , T_{rcs} at each indoor unit 4a, 4b, 4c performing air conditioning operations (when performing start/stop frequency-reducing rotation speed control). In this embodiment, the description is given imagining the case in which all of the indoor units 4a, 4b, 4c are performing air conditioning operations.

First, in step ST1, the controller 8 determines whether each indoor temperature T_{ra} , T_{rb} , T_{rc} at all indoor units 4a, 4b, 4c performing air conditioning operations is within the scope of the prescribed threshold temperature range (in the present embodiment, thermo temperature range) surrounding the target indoor temperature T_{ras} , T_{rbs} , T_{rcs} at each indoor unit 4a, 4b, 4c performing air conditioning operations. When it is determined that each indoor temperature T_{ra} , T_{rb} , T_{rc} at all indoor units 4a, 4b, 4c performing air conditioning operations is within the scope of the prescribed threshold temperature range and the condition that the indoor temperatures T_{ra} , T_{rb} , T_{rc} be close to the target indoor temperatures T_{ras} , T_{rbs} , T_{rcs} is satisfied (see FIG. 6 and FIG. 8), the flow transitions to the process of step ST2.

Meanwhile, when it is not determined in step ST1 that each indoor temperature T_{ra} , T_{rb} , T_{rc} at all indoor units 4a, 4b, 4c performing air conditioning operations is within the scope of the prescribed threshold temperature range and the condition that the indoor temperatures T_{ra} , T_{rb} , T_{rc} be close to the target indoor temperatures T_{ras} , T_{rbs} , T_{rcs} is not satisfied, it is the case when there is an indoor unit for which the indoor temperature T_{ra} , T_{rb} , T_{rc} , is beyond the scope of the threshold temperature range and increase in air conditioning capacity is being requested (see FIG. 3 and FIG. 4), and therefore the flow transitions to the process of normal rotation speed control in step ST4.

Here, the details of the processing of normal rotation speed control in step ST4 are the same as those of the control already described. In other words, when there is an indoor unit for which the indoor temperature is beyond the scope of the threshold temperature range and air conditioning capacity is being requested, the rotation speed of the compressor 21 is controlled on the basis of the request value for which the extent of increase in air conditioning capacity is greatest, so that the indoor temperatures T_{ra} , T_{rb} , T_{rc} are quickly brought closer to the target indoor temperatures T_{ras} , T_{rbs} , T_{rcs} . For example, as illustrated in FIG. 3, when each indoor temperature T_{ra} , T_{rb} , T_{rc} at all indoor units 4a, 4b, 4c

performing air conditioning operations is beyond the scope of the threshold temperature range and increase in air conditioning capacity is being requested, the target evaporation temperature T_{es} or the target condensation temperature T_{cs} is decided on the basis of the request value (in the present embodiment, the request value ΔQ_{Cb} , ΔQ_{Hb} from the indoor unit 4b) for which the extent of increase in air conditioning capacity is greatest among the request values from the indoor units 4a, 4b, 4c requesting an increase in air conditioning capacity. Also, as illustrated in FIG. 4, when each indoor temperature (in FIG. 4, the indoor temperatures T_{ra} , T_{rb}) at some of the indoor units (in FIG. 4, the indoor units 4a, 4b) performing air conditioning operations is beyond the scope of the threshold temperature range and increase in air conditioning capacity is being requested, the target evaporation temperature T_{es} or the target condensation temperature T_{cs} is decided on the basis of the request value (in the present embodiment, the request value ΔQ_{Cb} , ΔQ_{Hb} from the indoor unit 4b) for which the extent of increase in air conditioning capacity is greatest among the request values from the indoor units 4a, 4b, 4c requesting an increase in air conditioning capacity. The rotation speed of the compressor 21 is controlled so that the evaporation temperature T_e of the refrigerant arrives at the decided target evaporation temperature T_{es} or so that the condensation temperature T_c of the refrigerant arrives at the decided target condensation temperature T_{cs} .

Next, in step ST2, the controller 8 determines whether there is an indoor unit requesting a decrease in air conditioning capacity among the indoor units 4a, 4b, 4c performing air conditioning operations. When there is an indoor unit requesting a decrease in air conditioning capacity (for example, indoor units 4a, 4c in FIG. 6 and FIG. 8), the flow transitions to the process of start/stop frequency-reducing rotation speed control in step ST3.

