

## DESCRIPTION

## TITLE OF THE INVENTION:

TEMPERATURE CONTROL SYSTEM, TEMPERATURE CONTROL METHOD,  
CONTROL DEVICE, AND COMPUTER PROGRAM

## TECHNICAL FIELD

[0001]

Embodiments of the present invention relate to a temperature control system, a temperature control method, a control device, and a computer program.

## BACKGROUND ART

[0002]

There is known a temperature control system including a refrigeration apparatus having a compressor, a condenser, an expansion valve, and an evaporator, and a fluid circulation apparatus circulating a fluid such as water or brine, in which the fluid circulated by the fluid circulation apparatus is cooled by the evaporator of the refrigeration apparatus. The present applicant has previously proposed this type of system, for example, in Patent Literature 1 (JPB6053907).

## SUMMARY OF THE INVENTION

[0003]

In a manufacturing plant, temperature conditions may be switched as a manufacturing process is switched. In such a temperature control at the time of switching temperature conditions, a demand for improvement in responsiveness is increasing year by year.

[0004]

When the temperature control system described above the switching of the temperature condition of the manufacturing process, the temperature control system may perform a temperature control of the temperature of a fluid circulated by the fluid circulation apparatus, for example, by PID control. In the PID control, responsiveness is improved by gain adjustment. However, even when gain adjustment is performed in the PID control, a recent high demand for responsiveness cannot be satisfied in some cases.

[0005]

On the other hand, a feedforward control may be incorporated into a PID control system to improve responsiveness. In the feedforward control, since a large control amount can be input separately from the PID control, responsiveness can be improved. However, when a large control amount is

suddenly input, a stable operation of the device or a constituent device of the system may be impaired, or an undesirable load or impact may be applied to the constituent device.

[0006]

Therefore, an object of the present invention is to provide a temperature control system, a temperature control method, a control device, and a computer program capable of suppressing an undesirable influence on an operation state and a constituent device while improving the responsiveness of the temperature control in the temperature control system.

[0007]

A temperature control system according to an embodiment of the present invention is a temperature control system including: a refrigeration apparatus including a compressor, a condenser, an expansion valve, and an evaporator, a refrigerant flowing out from the compressor passing through the condenser, the expansion valve, and the evaporator in this order and then returning to the compressor; a fluid circulation apparatus including a main flow path having a heat exchange unit between an inlet and an outlet and allowing a fluid received at the inlet to circulate to the outlet through the heat exchange unit, the fluid circulation apparatus allowing the fluid in the heat exchange unit to exchange heat with the refrigerant in the evaporator; and a control device controlling the refrigeration apparatus and the fluid circulation apparatus, in which the control device controls the compressor so that a rotation speed of the compressor is changed to a set value derived based on a changed target temperature or a changed temperature of the fluid when the target temperature of the fluid is changed or the temperature of the fluid before flowing into the heat exchange unit is changed, and performs an initial operation control of changing a flow rate of the fluid circulating in the heat exchange unit in the main flow path simultaneously with, before, or after the control of the compressor.

[0008]

A temperature control method according to an embodiment of the present invention is a temperature control method in a temperature control system including: a refrigeration apparatus including a compressor, a condenser, an expansion valve, and an evaporator, a refrigerant flowing out from the compressor passing through the condenser, the expansion valve, and the evaporator in this order and then returning to the compressor; and a fluid circulation apparatus including a main flow path having a heat exchange unit between an inlet and an outlet and allowing a fluid received at the inlet to circulate to the outlet through the heat exchange unit, the fluid circulation

apparatus allowing the fluid in the heat exchange unit to exchange heat with the refrigerant in the evaporator. The method is a temperature control method including: a detection process of detecting a change in a target temperature of the fluid or a change in a temperature of the fluid before flowing into the heat exchange unit; and a control process of controlling the compressor so that a rotation speed of the compressor is changed to a set value derived based on a changed target temperature or a changed temperature of the fluid when the change in a target temperature of the fluid or the change in a temperature of the fluid before flowing into the heat exchange unit is detected in the detection process, and changing a flow rate of the fluid circulating in the heat exchange unit in the main flow path simultaneously with, before, or after the control of the compressor.

[0009]

A control device according to an embodiment of the present invention is a control device controlling a temperature control system including: a refrigeration apparatus including a compressor, a condenser, an expansion valve, and an evaporator, a refrigerant flowing out from the compressor passing through the condenser, the expansion valve, and the evaporator in this order and then returning to the compressor; and a fluid circulation apparatus including a main flow path having a heat exchange unit between an inlet and an outlet and allowing a fluid received at the inlet to circulate to the outlet through the heat exchange unit, the fluid circulation apparatus allowing the fluid in the heat exchange unit to exchange heat with the refrigerant in the evaporator, the control device controlling the compressor so that a rotation speed of the compressor is changed to a set value derived based on a changed target temperature or a changed temperature of the fluid when the target temperature of the fluid is changed or the temperature of the fluid before flowing into the heat exchange unit is changed, and performing an initial operation control of changing a flow rate of the fluid circulating in the heat exchange unit in the main flow path simultaneously with, before, or after the control of the compressor.

[0010]

A computer program according to an embodiment of the present invention is a computer program for controlling a refrigeration apparatus including a compressor, a condenser, an expansion valve, and an evaporator, a refrigerant flowing out from the compressor passing through the condenser, the expansion valve, and the evaporator in this order and then returning to the compressor, and a fluid circulation apparatus including a main flow path having a heat exchange unit between an inlet and an outlet and allowing a

fluid received at the inlet to circulate to the outlet through the heat exchange unit, the fluid circulation apparatus allowing the fluid in the heat exchange unit to exchange heat with the refrigerant in the evaporator, the computer program configured to cause a computer to execute: a detection step of detecting a change in a target temperature of the fluid or a change in a temperature of the fluid before flowing into the heat exchange unit; and a control step of controlling the compressor so that a rotation speed of the compressor is changed to a set value derived based on a changed target temperature or a changed temperature of the fluid when the change in a target temperature of the fluid or the change in a temperature of the fluid before flowing into the heat exchange unit is detected in the detection step, and changing a flow rate of the fluid circulating in the heat exchange unit in the main flow path simultaneously with, before, or after the control of the compressor.

