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JP 2013231542 A   JP 2012112557 A
JP 2000002474 A

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Other: **NOT ADVISED**

(54) Title of the Invention: **Refrigeration system and control device**
Abstract Title: **Refrigeration system and control device**

(57) A control device includes a compressor control unit that operates both of a first compressor and a second compressor when a first frequency ratio is greater than or equal to a preset threshold value and operates one of the first compressor and the second compressor when the first frequency ratio is less than the threshold value, where the first frequency ratio is a value obtained by dividing the sum of the operation frequency of the first compressor and the operation frequency of the second compressor by a preset first rated frequency. The threshold value is determined on the basis of the outside air temperature, the temperature of a heat medium flowing in a heat medium circuit, or the output of a pump.
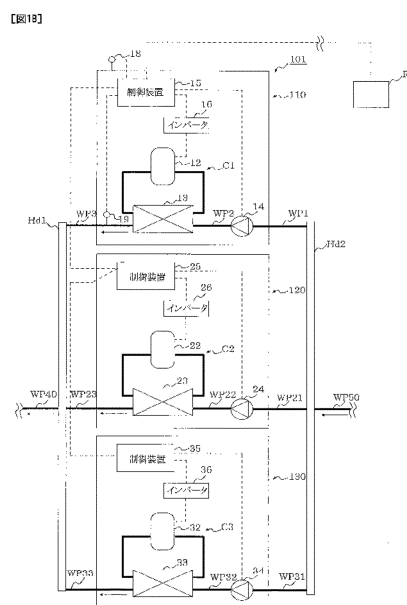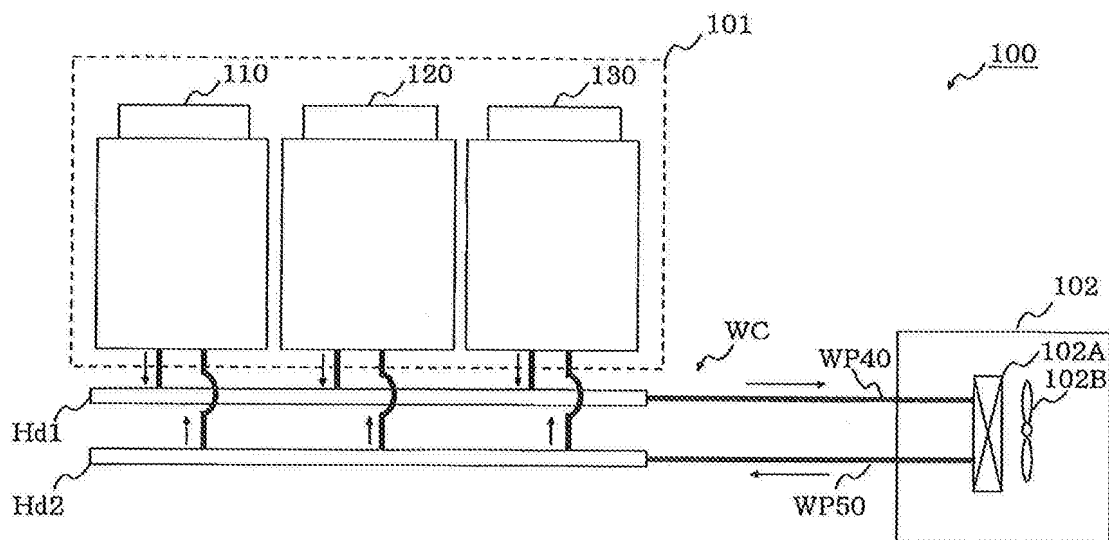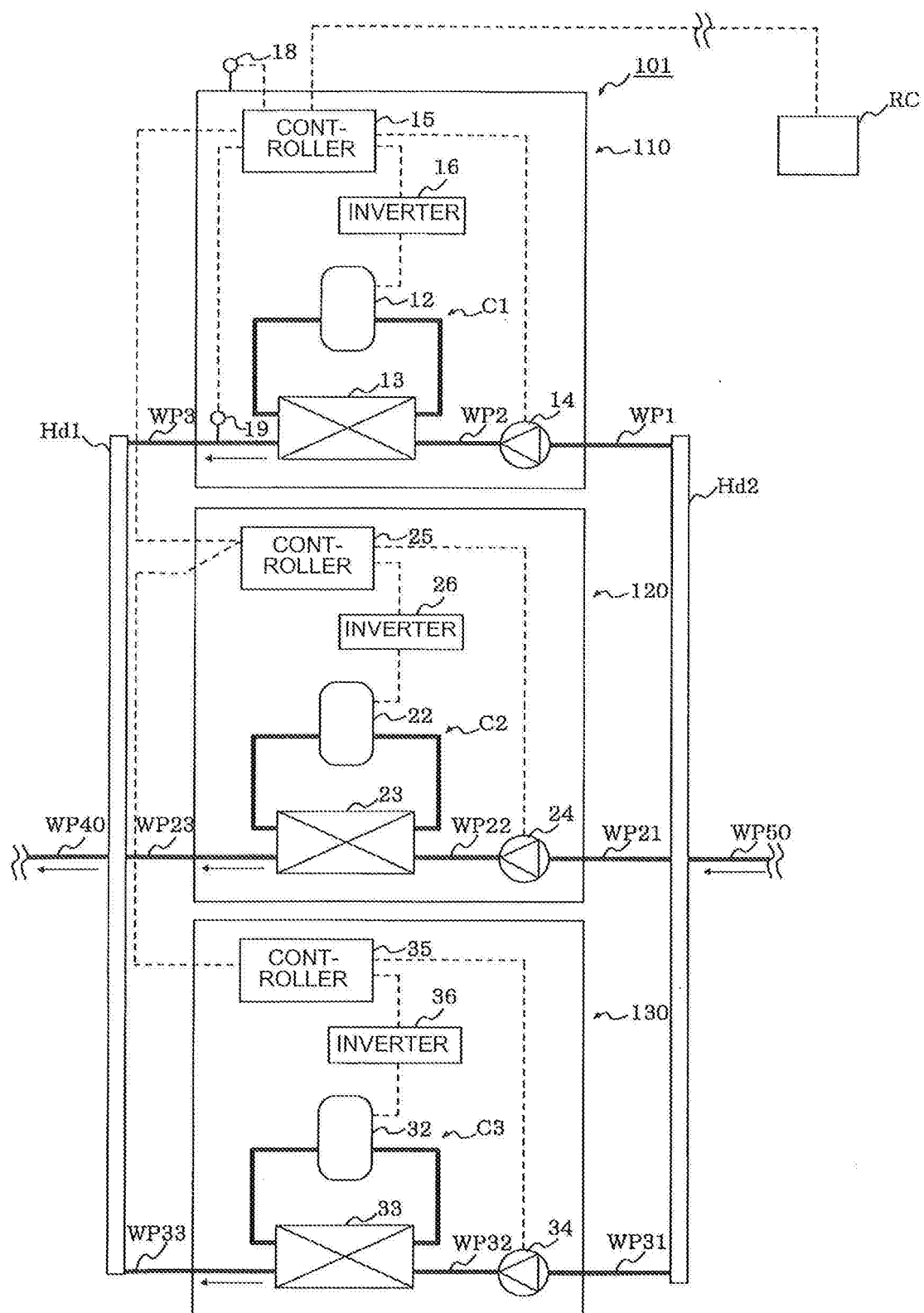