When it is not determined in step ST2 that there is an indoor unit requesting a decrease in air conditioning capacity, and when there is an indoor unit for which the indoor temperature is within the scope of the threshold temperature range and increase in air conditioning capacity is being requested, the flow transitions to the process of normal rotation speed control in step ST4. In other words, in this case as well, as in the case when there is an indoor unit for which the indoor temperature is beyond the scope of the threshold temperature range and air conditioning capacity is being requested, normal rotation speed control in step ST4 is performed so that the indoor temperatures T_{ra} , T_{rb} , T_{rc} are quickly brought closer to the target indoor temperatures T_{ras} , T_{rbs} , T_{rcs} .

Next, in step ST3, the controller 8 controls the rotation speed of the compressor 21 on the basis of the request values from the indoor units requesting a decrease in air

conditioning capacity, disregarding the request values from the indoor units requesting an increase in air conditioning capacity. For example, when the indoor unit 4b is requesting an increase in air conditioning capacity and the indoor units 4a, 4c are requesting a decrease in air conditioning capacity among the indoor units 4a, 4b, 4c performing air conditioning operations (see FIG. 8), the target evaporation temperature T_{es} or the target condensation temperature T_{cs} is decided on the basis of the request value ΔQCa , ΔQHa from the indoor unit 4a and the request value ΔQCc , ΔQHc from the indoor unit 4c requesting a decrease in air conditioning capacity, disregarding, disregarded the request value ΔQCb , ΔQHb from the indoor unit 4b requesting an increase in air conditioning capacity. The rotation speed of the compressor 21 is controlled so that the evaporation temperature T_e of the refrigerant arrives at the target evaporation temperature T_{es} or so that the condensation temperature T_c of the refrigerant arrives at the target condensation temperature T_{cs} . In other words, given that, in normal rotation speed control in step ST4, the target evaporation temperature T_{es} or the target condensation temperature T_{cs} is decided on the basis of the request value ΔQCb , ΔQHb from the indoor unit 4b for which increase in air conditioning capacity is being requested and the greatest air conditioning capacity is obtained, among the request values from the indoor units 4a, 4b, 4c during air conditioning operations, in the present embodiment, the target evaporation temperature T_{es} or the target condensation temperature T_{cs} is decided on the basis of the request value ΔQCa , ΔQHa from the indoor unit 4a and the request value ΔQCc , ΔQHc from the indoor unit 4c requesting a decrease in air conditioning capacity.

By performing such start/stop frequency-reducing rotation speed control, the target evaporation temperature T_{es} can be set high or the target condensation temperature T_{cs} can be set low under conditions in which the indoor temperatures T_{ra} , T_{rb} , T_{rc} at all of the indoor units 4a, 4b, 4c performing air conditioning operations are within the scope of the thermo temperature range; i.e., the indoor temperatures T_{ra} , T_{rb} , T_{rc} are close to the target indoor temperatures T_{ras} , T_{rbs} , T_{rcs} . By doing so, the rotation speed of the compressor 21 can be kept low and the occurrence of stopping of the compressor 21; i.e., outdoor thermo-off can be suppressed while reducing the air conditioning capacity.

Here, when there is only one indoor unit requesting a decrease in air conditioning capacity, it suffices that the target evaporation temperature T_{es} or the target condensation temperature T_{cs} is decided on the basis of the request value from that indoor unit. However, when there are a plurality of indoor units requesting a decrease in air conditioning capacity (see FIG. 8), the extent of reduction of the frequency of thermo-start/stop, or the like, varies depending on how the request value ΔQCa , ΔQHa from the indoor unit 4a and the request

value ΔQ_{Cc} , ΔQ_{Hc} from the indoor unit 4c requesting a decrease in air conditioning capacity are used. Here, the extent of reduction of the frequency of thermo-start/stop is improved when the rotation speed of the compressor 21 is kept low, but there appears a tendency for the air conditioning capacity to become insufficient at the indoor unit 4b requesting an increase
5 in air conditioning capacity, and the indoor temperature Tr_b having come close to the target indoor temperature Tr_{bs} up to within the scope of the threshold temperature range might deviate from the target indoor temperature Tr_{bs} and go beyond the scope of the threshold temperature range.

Therefore, in the present embodiment, the target evaporation temperature T_{es} or the
10 target condensation temperature T_{cs} is decided on the basis of the request value ΔQ_{Ca} , ΔQ_{Ha} from the indoor unit 4a for which the extent of decrease in air conditioning capacity is smallest between the request value ΔQ_{Ca} , ΔQ_{Ha} from the indoor unit 4a and the request value ΔQ_{Cc} , ΔQ_{Hc} from the indoor unit 4c requesting a decrease in air conditioning capacity.

As a consequence thereof, the rotation speed of the compressor 21 can be kept low,
15 and the tendency for the air conditioning capacity to become insufficient at the indoor unit 4b requesting an increase in air conditioning capacity can be suppressed to the extent possible.