[0011]

According to the present invention, it is possible to suppress an undesirable influence on an operation state and a constituent device while improving the responsiveness of the temperature control in a temperature control system.

## BRIEF DESCRIPTION OF DRAWINGS

[0012]

[Fig. 1] Fig. 1 is a diagram schematically illustrating a temperature control system according to an embodiment.

[Fig. 2] Fig. 2 is a block diagram illustrating a functional configuration of a control device constituting the temperature control system of Fig. 1.

[Fig. 3] Fig. 3 is a conceptual diagram illustrating information for deriving a relational expression used for control by the control device constituting the temperature control system of Fig. 1.

[Fig. 4] Fig. 4 is a view showing a graph showing a relationship between a thermal load expressed by a relational expression used for control by the control device constituting the temperature control system of Fig. 1 and a rotation speed of a compressor.

[Fig. 5] Fig. 5 is a flowchart for explaining an operation of the temperature control system of Fig. 1.

[Fig. 6] Fig. 6 is a flowchart for explaining an operation of the temperature control system of Fig. 1.

[Fig. 7] Fig. 7 is a view showing a graph for explaining an operation of a constituent device of the temperature control system of Fig. 1 and a

temperature control state.

[Fig. 8] Fig. 8 is a view showing a set value table that can be used in control of the control device constituting the temperature control system of Fig. 1.

[Fig. 9] Fig. 9 is a diagram schematically illustrating a temperature control system according to a modification.

[Fig. 10] Fig. 10 is a diagram schematically illustrating a temperature control system according to another modification.

[Fig. 11] Fig. 11 is a flowchart for explaining an operation of a temperature control system according to a modification.

[Fig. 12] Fig. 12 is a flowchart for explaining an operation of the temperature control system related to Fig. 11.

[Fig. 13] Fig. 13 is a view showing a graph for explaining an operation of a constituent device of the temperature control system corresponding to the operations of Figs. 11 and 12 and a temperature control state.

[Fig. 14] Fig. 14 is a flowchart for explaining an operation of a temperature control system according to another modification.

[Fig. 15] Fig. 15 is a diagram for explaining an application example of a temperature control system according to an embodiment or a modification.

## BEST MODE FOR CARRYING OUT THE INVENTION

[0013]

Hereinafter, an embodiment of the present invention will be described.

[0014]

### <Configuration of Temperature Control System>

Fig. 1 is a schematic diagram of a temperature control system 1 according to an embodiment. The temperature control system 1 illustrated in Fig. 1 includes a refrigeration apparatus 10, a fluid circulation apparatus 20, and a control device 30.

[0015]

The refrigeration apparatus 10 controls the temperature of a fluid circulated by the fluid circulation apparatus 20 using a refrigerant. The fluid circulation apparatus 20 supplies the fluid whose temperature is controlled by the refrigeration apparatus 10 to a temperature control target T.

[0016]

The fluid circulation apparatus 20 is configured to circulate the fluid having passed through the temperature control target T. The fluid returned from the temperature control target T is temperature-controlled again by the refrigeration apparatus 10. The fluid circulated in the fluid circulation

apparatus 20 is, for example, brine, but may be another fluid such as water.  
[0017]

The control device 30 is configured to control the refrigeration apparatus 10 and the fluid circulation apparatus 20, and for example, sets a target temperature of the fluid to be supplied to the temperature control target T according to an operation of a user, or controls each unit so that the temperature of the fluid becomes the set target temperature. Hereinafter, each unit of the temperature control system 1 will be described in detail.  
[0018]

The refrigeration apparatus 10 includes a compressor 11, a condenser 12, an expansion valve 13, and an evaporator 14. The compressor 11, the condenser 12, the expansion valve 13, and the evaporator 14 are connected by a pipe 15 in this order so as to circulate the refrigerant.  
[0019]

The compressor 11 is configured to compress the refrigerant in a low-temperature and low-pressure gas state flowing out from the evaporator 14 into a high-temperature and high-pressure gas state and supply the refrigerant to the condenser 12. The condenser 12 is configured to cool and condense the refrigerant compressed by the compressor 11 with, for example, cooling water, into a high-pressure liquid state at a predetermined cooling temperature and supply the refrigerant to the expansion valve 13. The cooling water passing through the condenser 12 may be water or other refrigerants. Note that the condenser 12 may be an air-cooled condenser.  
[0020]

The expansion valve 13 is configured to decompress the refrigerant supplied from the condenser 12 by expanding the refrigerant into a low-temperature and low-pressure gas-liquid mixed state and supply the refrigerant to the evaporator 14. The evaporator 14 heat-exchanges the refrigerant supplied from the expansion valve 13 with the fluid of the fluid circulation apparatus 20. The refrigerant heat-exchanged with the fluid is in a low-temperature and low-pressure gas state, flows out from the evaporator 14, and returns to the compressor 11. The refrigerant flowing out from the evaporator 14 is compressed again by the compressor 11.  
[0021]

The fluid circulation apparatus 20 includes a main flow path 21 having an inlet 21U and an outlet 21D, and the main flow path 21 connects each of the inlet 21U and the outlet 21D to the temperature control target T. The main flow path 21 has a heat exchange unit 21E between the inlet 21U and the outlet 21D, and causes the fluid received at the inlet 21U to flow to the

outlet 21D through the heat exchange unit 21E.

[0022]

The fluid circulation apparatus 20 heat-exchanges the fluid in the heat exchange unit 21E with the refrigerant in the evaporator 14, and then sends the fluid from the outlet 21D to the temperature control target T. The fluid circulation apparatus 20 receives the fluid having passed through the temperature control target T at the inlet 21U. The fluid circulation apparatus 20 guides the fluid flowing into the inlet 21U to the heat exchange unit 21E and causes the evaporator 14 to exchange heat again.

[0023]

The fluid circulation apparatus 20 further includes a pump 22, a tank 23, a bypass flow path 24, a valve mechanism 25, a first temperature sensor 26, a second temperature sensor 27, and a flow rate sensor 28.