15, 25, 35   Control device
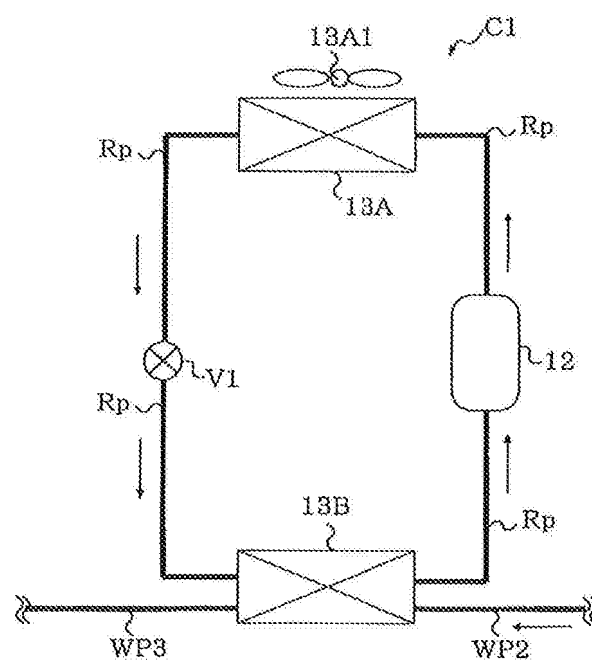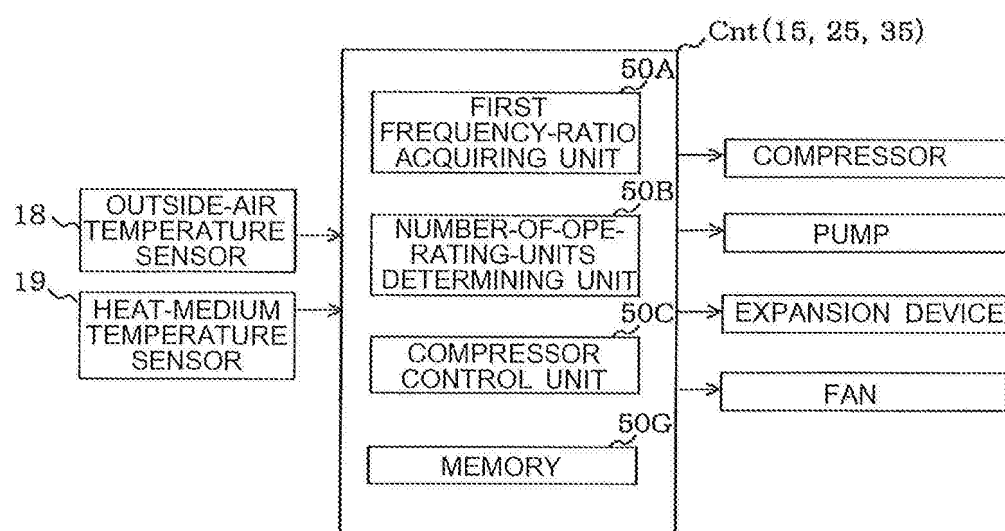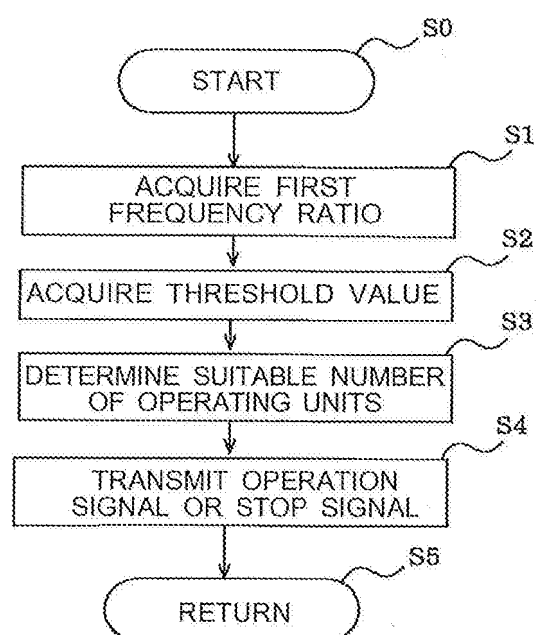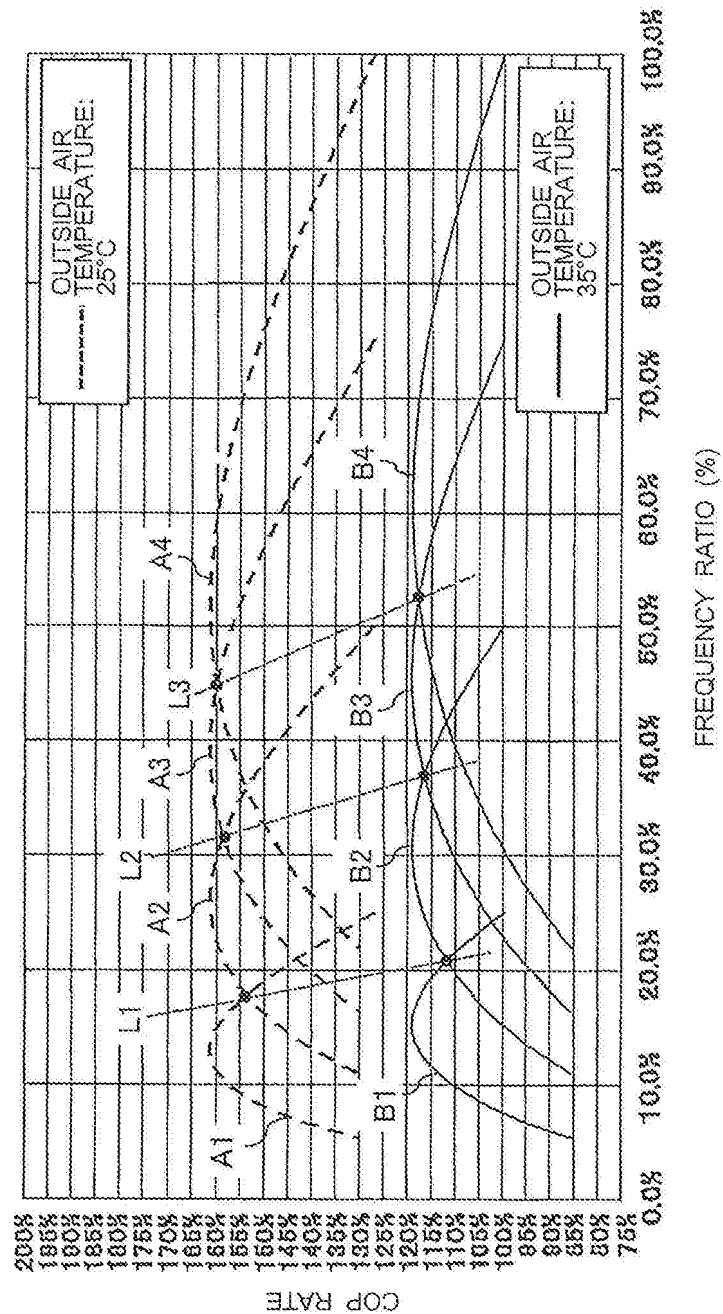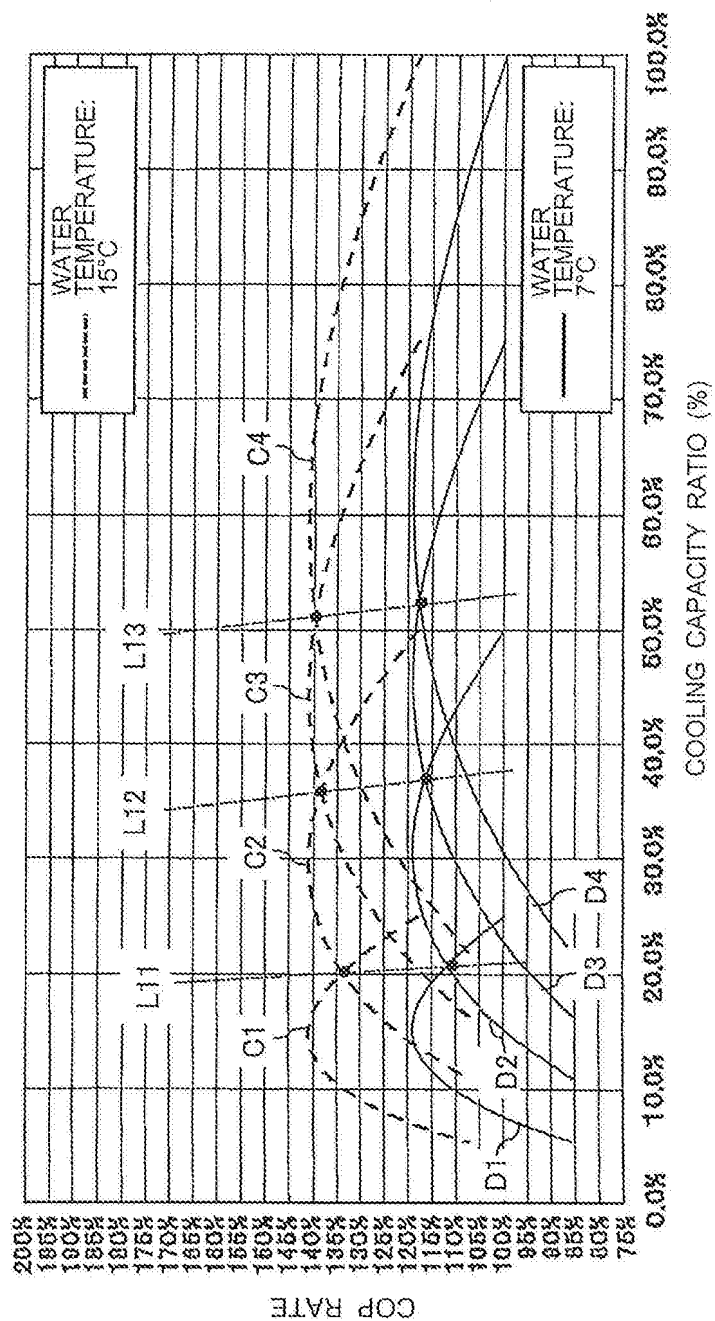16, 26, 36   Inverter