(4) Characteristics of the air conditioning apparatus

The air conditioning apparatus 1 has the following characteristics.

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20 In this embodiment, as described above, start/stop frequency-reducing rotation speed control is performed, controlling the rotation speed of the compressor 21 on the basis of the request values from the indoor units requesting a decrease in air conditioning capacity, disregarding the request values from the indoor units requesting an increase in air conditioning capacity, when each indoor temperature at all indoor units performing air
25 conditioning operations is within the scope of a prescribed threshold temperature range surrounding a target indoor temperature at each indoor unit performing air conditioning operations (see FIG. 8).

As a consequence thereof, in the present embodiment, the rotation speed of the compressor 21 is kept low and the incidence of stopping of the compressor 21; i.e., outdoor
30 thermo-off, can be suppressed while reducing the air conditioning capacity. Therefore, when air conditioning operations are performed under conditions in which the air conditioning capacity requested by each indoor unit is small and the indoor temperature is close to the target indoor temperature, the operation of the compressor 21 can be continued to the extent possible while reducing the air conditioning capacity. As a consequence thereof, in the

present embodiment, the frequency of thermo-start/stop can be sufficiently reduced while suppressing air conditioning operations in a state of excess air conditioning capacity.

In this embodiment, as described above, when performing start/stop frequency-reducing rotation speed control, the rotation speed of the compressor 21 is controlled on the basis of the request value for which the extent of decrease in air conditioning capacity is smallest among the request values from the indoor units requesting a decrease in air conditioning capacity. Therefore, the rotation speed of the compressor 21 can be kept low, and the tendency for the air conditioning capacity to become insufficient at indoor units requesting an increase in air conditioning capacity can be suppressed as much as possible.

As for how to use the request values from indoor units requesting a decrease in air conditioning capacity, it may also be considered to use the request value for which the extent of decrease in air conditioning capacity is greatest among the request values from indoor units requesting a decrease in air conditioning capacity, but in this case, although the rotation speed of the compressor 21 can be kept very low, it becomes difficult to suppress the tendency for the air conditioning capacity to become insufficient at indoor units requesting an increase in air conditioning capacity. It may also be considered to use the average value of the request values from indoor units requesting a decrease in air conditioning capacity, but in this case, the extent of keeping down the rotation speed of the compressor 21 or the extent of suppressing the tendency for the air conditioning capacity to become insufficient at indoor units requesting an increase in air conditioning capacity comes to an intermediate extent between that of the case when using the request value for which the extent of decrease in air conditioning capacity is smallest and that of the case when using the request value for which the extent of decrease is greatest. Thus, when performing start/stop frequency-reducing rotation speed control, the extent of reduction of the frequency of thermo-start/stop, or the like, comes to vary depending on how the request values from indoor units requesting a decrease in air conditioning capacity are used. In this embodiment, emphasis is placed on the extent of suppressing the tendency for the air conditioning capacity to become insufficient at indoor units requesting an increase in air conditioning capacity, and it is arranged to use the request value for which the extent of decrease in air conditioning capacity is smallest among the request values from indoor units requesting a decrease in air conditioning capacity.

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In this embodiment, as described above, the threshold temperature range is made to coincide with the thermo temperature range. As a consequence thereof, the rotation speed of

the compressor 21 can be kept low until all of the indoor units assume indoor thermo-off, and the occurrence of stopping of the compressor 21; i.e., outdoor thermo-off, can be suppressed while reducing the air conditioning capacity.

It is permissible for the threshold temperature range not to coincide with the thermo temperature range. For example, the threshold temperature range can be set wider than the thermo temperature range so that conditions for performing the start/stop frequency-reducing rotation speed control in steps ST1, ST2 above are more easily satisfied.

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In this embodiment, as described above, normal rotation speed control is performed, in which the rotation speed of the compressor 21 is controlled on the basis of the request value for which the extent of increase in air conditioning capacity is greatest among the request values from the indoor units requesting an increase in air conditioning capacity, when there are indoor units for which the indoor temperature is beyond the scope of the threshold temperature range and increase in air conditioning capacity is being requested among the indoor units performing air conditioning operations (see FIG. 3 and FIG. 4).