[0024]

The pump 22 constitutes a part of the main flow path 21 and generates a driving force for causing the fluid to flow. The pump 22 is disposed in an upstream portion of the heat exchange unit 21E in the main flow path 21, but the position thereof is not particularly limited. The pump 22 is electrically connected to the control device 30, and the rotation speed is controlled by the control device 30. When the rotation speed of the pump 22 is increased or decreased, the flow rate of the fluid circulating in the fluid circulation apparatus 20 can be adjusted.

[0025]

The tank 23 is also disposed in the upstream portion of the heat exchange unit 21E in the main flow path 21. The tank 23 is provided to store a certain amount of the fluid and constitutes a part of the main flow path 21. In the present embodiment, the pump 22 is disposed in the tank 23, but the pump 22 may be provided outside the tank 23.

[0026]

The bypass flow path 24 connects the upstream portion and the downstream portion of the heat exchange unit 21E in the main flow path 21, and allows the fluid received from the upstream portion of the main flow path 21 to circulate. The valve mechanism 25 adjusts the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 and the flow rate of the fluid circulating in the bypass flow path 24.

[0027]

The valve mechanism 25 in the present embodiment includes a three-way valve 25V. The three-way valve 25V includes a first port 251, a second port 252, and a third port 253. A flow path from the first port 251 to the

second port 252 constitutes a part of the main flow path 21. An upstream end opening of the bypass flow path 24 is connected to the downstream portion of the pump 22 and the upstream portion of the heat exchange unit 21E in the main flow path 21, and the downstream end opening is connected to the third port 253 of the three-way valve 25V.

[0028]

The three-way valve 25V can adjust a ratio between the flow rate of the fluid flowing into the first port 251 and flowing out from the second port 252 and the flow rate of the fluid flowing into the third port 253 and flowing out from the second port 252. As a result, a ratio between the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 and the flow rate of the fluid circulating in the bypass flow path 24 can be adjusted. Note that although the valve mechanism 25 includes the three-way valve 25V, a configuration in which two or more two-way valves are combined may be used. The three-way valve 25V may be a motor valve, and the two-way valve may be an electromagnetic valve.

[0029]

The first temperature sensor 26 detects the temperature of the fluid circulating in the downstream portion of the heat exchange unit 21E in the main flow path 21. Specifically, the first temperature sensor 26 detects the temperature of the fluid circulating in the downstream portion of a connection position with the downstream end of the bypass flow path 24 in the main flow path 21, specifically, the temperature of the fluid circulating in the downstream portion of the three-way valve 25V.

[0030]

The second temperature sensor 27 detects the temperature of the fluid circulating in the upstream portion of the heat exchange unit 21E in the main flow path 21. Specifically, the second temperature sensor 27 detects the temperature of the fluid circulating in a portion between the inlet 21U and the tank 23 in the main flow path 21. Note that the detection position of the second temperature sensor 27 may not be in the above aspect, and may be in the tank 23, a portion between the tank 23 and the heat exchange unit 21E in the main flow path 21, or the like.

[0031]

The flow rate sensor 28 detects the flow rate of the fluid circulating in the downstream portion of a connection position with the downstream end of the bypass flow path 24 in the main flow path 21, specifically, the flow rate of the fluid circulating in the downstream portion of the three-way valve 25V. That is, the flow rate sensor 28 detects the flow rate of the fluid supplied to

the temperature control target T.

[0032]

The first temperature sensor 26, the second temperature sensor 27, and the flow rate sensor 28 described above are electrically connected to the control device 30, and information detected by each sensor (temperature information, flow rate information) is transmitted to the control device 30.

[0033]

The control device 30 is a controller that controls the operations of the refrigeration apparatus 10 and the fluid circulation apparatus 20, and may be configured by, for example, a computer having a CPU, a ROM, and the like. In this case, various processes are performed according to the program stored in the ROM. Note that the control device 30 may include another processor or an electric circuit (for example, field programmable gate alley (FPGA) or the like).

[0034]

The control device 30 controls the refrigeration apparatus 10 and the fluid circulation apparatus 20 so as to control the temperature of the fluid to a target temperature set for the fluid circulated by the fluid circulation apparatus 20, for example. At this time, the control device 30 controls the rotation speed of the compressor 11 and the opening degree of the expansion valve 13 in the refrigeration apparatus 10. The control device 30 controls the rotation speed of the pump 22 and the operation of the valve mechanism 25 in the fluid circulation apparatus 20. Hereinafter, the configuration of the control device 30 will be described in detail.

[0035]

#### <Configuration of Control Device>

Fig. 2 is a block diagram illustrating a functional configuration of the control device 30. As illustrated in Fig. 2, the control device 30 includes an interface unit 301, a target temperature setting unit 302, a temperature acquisition unit 303, a flow rate acquisition unit 304, a thermal load calculation unit 305, a transition determination unit 306, a compressor control unit 307, an expansion valve control unit 308, a valve mechanism control unit 309, a pump control unit 310, and a set value information holding unit 311. Most of these functional units are realized, for example, by executing a program. The set value information holding unit 311 may include a part of a recording medium such as a ROM.

[0036]

Note that the control device 30 may include, for example, one computer or a plurality of computers. In the case of including a plurality of

computers, the plurality of functional units described above may be distributed to a plurality of computers. The control device 30 controls the refrigeration apparatus 10 and the fluid circulation apparatus 20, and specifically controls the refrigeration apparatus 10 and the fluid circulation apparatus 20 using any of the plurality of functional units described above. Hereinafter, each functional unit will be described in detail.

[0037]

The interface unit 301 receives information from the outside and supplies the information to the outside. The interface unit 301 acquires information on the target temperature of the fluid circulated by the fluid circulation apparatus 20 by, for example, an input from an operation means operated by a user or an input from the outside of the device, and supplies the information to, for example, the target temperature setting unit 302. The interface unit 301 also acquires information such as an operation start command, a stop command from a user, a target flow rate of the fluid circulated by the fluid circulation apparatus 20, and the like. When acquiring the information on the target flow rate, the interface unit 301 supplies the information to the pump control unit 310 and the like.