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FIG. 1A

FIG. 1B

FIG. 1C

FIG. 1D

FIG. 2

FIG. 3

FIG. 4

FIG. 5

FIG. 6A

FIG. 6B

FIG. 7

FIG. 8

FIG. 9

OUTSIDE AIR
TEMPERATURE:
25°C

OUTSIDE AIR
TEMPERATURE:
35°C

COP RATE

FREQUENCY RATIO (%)
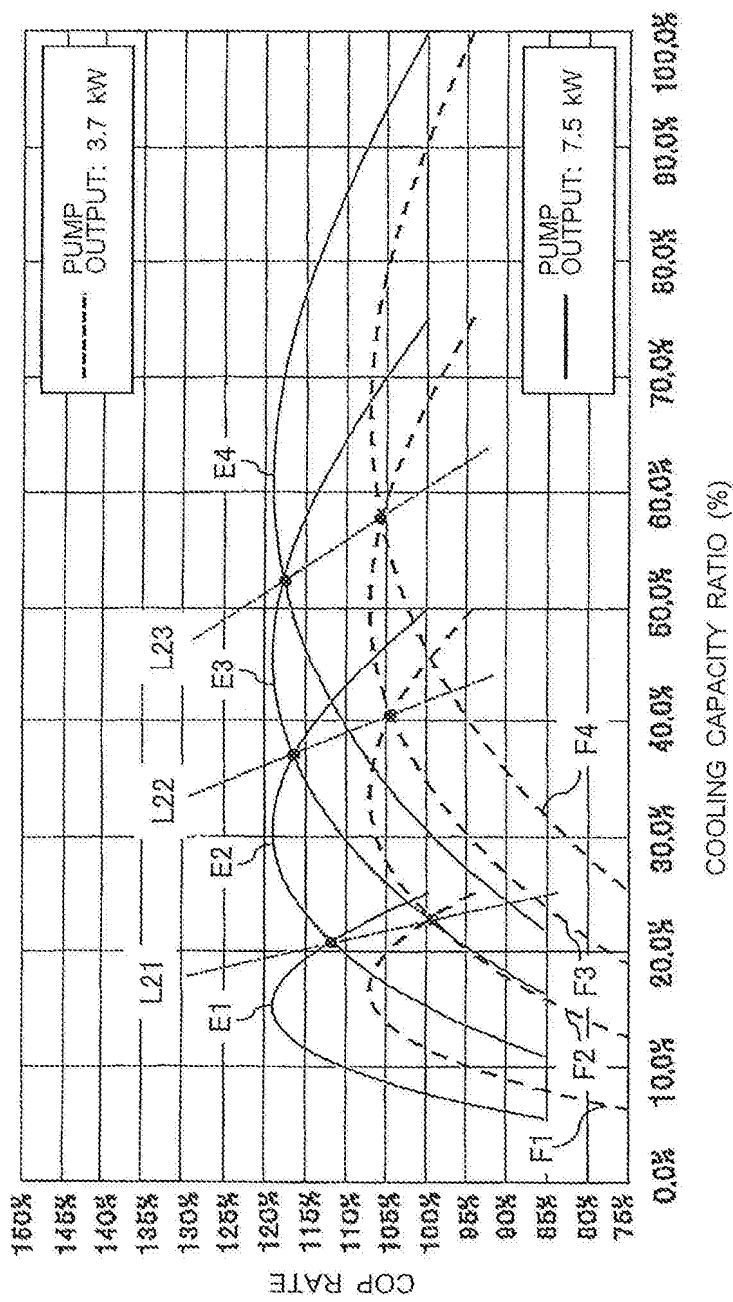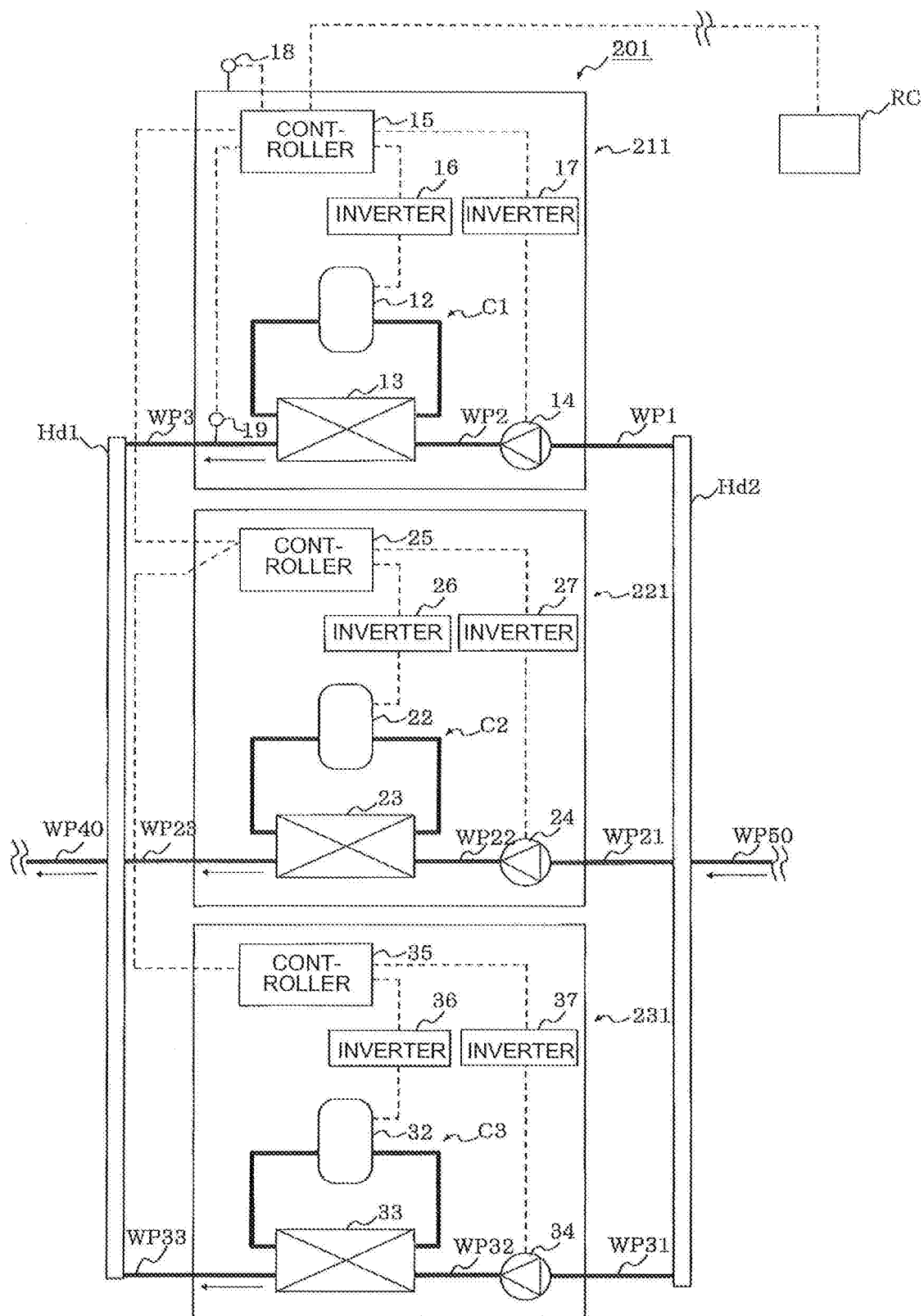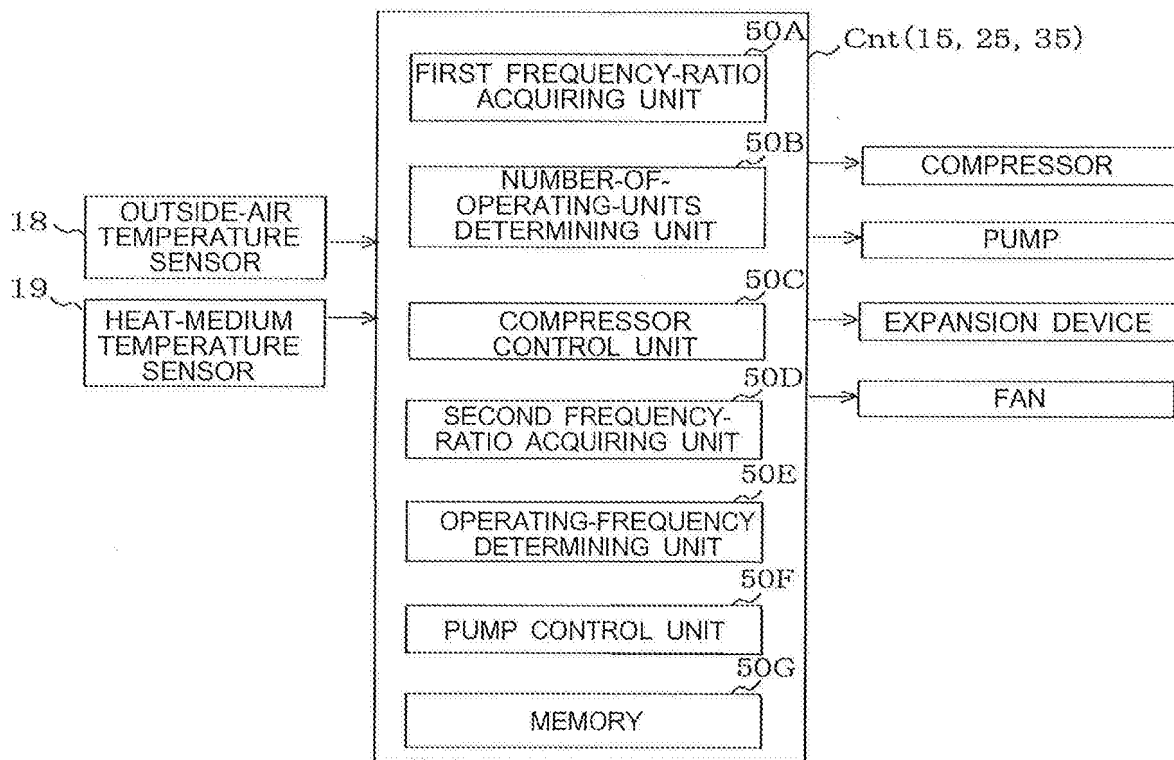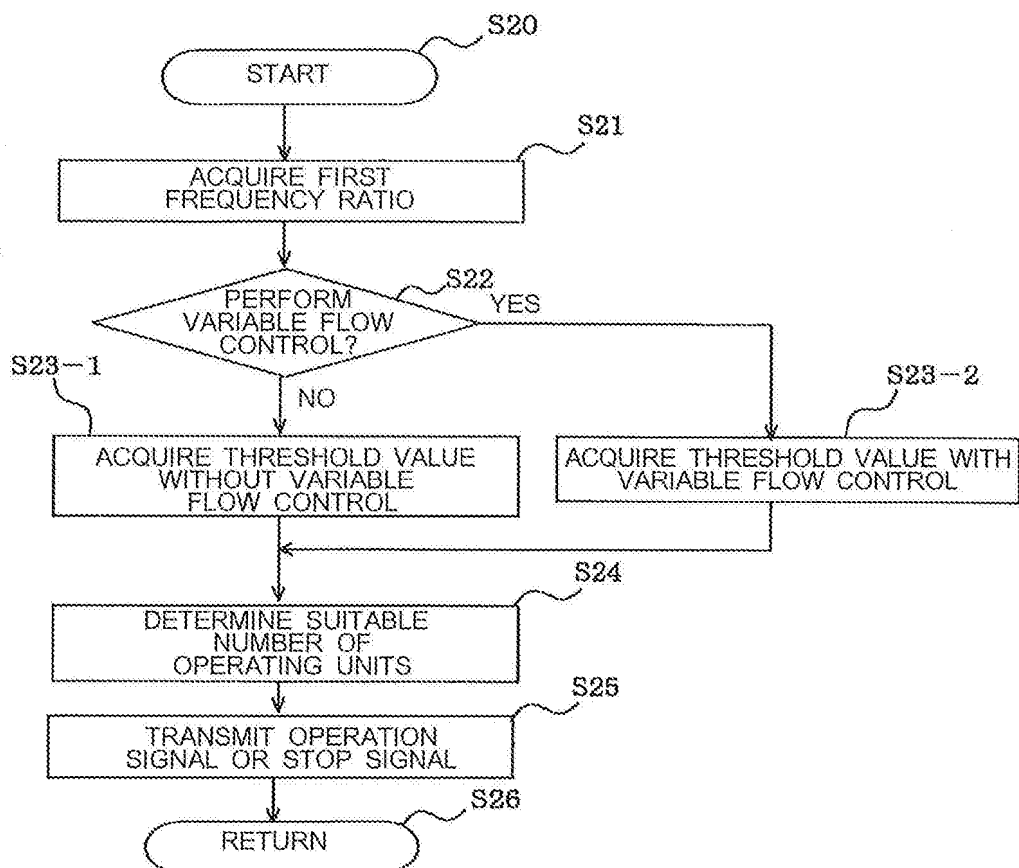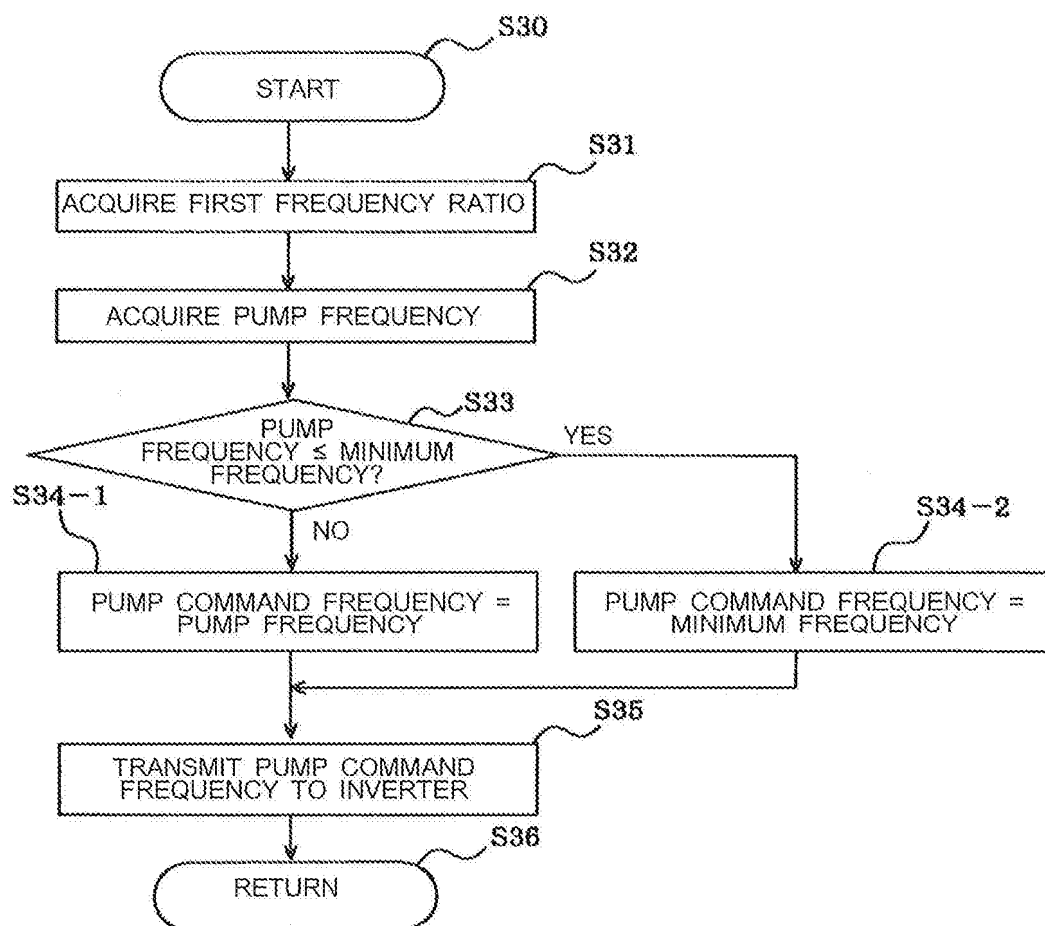
DESCRIPTION