Therefore, in the present embodiment, the normal rotation speed control and the start/stop frequency-reducing rotation speed control come to be switched in accordance with the indoor temperatures at the indoor units performing air conditioning operations. In other words, when there are indoor units for which the indoor temperature is beyond the scope of the threshold temperature range and air conditioning capacity is being requested, the rotation speed of the compressor 21 is controlled on the basis of the request value for which the extent of increase in air conditioning capacity is greatest, so that the indoor temperatures are quickly brought closer to the target indoor temperature. When the indoor temperatures at all indoor units performing air conditioning operations are within the scope of the threshold temperature range and the air conditioning capacity requested by each indoor unit has become small, the rotation speed of the compressor 21 is controlled on the basis of the request value from the indoor unit requesting a decrease in air conditioning capacity, so that the operation of the compressor 21 can be continued to the extent possible while reducing the air conditioning capacity. As a consequence thereof, in the present embodiment, the indoor temperatures can be quickly brought closer to the target indoor temperature during air conditioning operations, and air conditioning operations in a state of excess air conditioning capacity can be suppressed and the frequency of thermo-start/stop can be reduced thereafter.

In this embodiment, as described above, normal rotation speed control is performed, rather than start/stop frequency-reducing rotation speed control, when there is no indoor unit

requesting a decrease in air conditioning capacity, even when the indoor temperature is within the scope of the threshold temperature range, among the indoor units performing air conditioning operations. As a consequence thereof, the conditions for performing start/stop frequency-reducing rotation speed control can be narrowed down to the extent possible, and
5 priority can be given to bringing the indoor temperature quickly closer to the target indoor temperature.

(5) Modifications

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In the above embodiment, a description was given in which the thermo temperature
10 range used as the threshold temperature range is set to the same temperature range for all of the indoor units 4a, 4b, 4c (see FIG. 3 to FIG. 7 and FIG. 8). However, there is no limitation to setting to the same temperature range for all of the indoor units; different temperature ranges for each indoor unit are possible.

In the above embodiment, the start/stop frequency-reducing rotation speed control is
15 applied to an air conditioning apparatus capable of switching between an air-cooling operation and an air-warming operation, but no limitation is provided thereby. For example, the start/stop frequency-reducing rotation speed control may be applied to an air conditioning apparatus dedicated to air-cooling operation or an air conditioning apparatus dedicated to air-
20 warming operation.

INDUSTRIAL APPLICABILITY

The present invention is widely applicable to air conditioning apparatuses that are configured by connecting a plurality of indoor units and an outdoor unit having a compressor and perform air conditioning operations so that an indoor temperature at each indoor unit
25 arrives at a target indoor temperature at each indoor unit.

REFERENCE SIGNS LIST

- 1 Air conditioning apparatus
- 2 Outdoor unit
- 4a, 4b, 4c Indoor units
- 30 8 Controller
- 21 Compressor

CITATION LIST

PATENT LITERATURE

[Patent Literature 1]

Japanese Laid-open Patent Application No. 4-93558

CLAIMS

1. An air conditioning apparatus (1) configured by connecting a plurality of indoor units (4a, 4b, 4c) and an outdoor unit (2) having a compressor (21), the air conditioning apparatus performing air conditioning operation so that an indoor temperature at each indoor unit arrives at a target indoor temperature at each indoor unit, wherein:

the air conditioning apparatus (1) is provided with a controller (8) to control a rotation speed of the compressor on the basis of a request value concerning air conditioning capacity at each indoor unit during the air conditioning operation; and

the controller performs a start/stop frequency-reducing rotation speed control in which the rotation speed of the compressor is controlled on the basis of the request values from the indoor units requesting a decrease in air conditioning capacity, disregarding the request values from the indoor units requesting an increase in air conditioning capacity, when each indoor temperature at all indoor units performing the air conditioning operation is within a scope of a prescribed threshold temperature range surrounding the target indoor temperature at each indoor unit performing the air conditioning operation.

2. The air conditioning apparatus (1) according to claim 1, wherein the start/stop frequency-reducing rotation speed control is to control the rotation speed of the compressor (21) on the basis of the request value for which the extent of decrease in air conditioning capacity is smallest among the request values from the indoor units requesting a decrease in air conditioning capacity.

3. The air conditioning apparatus (1) according to claim 1 or 2, wherein the threshold temperature range is a thermo temperature range that specifies a timing of indoor thermo-off, which suspends the air conditioning operations of the indoor units (4a, 4b, 4c) performing the air conditioning operations, and indoor thermo-on, which restarts the air conditioning operations of the indoor units in the indoor thermo-off state.

4. The air conditioning apparatus (1) according to any one of claims 1 to 3, wherein the controller (8) performs a normal rotation speed control in which the rotation speed of the compressor (21) is controlled on the basis of the request value for which the extent of increase in air conditioning capacity is greatest among the request values from the indoor units requesting an increase in air conditioning capacity, when there are indoor units for which the indoor temperature is beyond the scope of the threshold temperature range and increase in air conditioning capacity is being requested among the indoor units (4a, 4b, 4c) performing the air conditioning operations.