[0038]

The target temperature setting unit 302 internally sets and holds information on the target temperature acquired from the interface unit 301 as the target temperature. The target temperature setting unit 302 supplies the acquired information on the target temperature to the thermal load calculation unit 305, the transition determination unit 306, the compressor control unit 307, the expansion valve control unit 308, the valve mechanism control unit 309, and the like.

[0039]

The temperature acquisition unit 303 acquires information on the temperature of the fluid detected by the first temperature sensor 26 and information on the temperature of the fluid detected by the second temperature sensor 27. The temperature acquisition unit 303 acquires temperature information constantly or at a predetermined cycle, and supplies the temperature information of the fluid circulating downstream of the heat exchange unit 21E acquired from the first temperature sensor 26 to the transition determination unit 306, the compressor control unit 307, the expansion valve control unit 308, the valve mechanism control unit 309, and the like. The temperature acquisition unit 303 supplies information on the temperature of the fluid circulating upstream of the heat exchange unit 21E acquired from the second temperature sensor 27 to the thermal load

calculation unit 305.

[0040]

The flow rate acquisition unit 304 acquires flow rate information of the fluid detected by the flow rate sensor 28. The flow rate acquisition unit 304 acquires flow rate information constantly or at a predetermined cycle, and supplies the acquired flow rate information to the thermal load calculation unit 305, the pump control unit 310, and the like.

[0041]

The thermal load calculation unit 305 calculates a thermal load for setting the temperature of the fluid before flowing into the heat exchange unit 21E in the main flow path 21 to the target temperature set by the target temperature setting unit 302. Specifically, the thermal load calculation unit 305 calculates the thermal load based on the target temperature, the temperature information acquired from the second temperature sensor 27, and the flow rate information of the fluid acquired from the flow rate acquisition unit 304.

[0042]

The thermal load can be obtained, for example, by multiplying a difference between the target temperature and the temperature specified by the second temperature sensor 27 by the flow rate of the fluid, the density of the fluid, and the specific heat. The thermal load calculation unit 305 may derive the thermal load on the basis of the above calculation as an example. The thermal load calculation unit 305 provides the calculated thermal load to the compressor control unit 307.

[0043]

The transition determination unit 306 acquires information on the target temperature from the target temperature setting unit 302 and temperature information on the fluid circulating downstream of the heat exchange unit 21E from the first temperature sensor 26. The transition determination unit 306 may acquire temperature information of the fluid from the second temperature sensor 27. The transition determination unit 306 in the present embodiment determines a control mode for controlling the temperature of the fluid circulating downstream of the heat exchange unit 21E to the target temperature on the basis of the information on the target temperature and the temperature information on the fluid circulating downstream of the heat exchange unit 21E. The transition determination unit 306 in the present embodiment determines any one of a steady control, an initial operation control, and a preliminary steady control as the control mode, and supplies information on the determined control mode to the compressor

control unit 307, the expansion valve control unit 308, and the valve mechanism control unit 309.

[0044]

Specifically, the transition determination unit 306 first determines to perform control in a steady control as a control mode during the first operation. That is, when the operation start is instructed after the target temperature is set in the temperature control system 1 in a stopped state, the transition determination unit 306 determines to perform control in a steady control. Thereafter, the transition determination unit 306 determines whether to maintain the steady control or transition to the "initial operation control" when the target temperature is changed. The initial operation control is processing performed to improve the responsiveness of the temperature control. Specifically, when the changed target temperature is higher than the temperature of the fluid detected by the first temperature sensor 26 at the time of change to the target temperature and an absolute value of a difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or more than the temperature threshold, the transition determination unit 306 in the present embodiment determines to transition to the initial operation control.

[0045]

In the steady control, temperature control is performed by feedback-controlling the compressor 11 and the expansion valve 13 or feedback-controlling the expansion valve 13 with the rotation speed of the compressor 11 set to a constant value. On the other hand, when a difference between the current fluid temperature and the target temperature is relatively large, the initial operation control is performed to enhance the responsiveness of the temperature control as compared with the feedback control. In the initial operation control, a relatively large operation amount is scheduled to be input to the compressor 11 and the expansion valve 13. Specifically, in the initial operation control, the rotation speed of the compressor 11 and the opening degree of the expansion valve 13 are lowered by a relatively large operation amount. Such an initial operation control is effective when the difference between the current fluid temperature and the target temperature is relatively large, and when the difference between the current fluid temperature and the target temperature is small, superiority over the feedback control may not be obtained. From the above viewpoint, the above temperature threshold is preferably a relatively large value, for example, 5 degrees. The temperature threshold may be 3 degrees or more, 5 degrees or more, or 10 degrees or more. In the present embodiment, the temperature threshold is set to 5

degrees as an example, and the initial operation control is performed when the temperature is raised by 5 degrees or more.

[0046]

When the changed target temperature is lower than the temperature of the fluid detected by the first temperature sensor 26 or when the changed target temperature is higher than the temperature of the fluid detected by the first temperature sensor 26 but the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is less than the temperature threshold, the transition determination unit 306 maintains the steady control.

[0047]

The transition determination unit 306 in the present embodiment determines the transition to the preliminary steady control when a predetermined condition is satisfied after the transition to the initial operation control. Specifically, the transition determination unit 306 determines the transition to the preliminary steady control when the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or less than a first predetermined value after the rotation speed of the compressor 11 and the opening degree of the expansion valve 13 are lowered in the initial operation control. The first predetermined value may be, for example, half the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature at the time of change to the target temperature. In this case, for example, when the target temperature is higher than the temperature of the fluid at the time of setting the target temperature by exactly 10 degrees, the first predetermined value is 5 degrees. In the preliminary steady control, as described later, while a state where the rotation speed of the compressor 11 is lowered in the initial operation control is maintained, the opening degree of the expansion valve 13 is feedback-controlled.