Title of Invention

REFRIGERATION SYSTEM AND CONTROLLER

Technical Field

[0001]

The present invention relates to a refrigeration system including a first refrigerant circuit, a second refrigerant circuit, and a heat-medium circuit connected to the first refrigerant circuit and the second refrigerant circuit, and to a controller that controls the refrigeration system.

Background Art

[0002]

An existing refrigeration system has a plurality of refrigerant circuits and improves the coefficient of performance (COP) by determining the number of operating compressors (also referred to as "the number of operating units" hereinafter) among compressors in the plurality of refrigerant circuits on the basis of a frequency ratio (e.g., see Patent Literature 1). The frequency ratio can be acquired by dividing a total value of operating frequencies of the plurality of compressors by a rated frequency. When maximum operating frequencies of the compressors are defined as maximum frequencies, the rated frequency can be acquired by adding together the maximum frequencies of the plurality of compressors.

Citation List

Patent Literature

[0003]

Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2012-112557

Summary of Invention

Technical Problem

[0004]

In the existing refrigeration system, the predetermined frequency ratio is set as a threshold value used when the number of operating units is to be changed. In the

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existing refrigeration system, this threshold value is a fixed value. The suitable number of operating units for improving the COP varies on the basis of not only the frequency ratio but also a factor such as the outside-air temperature. Consequently, when the threshold value used when the number of operating units is to be changed is a fixed value, there may be a case where the COP cannot be improved.

[0005]

The present invention has been made to solve the aforementioned problem, and an object of the present invention is to provide a refrigeration system and a controller that can improve the COP more reliably.

Solution to Problem

[0006]

A refrigeration system of an embodiment of the present invention includes a first refrigerant circuit including a first compressor and a first heat exchanger; a second refrigerant circuit including a second compressor and a second heat exchanger; a heat-medium circuit having a pump, a first heat-medium flow path connected to the first heat exchanger, and a second heat-medium flow path connected to the second heat exchanger; and a controller configured to control the first compressor, the second compressor, and the pump. The controller includes a compressor control unit configured to cause both of the first compressor and the second compressor to operate when a first frequency ratio is larger than or equal to a predetermined threshold value, and to cause one of the first compressor and the second compressor to operate when the first frequency ratio is smaller than the threshold value. The first frequency ratio is a value obtained by dividing a total frequency of an operating frequency of the first compressor and an operating frequency of the second compressor by a predetermined first rated frequency. The threshold value is set on the basis of an outside-air temperature, a temperature of a heat medium flowing through the heat-medium circuit, or an output of the pump.

Advantageous Effects of Invention

[0007]

The refrigeration system according to an embodiment of the present invention includes the above-described components, so that the COP can be improved more reliably.

Brief Description of Drawings

[0008]

[Fig. 1A] Fig. 1A is an overall view of a refrigeration system according to Embodiment 1 of the present invention.

[Fig. 1B] Fig. 1B schematically illustrates a chiller unit group of the refrigeration system according to Embodiment 1 of the present invention.

[Fig. 1C] Fig. 1C illustrates an example of a refrigerant circuit of the refrigeration system according to Embodiment 1 of the present invention.

[Fig. 1D] Fig. 1D illustrates a controller of the refrigeration system according to Embodiment 1 of the present invention.

[Fig. 2] Fig. 2 is a control flowchart of the refrigeration system according to Embodiment 1 of the present invention.

[Fig. 3] Fig. 3 illustrates threshold values set on the basis of an outside-air temperature and a frequency ratio, according to Embodiment 1 of the present invention.

[Fig. 4] Fig. 4 illustrates threshold values set on the basis of an outlet temperature and a frequency ratio, according to Embodiment 1 of the present invention.

[Fig. 5] Fig. 5 illustrates threshold values set on the basis of a pump output and a frequency ratio, according to Embodiment 1 of the present invention.

[Fig. 6A] Fig. 6A schematically illustrates a chiller unit group of a refrigeration system according to Embodiment 2 of the present invention.

[Fig. 6B] Fig. 6B illustrates a controller of the refrigeration system according to Embodiment 2 of the present invention.

[Fig. 7] Fig. 7 is a control flowchart of the refrigeration system according to Embodiment 2 of the present invention.

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[Fig. 8] Fig. 8 is a control flowchart of each pump in the refrigeration system according to Embodiment 2 of the present invention.

[Fig. 9] Fig. 9 illustrates threshold values set on the basis of an outside-air temperature and a frequency ratio, according to Embodiment 2 of the present invention.

Description of Embodiments

[0009]

Embodiment 1

Fig. 1A is an overall view of a refrigeration system 100 according to Embodiment 1.   Fig. 1B schematically illustrates a chiller unit group 101 of the refrigeration system 100 according to Embodiment 1.   Fig. 1C illustrates an example of a refrigerant circuit C1 of the refrigeration system 100 according to Embodiment 1. Fig. 1D illustrates a controller Cnt of the refrigeration system 100 according to Embodiment 1.   In Figs. 1A to 1C, the direction of flow of a heat medium or the direction of flow of refrigerant is represented by an arrow.

[0010]

[Refrigeration System 100]

As shown in Fig. 1A, the refrigeration system 100 according to Embodiment 1 includes the chiller unit group 101 serving as a heat-source-side device and a device 102 serving as a load-side device.   As an alternative to the example in Fig. 1A in which the chiller unit group 101 and the device 102 are directly connected to each other, the chiller unit group 101 and the device 102 may be connected to each other with a relay unit (not shown), including a heat exchanger, interposed between the chiller unit group 101 and the device 102.   In other words, the refrigeration system 100 according to Embodiment 1 is only required to include the chiller unit group 101 and a device that utilizes heating energy or cooling energy generated in the chiller unit group 101.   The device 102 is supplied with, for example, water cooled as a result of operation of the chiller unit group 101.   The chiller unit group 101 includes a chiller unit 110, a chiller unit 120, and a chiller unit 130.   The device 102 includes, for example, a fan coil unit included in an indoor unit of an air-conditioning apparatus and

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a tank for retaining water of a water heater. In Embodiment 1, the device 102 is described as being a fan coil unit of an air-conditioning apparatus as an example. The device 102 includes a heat exchanger 102A and a fan 102B that supplies air to the heat exchanger 102A. The refrigeration system 100 includes a first header Hd1 and a second header Hd2. The first header Hd1 is connected to the heat exchanger 102A of the device 102 by a heat-medium pipe WP40. The second header Hd2 is connected to the heat exchanger 102A of the device 102 by a heat-medium pipe WP50. The refrigeration system 100 includes a heat-medium circuit WC. The heat-medium circuit WC includes the heat-medium pipe WP40, the heat-medium pipe WP50, the first header Hd1, and the second header Hd2.

[0011]

[Chiller Unit 110]

As shown in Fig. 1B, the chiller unit 110 includes the refrigerant circuit C1, a pump 14, a controller 15, an inverter 16, an outside-air temperature sensor 18, and a heat-medium temperature sensor 19. As shown in Fig. 1C, the refrigerant circuit C1 includes a compressor 12, a heat exchanger 13A, an expansion device V1, a heat exchanger 13B, and a refrigerant pipe Rp. The operating frequency of the compressor 12 is controllable. The compressor 12 operates on the basis of a signal output from the inverter 16. The heat exchanger 13A serves as a condenser or an evaporator. The expansion device V1 reduces the pressure of the refrigerant. The heat exchanger 13B serves as a condenser or an evaporator. In Fig. 1C, a circuit in which the refrigerant cools the heat medium is shown as an example. The refrigerant circuit C1 may include a flow switching valve (not shown) to switch between a mode in which the refrigerant cools the heat medium and a mode in which the refrigerant heats the heat medium.

[0012]

The refrigerant circuit C1 is connected to a heat-medium pipe WP2 and a heat-medium pipe WP3. The heat medium flowing through the heat-medium pipe WP2 is heated or cooled by the refrigerant flowing through the refrigerant circuit C1, and flows into the heat-medium pipe WP3. The pump 14 has a heat-medium inlet that is

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connected to a heat-medium pipe WP1 and a heat-medium outlet that is connected to the heat-medium pipe WP2. The heat-medium pipe WP3 is connected to the first header Hd1, and the heat-medium pipe WP1 is connected to the second header Hd2.

[0013]

The controller 15 controls the inverter 16 and the pump 14. Furthermore, the controller 15 controls the inverter 16 to change the frequency of the compressor 12. The controller 15 communicates with a remote controller RC. The remote controller RC is set in, for example, a manager's office. The controller 15 receives an operation command from the remote controller RC. The controller 15 communicates with a controller 25 and a controller 35 and operates in cooperation with the controller 25 and the controller 35. A temperature measured by the outside-air temperature sensor 18 is output to the controller 15. Moreover, a temperature measured by the heat-medium temperature sensor 19 is output to the controller 15. Furthermore, the controller 15 acquires an output of the pump 14. The refrigeration system 100 is not provided with an inverter for driving the pump 14. In other words, the pump 14 operates at a fixed frequency. With regard to the output of the pump 14, a set value for the operating frequency of the pump 14, transmitted from the controller 15 to the pump 14, may be used. The pump 14 may be provided with a wattmeter (not shown), and the power consumed by the pump 14 and acquired from the wattmeter may be used as the output of the pump 14.

[0014]

[Chiller Unit 120]

The chiller unit 120 includes a refrigerant circuit C2, a pump 24, the controller 25, and an inverter 26. The pump 24 has a configuration similar to that of the pump 14. The pump 24 has a heat-medium inlet that is connected to a heat-medium pipe WP21 and a heat-medium outlet that is connected to a heat-medium pipe WP22. The refrigerant circuit C2 is connected to the heat-medium pipe WP22 and a heat-medium pipe WP23. The heat medium flowing through the heat-medium pipe WP22 is heated or cooled by the refrigerant flowing through the refrigerant circuit C2, and flows into the heat-medium pipe WP23. The controller 25 controls the inverter 26

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and the pump 24.   Furthermore, the controller 25 controls the inverter 26 to change the frequency of a compressor 22.   The heat-medium pipe WP23 is connected to the first header Hd1, and the heat-medium pipe WP21 is connected to the second header Hd2.