[0048]

The transition determination unit 306 in the present embodiment determines the transition to the steady control when the control transitions to the preliminary steady control and a predetermined condition is satisfied. Although details will be described later, in the initial operation control, the valve mechanism 25 is adjusted by the valve mechanism control unit 309 so that the rotation speed of the compressor 11 and the opening degree of the expansion valve 13 are lowered and the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 lowers. The valve mechanism

25 thus adjusted is then controlled so that the flow rate of the fluid returns to the flow rate before adjustment. The above predetermined condition as a condition for transition from the preliminary steady control to the steady control is establishment of a state where the valve mechanism 25 adjusted so that the flow rate of the fluid lowers is returned to the state before adjustment. [0049]

Specifically, the control device 30 in the present embodiment adjusts the valve mechanism control unit 309 in the initial operation control so that the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 is lowered, and then controls the valve mechanism 25 so that the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 returns to the flow rate before adjustment when the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or less than a second predetermined value. When the operation of returning the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 to the flow rate before adjustment (hereinafter, referred to as a return operation) and the preliminary steady control are established, the transition determination unit 306 determines the transition to the steady control. [0050]

In the present embodiment, the first predetermined value and the second predetermined value are the same value. Therefore, the return operation of the valve mechanism 25 is performed at the same time as the transition to the preliminary steady control, and when the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or less than the first predetermined value (second predetermined value) after the initial operation control, the control mode transitions to the steady control. That is, in the present embodiment, the transition to the steady control substantially occurs simultaneously with the transition of the preliminary steady control. However, the first predetermined value and the second predetermined value may be different. When the first predetermined value is larger than the second predetermined value, the return operation of the valve mechanism 25 is performed after the preliminary steady control, and the control mode transitions to the steady control. The first predetermined value may be smaller than the second predetermined value. [0051]

In the steady control described above, as described above, the control is performed by feedback-controlling the compressor 11 and the expansion

valve 13 or feedback-controlling the expansion valve 13 with the rotation speed of the compressor 11 set to a constant value. That is, in the steady control, the compressor 11 and the expansion valve 13 are controlled by (1) an aspect of feedback-controlling the compressor 11 and the expansion valve 13 or (2) an aspect of feedback-controlling the expansion valve 13 with the rotation speed of the compressor 11 set to a constant value.

[0052]

Specifically, in the above aspect (1), both the rotation speed of the compressor 11 and the opening degree of the expansion valve 13 are feedback-controlled on the basis of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature. In the above aspect (2), the opening degree of the expansion valve 13 is feedback-controlled on the basis of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature while the rotation speed of the compressor 11 is maintained at a constant value. More specifically, when the control mode is the steady state during the first operation, the above aspect (1) is first performed, and when a predetermined condition is satisfied, the control is switched to the above aspect (2). The predetermined condition for the switching is that the temperature of the fluid detected by the first temperature sensor 26 reaches the target temperature in the present embodiment.

[0053]

In the initial operation control, the valve mechanism 25 is adjusted by the valve mechanism control unit 309 so that the rotation speed of the compressor 11 and the opening degree of the expansion valve 13 are lowered and the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 is lowered. Specifically, in the initial operation control, the rotation speed of the compressor 11 is lowered to a set value derived on the basis of the target temperature. That is, the rotation speed of the compressor 11 is lowered to a set value that becomes a different value according to the target temperature. In the initial operation control, the opening degree of the expansion valve 13 is lowered by a predetermined amount. This predetermined amount is a constant value regardless of the target temperature in the present embodiment. In the initial operation control, the valve mechanism 25 is adjusted so that the flow rate of the fluid circulating in the heat exchange unit 21E decreases by a predetermined flow rate. Specifically, in the initial operation control, the valve mechanism 25 lowers the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 by a predetermined flow rate and increases the flow rate of the fluid

circulating in the bypass flow path 24 by a predetermined flow rate. The above predetermined flow rate is a constant value regardless of the target temperature in the present embodiment.

[0054]

Note that the timing of lowering the flow rate of the fluid circulating in the heat exchange unit 21E in the initial operation control may be the same timing as the timing of lowering the rotation speed of the compressor 11 and the opening degree of the expansion valve 13, or may be before or after the timing of lowering the rotation speed of the compressor 11 and the opening degree of the expansion valve 13. When the timing of lowering the flow rate of the fluid circulating in the heat exchange unit 21E is before the timing of lowering the rotation speed of the compressor 11 and the opening degree of the expansion valve 13, the flow rate of the fluid circulating in the heat exchange unit 21E is lowered after the target temperature is changed, and then the rotation speed of the compressor 11 and the opening degree of the expansion valve 13 are lowered. In this case, the timing of lowering the rotation speed of the compressor 11 and the opening degree of the expansion valve 13 is within 5 seconds, preferably within 3 seconds, more preferably within 2 seconds, and still more preferably within 1 second after lowering the flow rate of the fluid circulating in the heat exchange unit 21E. In this case, the timing of lowering the flow rate of the fluid circulating in the heat exchange unit 21E after the target temperature is changed may be immediately after the target temperature is changed, for example, within 1 second after the change.

[0055]

When the timing of lowering the flow rate of the fluid circulating in the heat exchange unit 21E is after the timing of lowering the rotation speed of the compressor 11 and the opening degree of the expansion valve 13, the rotation speed of the compressor 11 and the opening degree of the expansion valve 13 are lowered after the target temperature is changed, and then the flow rate of the fluid circulating in the heat exchange unit 21E is lowered. In this case, the timing of lowering the flow rate of the fluid circulating in the heat exchange unit 21E is within 5 seconds, preferably within 3 seconds, more preferably within 2 seconds, and still more preferably within 1 second after lowering the rotation speed of the compressor 11 and the opening degree of the expansion valve 13. In this case, the timing of lowering the rotation speed of the compressor 11 and the opening degree of the expansion valve 13 after the target temperature is changed may be immediately after the target temperature is changed, for example, within 1 second after the change.

[0056]

When the timing of lowering the flow rate of the fluid circulating in the heat exchange unit 21E is the same as the timing of lowering the rotation speed of the compressor 11 and the opening degree of the expansion valve 13, the rotation speed of the compressor 11 and the opening degree of the expansion valve 13 may be lowered immediately after the target temperature is changed, for example, within 1 second after the change, and at the same time, the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 may be lowered. Note that it goes without saying that the above-described timing of lowering the rotation speed of the compressor 11 and the opening degree of the expansion valve 13 is, strictly speaking, the timing of inputting a control signal to the compressor 11 and the expansion valve 13. It goes without saying that the timing of lowering the flow rate of the fluid circulating in the heat exchange unit 21E is the timing of inputting a control signal to the three-way valve 25V.

[0057]

In the preliminary steady control, as described above, while a state where the rotation speed of the compressor 11 is lowered in the initial operation control is maintained, the opening degree of the expansion valve 13 is feedback-controlled. Specifically, in the preliminary steady control, while the rotation speed of the compressor 11 is maintained at the set value lowered in the initial operation control, the opening degree of the expansion valve 13 is feedback-controlled.

Note that, in the present embodiment, after the initial operation control, when a predetermined condition is satisfied, the steady control is performed simultaneously with the preliminary steady control or after the preliminary steady control. In this case, the control transitions to the above aspect (2) in the steady control. That is, in the preliminary steady control, while a state where the rotation speed of the compressor 11 is lowered in the initial operation control is maintained, the opening degree of the expansion valve 13 is feedback-controlled. Therefore, when the steady control is performed simultaneously with the preliminary steady control or after the preliminary steady control, in the steady control, while a state where the rotation speed of the compressor 11 is lowered in the initial operation control is maintained, the opening degree of the expansion valve 13 is feedback-controlled on the basis of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature.

[0058]

Subsequently, the compressor control unit 307 acquires information on

the control mode determined by the transition determination unit 306. In the steady control, the compressor control unit 307 controls the rotation speed of the compressor 11 by a feedback control based on the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature according to the above aspect (1), or maintains the rotation speed of the compressor 11 at a constant value according to the above aspect (2). More specifically, when the control transitions from the above aspect (1) to the above aspect (2), the rotation speed of the compressor 11 when the temperature reaches the target temperature in the above aspect (1) is maintained in the above aspect (2). When the control transitions to the above aspect (2) in the steady control after the initial operation control, the rotation speed of the compressor 11 is maintained at the set value lowered by the initial operation control.

[0059]

In the initial operation control, the compressor control unit 307 lowers the rotation speed of the compressor 11 to a set value derived on the basis of the target temperature. Specifically, when the target temperature of the fluid higher than the temperature of the fluid detected by the first temperature sensor 26 is set and the transition to the initial operation control is determined because the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or more than the temperature threshold, the compressor control unit 307 in the present embodiment determines the relational expression according to the target temperature and derives the above set value on the basis of the determined relational expression. The above relational expression is an expression varying depending on the target temperature. Specifically, the above relational expression defines a relationship between the thermal load for setting the temperature of the fluid before flowing into the heat exchange unit 21E to the target temperature and the set value (the rotation speed of the compressor 11). More specifically, the above relational expression is an expression for specifying the set value by the value of the thermal load.

[0060]

The compressor control unit 307 acquires information on the thermal load from the thermal load calculation unit 305. The compressor control unit 307 determines the above set value on the basis of the target temperature, the thermal load, and the relational expression determined according to the target temperature. Information for deriving a relational expression by the compressor control unit 307 is held in the set value information holding unit

311. Note that details of the relational expression used in the present embodiment will be described later with reference to Fig. 3.

[0061]

As described above, when a difference between the current fluid temperature and the target temperature is relatively large, the initial operation control is performed to enhance the responsiveness of the temperature control as compared with the feedback control. From this viewpoint, the difference between the rotation speed of the compressor 11 before the start of the initial operation control and the set value is preferably relatively large so that the refrigeration capacity is greatly reduced. Specifically, when the initial operation control is performed, the rotation speed of the compressor 11 is desirably lowered by a rotation speed corresponding to a refrigeration capacity of at least 5 Kw. This means that the refrigeration capacity corresponding to the circulation amount of the refrigerant discharged from the compressor 11 at the rotation speed corresponding to the difference between the rotation speed of the compressor 11 before the start of the initial operation control and the set value is at least 5 Kw.

[0062]

In the preliminary steady control, the compressor control unit 307 maintains the rotation speed of the compressor 11 at the set value lowered by the initial operation control. That is, the compressor control unit 307 makes no change in the initial operation control state. However, when the fact that the control mode has transitioned to the preliminary steady control is acquired from the transition determination unit 306, the compressor control unit 307 preferably holds a flag indicating that the current state is the preliminary steady control.

[0063]

The expansion valve control unit 308 also acquires information on the control mode determined by the transition determination unit 306, similarly to the compressor control unit 307. The expansion valve control unit 308 controls the opening degree of the expansion valve 13 by a feedback control based on the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature at all times in the steady control.

[0064]

The expansion valve control unit 308 lowers the opening degree of the expansion valve 13 by a predetermined amount in the initial operation control. As described above, this predetermined amount is a constant value regardless of the target temperature in the present embodiment. Specifically, the

expansion valve control unit 308 lowers the opening degree of the expansion valve 13 by a range of 5% or more and 10% or less from the current opening degree (at the time of transition to the initial operation control). More specifically, the expansion valve control unit 308 in the present embodiment lowers the opening degree of the expansion valve 13 by 6.5% in the initial operation control. That is, for example, when the opening degree of the expansion valve 13 is 100% before the initial operation control, the opening degree of the expansion valve 13 is lowered to 93.5%.

[0065]

Note that, in the present embodiment, the opening degree of the expansion valve 13 is lowered in the initial operation control, but the opening degree of the expansion valve 13 may not be lowered in the initial operation control. However, the inventors of the present application have found through intensive experiments that when the opening degree of the expansion valve 13 is lowered together with the rotation speed of the compressor 11 in the initial operation control, the responsiveness to the target temperature is improved. The above predetermined amount, which is the lowering width of the expansion valve 13 in the initial operation control, is not particularly limited, but when the predetermined amount is too small, improvement in responsiveness does not significantly appear, and when the predetermined amount is too large, responsiveness may be impaired due to rapid pressure fluctuation on the side of the refrigeration apparatus 10. From these viewpoints, the inventors of the present application have found a configuration in which the predetermined amount is in a range of 5% or more and 10% or less of the opening degree, but the predetermined amount may be another numerical value.