5   [0015]

[Chiller Unit 130]

The chiller unit 130 includes a refrigerant circuit C3, a pump 34, the controller 35, and an inverter 36.   The pump 34 has a configuration similar to that of the pump 14.   The pump 34 has a heat-medium inlet that is connected to a heat-medium pipe

10   WP31 and a heat-medium outlet that is connected to a heat-medium pipe WP32. The refrigerant circuit C3 is connected to the heat-medium pipe WP32 and a heat-medium pipe WP33.   The heat medium flowing through the heat-medium pipe WP32 is heated or cooled by the refrigerant flowing through the refrigerant circuit C3, and flows into the heat-medium pipe WP33.   The controller 35 controls the inverter 36

15   and the pump 34.   Furthermore, the controller 35 controls the inverter 36 to change the frequency of a compressor 32.   The heat-medium pipe WP33 is connected to the first header Hd1, and the heat-medium pipe WP31 is connected to the second header Hd2.

[0016]

20   In the following description, the controller 15, the controller 25, and the controller 35 are collectively referred to as a controller Cnt.   The controller Cnt is constituted of, for example, dedicated hardware or a central processing unit (also called a CPU, a central processing device, a processing device, an arithmetic device, a microprocessor, a microcomputer, or a processor) that executes a program stored

25   in a memory.   When the controller Cnt is dedicated hardware, the controller Cnt corresponds to, for example, a single circuit, a composite circuit, an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or a combination of these arrangements.   The function units included in the controller Cnt may each be included in the corresponding one of hardware units, or the function

30   units may be included in a single hardware unit.

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When the controller Cnt is a CPU, the functions performed by the controller Cnt are performed by software, firmware, or a combination of software and firmware. Software and firmware are described as programs and are stored in the memory. The CPU reads and executes the programs stored in the memory to perform the functions of the controller Cnt. The memory used may be, for example, a nonvolatile or volatile semiconductor memory, such as a RAM, a ROM, a flash memory, an EPROM, and an EEPROM. One of more functions of the controller Cnt may be performed by dedicated hardware, and the remaining one of more functions may be performed by software or firmware.

[0017]

As shown in Fig. 1D, the controller Cnt includes a first frequency acquiring unit 50A, a number-of-operating-units determining unit 50B, a compressor control unit 50C, and a memory 50G.

[0018]

The first frequency acquiring unit 50A acquires a first frequency ratio. A first frequency ratio can be acquired by dividing a total frequency of the operating frequency of the compressor 12, the operating frequency of the compressor 22, and the operating frequency of the compressor 32 by a predetermined first rated frequency. A first rated frequency can be acquired by adding together a maximum value of the operating frequency of the compressor 12, a maximum value of the operating frequency of the compressor 22, and a maximum value of the operating frequency of the compressor 32.

[0019]

The number-of-operating-units determining unit 50B determines the number of operating units on the basis of the first frequency ratio. The number-of-operating-units determining unit 50B determines the number of operating units on the basis of whether or not the first frequency ratio is larger than or equal to a threshold value to be described in, for example, Fig. 2. The threshold value used by the number-of-operating-units determining unit 50B is a value based on the outside-air temperature measured by the outside-air temperature sensor 18. Moreover, the threshold value

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used by the number-of-operating-units determining unit 50B is a value based on the heat-medium temperature measured by the heat-medium temperature sensor 19. Furthermore, the threshold value used by the number-of-operating-units determining unit 50B is a value based on the output of the pump 14.

5   The compressor control unit 50C causes at least one of the compressor 12, the compressor 22, and the compressor 32 to operate on the basis of whether or not the first frequency ratio is larger than or equal to a predetermined threshold value. The compressor control unit 50C controls the inverter 16, the inverter 26, and the inverter 36 to change the operating frequencies of the compressor 12, the compressor 22,

10   and the compressor 32.

[0020]

       The memory 50G has various types of data, such as threshold values, stored in the memory 50G.

[0021]

15   [Description of Control Flow]

       Fig. 2 is a control flowchart of the refrigeration system 100 according to Embodiment 1.

       The controller Cnt calculates a first frequency ratio (step S1). The controller Cnt acquires a threshold value on the basis of a measured outside-air temperature, a

20   measured heat-medium temperature, and an output of the pump 14 (step S2). The controller Cnt compares the first frequency ratio and the acquired threshold value to determine the number of operating units (step S3). The controller Cnt transmits an operation signal or a stop signal to the inverter corresponding to each compressor (step S4).

25   [0022]

       In addition to the number of operating units determined in step S3, it may be determined which of the compressors is caused to operate. For example, when the number of operating units is two, the compressor 12 and the compressor 22 may be caused to operate, and the compressor 32 may be stopped (first pattern).

30   Alternatively, the compressor 12 and the compressor 32 may be caused to operate,

and the compressor 22 may be stopped (second pattern).   As another alternative, the compressor 32 and the compressor 22 may be caused to operate, and the compressor 12 may be stopped (third pattern).   The controller Cnt may select any one of the first to third patterns on the basis of, for example, the operating time of

5   each compressor.

[0023]

Fig. 3 illustrates threshold values set on the basis of the outside-air temperature and the frequency ratio.

A curve A1 represents a COP rate when the measured outside-air temperature

10   is 25 degrees C and the number of operating compressors is one.   A curve A2 represents a COP rate when the measured outside-air temperature is 25 degrees C and the number of operating compressors is two.   A curve A3 represents a COP rate when the measured outside-air temperature is 25 degrees C and the number of operating compressors is three.   A curve A4 represents a COP rate when the

15   measured outside-air temperature is 25 degrees C and the number of operating compressors is four.

As shown in the curves A1 to A4, it is clear that the first frequency ratio that can improve the COP increases with increasing number of operating units.

[0024]

20   A curve B1 represents a COP rate when the measured outside-air temperature is 35 degrees C and the number of operating compressors is one.   A curve B2 represents a COP rate when the measured outside-air temperature is 35 degrees C and the number of operating compressors is two.   A curve B3 represents a COP rate when the measured outside-air temperature is 35 degrees C and the number of

25   operating compressors is three.   A curve B4 represents a COP rate when the measured outside-air temperature is 35 degrees C and the number of operating compressors is four.

The curves B1 to B4 show tendencies similar to those of the curves A1 to A4. In other words, it is clear that the first frequency ratio that can improve the COP

increases with increasing number of operating units.   However, the curves B1 to B4 are entirely located below the curves A1 to A4.

[0025]

A line L1 corresponds to a threshold value that separates a case where the number of operating units is set to one and a case where the number of operating units is set to two.   A line L2 corresponds to a threshold value that separates a case where the number of operating units is set to two and a case where the number of operating units is set to three.   A line L3 corresponds to a threshold value that separates a case where the number of operating units is set to three and a case where the number of operating units is set to four.   The lines L1, L2, and L3 are inclined.   In other words, Fig. 3 shows that the threshold values for determining the number of operating units change on the basis of the measured outside-air temperature.   The inclination of each of the lines L1, L2, and L3 represents that the threshold value increases with increasing outside-air temperature.

[0026]

The lines L1, L2, and L3 are linear expressions.   Furthermore, in a case where the accuracy of the suitable number of operating units is to be improved, the lines L1, L2, and L3 may be quadratic or cubic expressions in view of, for example, the memory of the controller Cnt.   The refrigeration system 100 employs the mode shown in Fig. 3 so that the COP increases by, for example, about 10%, as compared with an existing refrigeration system.

[0027]

Fig. 4 illustrates threshold values set on the basis of the outlet temperature and the frequency ratio.

A curve C1 represents a COP rate when the measured heat-medium temperature is 15 degrees C and the number of operating compressors is one.   A curve C2 represents a COP rate when the measured heat-medium temperature is 15 degrees C and the number of operating compressors is two.   A curve C3 represents a COP rate when the measured heat-medium temperature is 15 degrees C and the number of operating compressors is three.   A curve D4 represents a COP rate when

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the measured heat-medium temperature is 15 degrees C and the number of operating compressors is four.

As shown in the curves C1 to C4, it is clear that the first frequency ratio that can improve the COP increases with increasing number of operating units.

[0028]

A curve D1 represents a COP rate when the measured heat-medium temperature is 7 degrees C and the number of operating compressors is one. A curve D2 represents a COP rate when the measured heat-medium temperature is 7 degrees C and the number of operating compressors is two. A curve D3 represents a COP rate when the measured heat-medium temperature is 7 degrees C and the number of operating compressors is three. A curve D4 represents a COP rate when the measured heat-medium temperature is 7 degrees C and the number of operating compressors is four.

The curves D1 to D4 show tendencies similar to those of the curves C1 to C4. In other words, it is clear that the first frequency ratio that can improve the COP increases with increasing number of operating units. However, the curves D1 to D4 are entirely located below the curves C1 to C4.