[0066]

In the preliminary steady control, the expansion valve control unit 308 switches to a state where the opening degree of the expansion valve 13 is controlled by a feedback control. Note that the feedback control on the rotation speed of the compressor 11 and the opening degree of the expansion valve 13 in the above aspect (1) of the steady control described above, the feedback control on the opening degree of the expansion valve 13 in the above aspect (2), and the feedback control on the opening degree of the expansion valve 13 in the preliminary steady control are PID control. However, these feedback controls may be P control, PI control, or PD control. In any feedback control, the control is performed so that the temperature of the fluid detected by the first temperature sensor 26 becomes the target temperature.

[0067]

The valve mechanism control unit 309 also acquires information on the control mode determined by the transition determination unit 306, similarly to the compressor control unit 307 and the expansion valve control unit 308. In the steady control, the valve mechanism control unit 309 closes the bypass flow path 24 by the valve mechanism 25, and forms a state where the fluid circulates only in the main flow path 21. That is, in the steady control, a state where only the fluid whose temperature is controlled by the evaporator 14 flows into the temperature control target T is formed. Note that, in the steady control, the valve mechanism control unit 309 may form a state where the fluid circulates in both the main flow path 21 and the bypass flow path 24. In this case, the valve mechanism control unit 309 holds the ratio between the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 and the flow rate of the fluid circulating in the bypass flow path 24 at a constant value.

[0068]

The valve mechanism control unit 309 adjusts the valve mechanism 25 so that the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 is lowered by a predetermined flow rate at the time of the initial operation control. Specifically, in the initial operation control, the valve mechanism 25 lowers the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 by a predetermined flow rate and increases the flow rate of the fluid circulating in the bypass flow path 24 by a predetermined flow rate.

[0069]

The above predetermined flow rate is a constant value regardless of the target temperature in the present embodiment. Specifically, in the present embodiment, the above predetermined flow rate is determined in a range of 5% or more and 15% or less of the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 in the steady control. That is, in the initial operation control, the valve mechanism 25 is adjusted so that the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 lowers by 5% or more and 15% or less from the current flow rate. More specifically, in the initial operation control in the present embodiment, the valve mechanism 25 is adjusted so that the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 lowers by 10%.

[0070]

The reason why the valve mechanism control unit 309 lowers the flow rate of the fluid circulating in the heat exchange unit 21E in the initial operation control is to take balance against a decrease in the refrigeration

capacity of the evaporator 14 due to a decrease in the rotation speed of the compressor 11. When the lowering width of the fluid circulating in the heat exchange unit 21E is small, the degree of superheating of the refrigerant returning from the evaporator 14 to the compressor 11 is not sufficiently lowered, and when the lowering width is large, the risk of liquid back to the compressor 11 is conversely increased. From these viewpoints, the inventors of the present application adopt a configuration in which the flow rate of the fluid circulating in the heat exchange unit 21E is lowered by 5% or more and 15% or less, for example, by 10% in the initial operation control. However, such a lowering width of the flow rate is not particularly limited. Note that a relationship between the opening degree of the three-way valve 25V and the flow rate change is specified in advance, and the flow rate is adjusted on the basis of the relationship.

[0071]

The valve mechanism control unit 309 in the present embodiment adjusts the valve mechanism 25 in the initial operation control so that the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 lowers, and then controls the valve mechanism 25 so that the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 returns to the flow rate before adjustment before the temperature of the fluid detected by the first temperature sensor 26 reaches the target temperature. Specifically, when the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or less than the second predetermined value, the valve mechanism control unit 309 controls the valve mechanism 25 so that the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 returns to the flow rate before adjustment.

[0072]

In the present embodiment, as described above, the transition determination unit 306 determines the transition to the preliminary steady control when the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or less than a first predetermined value after the rotation speed of the compressor 11 and the opening degree of the expansion valve 13 are lowered in the initial operation control. The second predetermined value is the same as the first predetermined value. Therefore, the valve mechanism control unit 309 substantially controls the valve mechanism 25 so that the flow rate of the fluid circulating in the heat exchange unit 21E returns to the flow rate before adjustment at the same time as the

acquisition of the information on the transition to the preliminary steady control. Note that the valve mechanism control unit 309 may control the valve mechanism 25 so that the flow rate of the fluid circulating in the heat exchange unit 21E returns to the flow rate before adjustment with the acquisition of the information on the transition to the preliminary steady control as a trigger without performing the determination using the second predetermined value. [0073]

The pump control unit 310 acquires information on the target flow rate from the interface unit 301. The pump control unit 310 controls the rotation speed so that the flow rate of the fluid specified by the flow rate information from the flow rate sensor 28 matches the target flow rate.

[0074]

As described above, the set value information holding unit 311 holds information for deriving a relational expression used by the compressor control unit 307 to determine the set value. In the present embodiment, as an example, the set value information holding unit 311 holds a basic expression including at least a variable to which the thermal load calculated by the thermal load calculation unit 305 is substituted and a coefficient for increasing or decreasing the variable, and a plurality of coefficient eigenvalues held in advance corresponding to a plurality of target temperature candidate values. The relational expression used by the compressor control unit 307 is determined by substituting a coefficient eigenvalue determined on the basis of the comparison between the target temperature and the above target temperature candidate value into the above basic expression.

[0075]

#### <Information for Deriving Relational Expression Used for Control>

Hereinafter, the concept of the basic expression and the coefficient eigenvalue used when the relational expression is determined in the present embodiment will be described with reference to Fig. 3. Fig. 3 is a conceptual diagram illustrating a basic expression and a coefficient eigenvalue for deriving a relational expression used for determining a set value to be used in the initial operation control, which is information held by the set value information holding unit 311 in the control device 30. " $F = aX + c$ " in Fig. 3 corresponds to the basic expression. " $X$ " in the basic expression corresponds to a variable into which the thermal load calculated by the thermal load calculation unit 305 is substituted. " $a$ " and " $c$ " in the basic expression correspond to coefficients for increasing or decreasing the thermal load as a variable. " $F$ " corresponds to the rotation speed as a set value. Note that " $F$ " may be expressed by a frequency of an input voltage to an inverter that controls the rotation of the

compressor 11. The rotation speed (RPM) is specified by  $(120 \times (\text{frequency of input voltage}))/\text{motor pole number}$ .

[0076]

A coefficient eigenvalue table illustrated in Fig. 3 specifies and holds a relationship between a plurality of target temperature candidate values and coefficient eigenvalues as specific values of the coefficients "a" and "c" corresponding to the plurality of target temperature candidate values.