[0029]

A line L11 corresponds to a threshold value that separates a case where the number of operating units is set to one and a case where the number of operating units is set to two. A line L12 corresponds to a threshold value that separates a case where the number of operating units is set to two and a case where the number of operating units is set to three. A line L13 corresponds to a threshold value that separates a case where the number of operating units is set to three and a case where the number of operating units is set to four. The lines L11, L12, and L13 are inclined. In other words, Fig. 4 shows that the threshold values for determining the number of operating units change on the basis of the measured outside-air temperature. The inclination of each of the lines L11, L12, and L13 represents that the threshold value increases with increasing heat-medium temperature.

[0030]

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The lines L11, L12, and L13 are linear expressions. Furthermore, in a case where the accuracy of the suitable number of operating units is to be improved, the lines L11, L12, and L13 may be quadratic or cubic expressions in view of, for example, the memory of the controller Cnt. The refrigeration system 100 employs the mode shown in Fig. 4 so that the COP increases by, for example, about 5%, as compared with an existing refrigeration system.

[0031]

Fig. 5 illustrates threshold values set on the basis of the outside and the frequency ratio.

A curve E1 represents a COP rate when the pump output is 3.7 kW and the number of operating compressors is one. A curve E2 represents a COP rate when the pump output is 3.7 kW and the number of operating compressors is two. A curve E3 represents a COP rate when the pump output is 3.7 kW and the number of operating compressors is three. A curve E4 represents a COP rate when the pump output is 3.7 kW and the number of operating compressors is four.

As shown in the curves E1 to E4, it is clear that the first frequency ratio that can improve the COP increases with increasing number of operating units.

[0032]

A curve F1 represents a COP rate when the pump output is 7.5 kW and the number of operating compressors is one. A curve F2 represents a COP rate when the pump output is 7.5 kW and the number of operating compressors is two. A curve F3 represents a COP rate when the pump output is 7.5 kW and the number of operating compressors is three. A curve F4 represents a COP rate when the pump output is 7.5 kW and the number of operating compressors is four.

The curves F1 to F4 show tendencies similar to those of the curves E1 to E4. In other words, it is clear that the first frequency ratio that can improve the COP increases with increasing number of operating units. However, the curves F1 to F4 are entirely located below the curves E1 to E4.

[0033]

A line L21 corresponds to a threshold value that separates a case where the number of operating units is set to one and a case where the number of operating units is set to two. A line L22 corresponds to a threshold value that separates a case where the number of operating units is set to two and a case where the number of operating units is set to three. A line L23 corresponds to a threshold value that separates a case where the number of operating units is set to three and a case where the number of operating units is set to four. The lines L21, L22, and L23 are inclined. In other words, Fig. 5 shows that the threshold values for determining the number of operating units change on the basis of the pump output. The inclination of each of the lines L21, L22, and L23 represents that the threshold value increases with increasing pump output.

[0034]

The lines L21, L22, and L23 are linear expressions. Furthermore, in a case where the accuracy of the suitable number of operating units is to be improved, the lines L21, L22, and L23 may be quadratic or cubic expressions in view of, for example, the memory of the controller Cnt. The refrigeration system 100 employs the mode shown in Fig. 5 so that the COP increases by, for example, about 10%, as compared with an existing refrigeration system.

[0035]

The controller Cnt has data corresponding to the lines L1, L2, L3, L11, L12, L13, L21, L22, and L23 stored in the controller Cnt. The controller Cnt acquires information about the measured outside-air temperature, the measured heat-medium temperature, and the pump output, and determines the number of operating units.

[0036]

[Advantage of Embodiment 1]

In the refrigeration system 100, a threshold value for determining the number of operating units is set on the basis of at least one of the outside-air temperature, the temperature of the heat medium flowing through the heat-medium circuit, and the pump output. Consequently, the COP can be increased more reliably.

[0037]

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Embodiment 2

Fig. 6A schematically illustrates a chiller unit group 201 of a refrigeration system according to Embodiment 2.   Fig. 6B illustrates a controller Cnt of the refrigeration system according to Embodiment 2.   In Embodiment 2, sections

5   different from those in Embodiment 1 will mainly be described, the same sections will be given the same reference signs, and descriptions of the sections will be omitted.
[0038]

In Embodiment 1, a case is described where the flow rate of the heat medium is fixed.   In other words, in Embodiment 1, the operating frequency of each pump is

10   fixed.   In Embodiment 2, inverters (an inverter 17, an inverter 27, and an inverter 37) for controlling the pumps are provided.   A chiller unit 211 is provided with the inverter 17, a chiller unit 221 is provided with the inverter 27, and a chiller unit 231 is provided with the inverter 37.   The controller Cnt controls the inverter 17, the inverter 27, and the inverter 37 to change the operating frequencies of the pump 14, the pump 24, and

15   the pump 34.   For the operating frequency of each of the pump 14, the pump 24, and the pump 34, a minimum frequency is predetermined.   In other words, the minimum frequencies are stored in the controller Cnt.   The refrigeration system according to Embodiment 2 can reduce the power consumption of each pump by lowering the operating frequency of the pump depending on the circumstances.   For example, in

20   a case where the heat medium heated by the device 102 is to be conveyed, when a load generated in the device 102 (i.e., a requested amount of heat in the device 102) decreases, the controller Cnt controls the inverters to lower the operating frequencies of the pumps.   Consequently, the refrigeration system according to Embodiment 2 can improve the COP.

25   [0039]

As shown in Fig. 6B, a second frequency-ratio acquiring unit 50D acquires a second frequency ratio.   A second frequency ratio can be acquired by dividing a total frequency of the operating frequency of the pump 14, the operating frequency of the pump 24, and the operating frequency of the pump 34 by a predetermined second

30   rated frequency.   A second rated frequency can be acquired by adding together a

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maximum value of the operating frequency of the pump 14, a maximum value of the operating frequency of the pump 24, and a maximum value of the operating frequency of the pump 34.

[0040]

An operating-frequency determining unit 50E determines the operating frequency of each operating pump on the basis of the first frequency ratio and the second frequency ratio.   For example, when the compressor 12 and the compressor 22 are operating, the operating-frequency determining unit 50E determines the operating frequencies of the pump 14 and the pump 24 on the basis of the first frequency ratio and the second frequency ratio.   The operating-frequency determining unit 50E determines the operating frequency of each operating pump in such a manner that the second frequency ratio approximates the first frequency ratio.

A pump control unit 50F controls the inverter 17, the inverter 27, and the inverter 37.   Consequently, the operating frequencies of the pump 14, the pump 24, and the pump 34 change.

[0041]

Fig. 7 is a control flowchart of the refrigeration system according to Embodiment 2.

As step S20, step S21, step S24, step S25, and step S26 in Fig. 7 are similar to step S0, step S1, and step S3 to step S5 in Fig. 2, descriptions of the steps will be omitted.

[0042]

The controller Cnt determines whether the operating frequency of each pump is to be fixed or whether variable flow control (inverter control) for variably controlling the operating frequency of each pump is to be performed (step S22).   The controller Cnt acquires a threshold value without setting a flag for executing the variable flow control (step S23-1).   Alternatively, the controller Cnt sets the flag for executing the variable flow control and acquires the threshold value (step S23-2).   After the process shown in the flowchart ends, the pump corresponding to the chiller unit in which the compressor is caused to operate executes the variable flow control.

[0043]

Fig. 8 is a control flowchart of each pump in the refrigeration system according to Embodiment 2.

The controller Cnt calculates a first frequency ratio (step S31). The controller Cnt acquires a second frequency ratio. The controller Cnt determines the operating frequency of each pump so that the second frequency ratio approximates the first frequency ratio acquired in the process shown in Fig. 7 (step S32). It is determined whether or not the determined operating frequency of each pump is lower than or equal to a predetermined minimum frequency (step S33). When the determined operating frequency is higher than the minimum frequency, the operating frequency determined in step S32 is set as a command frequency of each pump (step S34-2). When the determined operating frequency is lower than or equal to the minimum frequency, the minimum frequency is set as the command frequency of each pump (step S34-2). The controller Cnt transmits an operation signal or a stop signal to the inverter corresponding to each pump (step S35).

[0044]

Fig. 9 illustrates threshold values set on the basis of the outside-air temperature and the frequency ratio, according to Embodiment 2. Fig. 9 is a diagram when the pump output is 50%. When the pump output is 100%, the pump is operating with the maximum operating frequency. A curve G1 represents a COP rate when the measured outside-air temperature is 25 degrees C and the number of operating compressors is one. A curve G2 represents a COP rate when the measured outside-air temperature is 25 degrees C and the number of operating compressors is two. A curve G3 represents a COP rate when the measured outside-air temperature is 25 degrees C and the number of operating compressors is three. A curve G4 represents a COP rate when the measured outside-air temperature is 25 degrees C and the number of operating compressors is four.

As shown in the curves G1 to G4, it is clear that the first frequency ratio that can improve the COP increases with increasing number of operating units. The curves G1 to G4 have been moved to positions higher than the curves A1 to A4

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shown in Fig. 3.   This is because the COP of the refrigeration system is improved, owing to the pump output being lowered to 50%.

[0045]

A curve H1 represents a COP rate when the measured outside-air temperature is 35 degrees C and the number of operating compressors is one.   A curve H2 represents a COP rate when the measured outside-air temperature is 35 degrees C and the number of operating compressors is two.   A curve H3 represents a COP rate when the measured outside-air temperature is 35 degrees C and the number of operating compressors is three.   A curve H4 represents a COP rate when the measured outside-air temperature is 35 degrees C and the number of operating compressors is four.

As shown in the curves H1 to H4, it is clear that the first frequency ratio that can improve the COP increases with increasing number of operating units.   The curves H1 to H4 are located below the curves G1 to G4.   On the other hand, the curves H1 to H4 are located at positions of the curves B1 to B4 shown in Fig. 3. This is because the COP of the refrigeration system is improved, owing to the pump output being lowered to 50%.

[0046]

A line L31 corresponds to a threshold value that separates a case where the number of operating units is set to one and a case where the number of operating units is set to two.   A line L32 corresponds to a threshold value that separates a case where the number of operating units is set to two and a case where the number of operating units is set to three.   A line L33 corresponds to a threshold value that separates a case where the number of operating units is set to three and a case where the number of operating units is set to four.   The lines L31, L32, and L33 are inclined.   In other words, similar to Fig. 3, Fig. 9 shows that the threshold values for determining the number of operating units change on the basis of the measured outside-air temperature.   The inclination of each of the lines L31, L32, and L33 represents that the threshold value increases with increasing outside-air temperature.

[0047]

The lines L31, L32, and L33 are linear expressions. Furthermore, in a case where the accuracy of the suitable number of operating units is to be improved, the L31, L32, and L33 may be quadratic or cubic expressions in view of, for example, the memory of the controller Cnt. The refrigeration system according to Embodiment 2

5 improves the COP by, for example, about 10%, as compared with an existing refrigeration system.

[0048]

[Advantage of Embodiment 2]

In the refrigeration system according to Embodiment 2, not only the operation

10 of the compressors is improved, but also the operation of the pumps is improved, so that the COP can be further improved.

[0049]

Any one of the refrigerant circuit C1, the refrigerant circuit C2, and the refrigerant circuit C3 according to each of Embodiment 1 and Embodiment 2

15 corresponds to a first refrigerant circuit, and a remaining one of the refrigerant circuits corresponds to a second refrigerant circuit. A pump in the refrigerant circuit (i.e., any one of the refrigerant circuit C1, the refrigerant circuit C2, and the refrigerant circuit C3) corresponding to the first refrigerant circuit corresponds to a first pump, and a pump in the refrigerant circuit (i.e., the remaining one of the refrigerant circuit C1, the

20 refrigerant circuit C2, and the refrigerant circuit C3) corresponding to the second refrigerant circuit corresponds to a second pump. The same applies to a first compressor and a second compressor, as well as a first heat exchanger and a second heat exchanger. Any one of the heat-medium pipe WP2, the heat-medium pipe WP22, and the heat-medium pipe WP32 according to each of Embodiment 1

25 and Embodiment 2 corresponds to a first heat-medium flow path, and a remaining one of the heat-medium pipes corresponds to a second heat-medium flow path.

[0050]

In each of Embodiment 1 and Embodiment 2, the number of refrigerant circuits is three as an example. Alternatively, the number of refrigerant circuits may be two,

30 or may be four or more.

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Reference Signs List

[0051]

12 compressor 13A heat exchanger 13B heat exchanger 14 pump 15 controller 16 inverter 17 inverter 18 outside-air temperature sensor 19 heat-medium temperature sensor 22 compressor 24 pump 25 controller 26 inverter 27 inverter 32 compressor 34 pump 35 controller 36 inverter 37 inverter 50A first frequency acquiring unit 50B number-of-operating-units determining unit 50C compressor control unit 50D second frequency-ratio acquiring unit 50E operating-frequency determining unit 50F pump control unit 50G memory 100 refrigeration system 101 chiller unit group 102 device 102A heat exchanger 102B fan 110 chiller unit 120 chiller unit 130 chiller unit 201 chiller unit group 211 chiller unit 221 chiller unit 231 chiller unit C1 refrigerant circuit C2 refrigerant circuit C3 refrigerant circuit Cnt controller Hd1 first header Hd2 second header Rp refrigerant pipe V1 expansion device WC heat-medium circuit WP1 heat-medium pipe WP2 heat-medium pipe WP21 heat-medium pipe WP22 heat-medium pipe WP23 heat-medium pipe WP3 heat-medium pipe WP31 heat-medium pipe WP32 heat-medium pipe WP33 heat-medium pipe WP40 heat-medium pipe WP50 heat-medium pipe

CLAIMS

[Claim 1]

A refrigeration system, comprising:

a first refrigerant circuit including a first compressor and a first heat exchanger;

a second refrigerant circuit including a second compressor and a second heat exchanger;

a heat-medium circuit having a pump, a first heat-medium flow path connected to the first heat exchanger, and a second heat-medium flow path connected to the second heat exchanger; and

a controller configured to control the first compressor, the second compressor, and the pump,

the controller including a compressor control unit configured to cause both of the first compressor and the second compressor to operate when a first frequency ratio is larger than or equal to a predetermined threshold value, and to cause one of the first compressor and the second compressor to operate when the first frequency ratio is smaller than the threshold value,

the first frequency ratio being a value obtained by dividing a total frequency of an operating frequency of the first compressor and an operating frequency of the second compressor by a predetermined first rated frequency,

the threshold value being set on a basis of at least one of an outside-air temperature, a temperature of a heat medium flowing through the heat-medium circuit, and an output of the pump.

[Claim 2]

The refrigeration system of claim 1, wherein the threshold value is increased as the outside-air temperature increases.

[Claim 3]

The refrigeration system of claim 1 or 2, wherein the threshold value is increased as a temperature of the heat medium flowing through an outlet of the first heat exchanger in the first heat-medium flow path or a temperature of the heat

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medium flowing through an outlet of the second heat exchanger in the second heat-medium flow path decreases.

[Claim 4]

The refrigeration system of any one of claims 1 to 3, wherein the threshold value is increased as the output of the pump increases.

[Claim 5]

The refrigeration system of any one of claims 1 to 4, further comprising

an inverter configured to control the pump,

wherein the controller further includes a pump control unit configured to control the inverter.

[Claim 6]

The refrigeration system of claim 5,

wherein the pump includes a first pump provided in the first heat-medium flow path and a second pump provided in the second heat-medium flow path, and

wherein the pump control unit is configured to set an operating frequency of the first pump and an operating frequency of the second pump in such a manner that a second frequency ratio approximates the first frequency ratio, the second frequency ratio being a value obtained by dividing a total frequency of the operating frequency of the first pump and the operating frequency of the second pump by a predetermined second rated frequency.

[Claim 7]

A controller configured to control a refrigeration system,

the refrigeration system including

a first refrigerant circuit including a first compressor and a first heat exchanger,

a second refrigerant circuit including a second compressor and a second heat exchanger, and

a heat-medium circuit having a pump, a first heat-medium flow path connected to the first heat exchanger, and a second heat-medium flow path connected to the second heat exchanger,

the controller comprising

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a compressor control unit configured to cause both of the first compressor and the second compressor to operate when a first frequency ratio is larger than or equal to a predetermined threshold value, and to cause one of the first compressor and the second compressor to operate when the first frequency ratio is smaller than the threshold value,

the first frequency ratio being a value obtained by dividing a total frequency of an operating frequency of the first compressor and an operating frequency of the second compressor by a predetermined first rated frequency,

the threshold value being set on a basis of at least one of an outside-air temperature, a temperature of a heat medium flowing through the heat-medium circuit, and an output of the pump.

A. CLASSIFICATION OF SUBJECT MATTER
F25B1/00(2006.01)i, *F24F11/02*(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, F24F11/02

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   1996-2017
Kokai Jitsuyo Shinan Koho   1971-2017   Toroku Jitsuyo Shinan Koho   1994-2017

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2000-002474 A (Mitsubishi Electric Corp.), 07 January 2000 (07.01.2000), paragraphs [0084] to [00105]; fig. 7 to 11 (Family: none)	1-7
Y	JP 2014-214954 A (Mitsubishi Electric Corp.), 17 November 2014 (17.11.2014), paragraphs [0012] to [0028]; fig. 1 to 5 (Family: none)	1-7
Y	JP 2013-231542 A (Mitsubishi Electric Corp.), 14 November 2013 (14.11.2013), paragraphs [0009] to [0040]; fig. 1 to 5 (Family: none)	1-7

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

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C (Continuation).   DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	JP 2012-112557 A (Mitsubishi Electric Corp.), 14 June 2012 (14.06.2012), paragraphs [0010] to [0022]; fig. 1 to 6 (Family: none)	5-6