[0077]

In the present embodiment, when the target temperature of the fluid higher than the temperature of the fluid detected by the first temperature sensor 26 is set and the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or more than the temperature threshold, it is determined to transition to the initial operation control. At this time, the compressor control unit 307 determines the coefficient eigenvalue on the basis of the comparison between the target temperature and the above target temperature candidate value, and determines the relational expression by substituting the coefficient eigenvalue into the basic expression. More specifically, for example, when the target temperature is -30 degrees, the compressor control unit 307 determines a coefficient eigenvalue (a: "●□", c: "□□") corresponding to a target temperature candidate value of -30 degrees (see T30 in Fig. 3), and substitutes the coefficient eigenvalue into the basic expression to determine the relational expression. There may be a case where there is no target temperature candidate value matching the target temperature. In this case, when the target temperature is a value between two consecutive target temperature candidate values, the coefficient eigenvalue of the target temperature candidate value closer to the target temperature may be selected. When the target temperature is a value between two consecutive target temperature candidate values, a coefficient eigenvalue may be determined utilizing linear interpolation based on two coefficient eigenvalues.

[0078]

After determining the relational expression as described above, the compressor control unit 307 substitutes the thermal load calculated by the thermal load calculation unit 305 into the variable X to determine the rotation speed as a set value. Fig. 4 is a view showing a graph showing a relationship between the thermal load expressed by the relational expression and the rotation speed (set value) of the compressor 11. As shown in Fig. 4, the relational expression used by the compressor control unit 307 is different

according to the target temperature. For example, when the target temperature is -30 degrees and the thermal load is 2 Kw, the set value to be the target rotation speed of the compressor 11 in the initial operation control is determined as Z in Fig. 4 on the basis of a relational expression F30 corresponding to -30 degrees (°C). For example, when the target temperature is -20 degrees and the thermal load is 1 Kw, the set value to be the target rotation speed of the compressor 11 in the initial operation control is determined as W in Fig. 4 on the basis of a relational expression F20 corresponding to -20 degrees (°C). Note that, in two relational expressions different from each other among the plurality of relational expressions, when the same thermal load is substituted, a relationship is established in which the set value derived from the relational expression corresponding to the lower target temperature is larger than the set value derived from the relational expression corresponding to the higher target temperature.

[0079]

In the present embodiment, the set value information holding unit 311 holds the basic expression and the coefficient eigenvalue, but a plurality of relational expressions themselves corresponding to a plurality of target temperature candidate values may be held in the set value information holding unit 311. As will be described later, the compressor control unit 307 may refer to a set value table that is set for each target temperature candidate value and that defines a relationship between the thermal load and the rotation speed of the compressor 11 to be the set value, and determine the set value to be used in the initial operation control on the basis of a set value table.

[0080]

#### <Operation of Temperature Control System>

Fig. 5 is a flowchart for explaining an example of an operation of the temperature control system 1. Hereinafter, an example of the operation of the temperature control system 1 will be described with reference to Fig. 5.

[0081]

The operation illustrated in Fig. 5 is started by generation of an operation start command. When the operation start command is generated, the control device 30 first sets a target temperature of the fluid circulated by the fluid circulation apparatus 20 in step S501. Specifically, the target temperature of the fluid is set and held by the target temperature setting unit 302 in the control device 30. The target temperature setting unit 302 acquires information on the target temperature from the interface unit 301. At this time, although not illustrated, information on the target flow rate of the fluid circulated by the fluid circulation apparatus 20 is also sent from the interface

unit 301 to the pump control unit 310, and the pump control unit 310 drives the pump 22. At this time, the valve mechanism control unit 309 gradually closes the bypass flow path 24 by the valve mechanism 25, and forms a state where the fluid circulates only in the main flow path 21.

[0082]

Next, in step S502, the control device 30 determines the control mode by the transition determination unit 306. On the basis of the first operation, the transition determination unit 306 determines to perform control in a steady control as a control mode. This transition to the steady control starts a feedback control on the compressor 11 and the expansion valve 13 in the refrigeration apparatus 10.

[0083]

Next, in step S503, the control device 30 causes the temperature acquisition unit 303 to acquire information on the temperature of the fluid detected by the first temperature sensor 26. That is, the control device 30 acquires information on the temperature of the fluid circulating downstream of the heat exchange unit 21E in the main flow path 21 and flowing out from the three-way valve 25V. Note that step S503 corresponds to an example of the detection process (step).

[0084]

Next, in step S504, the control device 30 determines whether the absolute value of the difference between the temperature of the fluid circulating downstream of the heat exchange unit 21E in the main flow path 21 and the target temperature is equal to or less than a determination threshold or whether the current control state is the "return control" state on the basis of the information on the temperature of the fluid detected by the first temperature sensor 26. The above determination threshold is a relatively small value, and may be, for example, 0.5 degrees. The "return control" means that, after the initial operation control, the steady control is performed simultaneously with or after the preliminary steady control. Although the operation at the time of the initial operation control will be described later with reference to Fig. 6, when the process returns to the steady control after the initial operation control, the process proceeds from the process of Fig. 6 to step S503 via "A" of Fig. 5, and the process starts from step S503. In this case, it is determined in step S504 that the control mode is the return control.

[0085]

In step S504, when the absolute value of the difference between the temperature of the fluid circulating downstream of the heat exchange unit 21E in the main flow path 21 and the target temperature is not equal to or less

than the determination threshold, and when the control mode is not in the return control state, the process proceeds to step S505. In step S505, the control device 30 feedback-controls the rotation speed of the compressor 11 by the compressor control unit 307, and feedback-controls the opening degree of the expansion valve by the expansion valve control unit 308. The compressor control unit 307 controls the rotation speed of the compressor 11 so that the temperature of the fluid detected by the first temperature sensor 26 approaches the target temperature by a feedback control based on the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature. The expansion valve control unit 308 controls the opening degree of the expansion valve 13 so that the temperature of the fluid detected by the first temperature sensor 26 approaches the target temperature by a feedback control based on the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature.

[0086]

After step S505, the control device 30 determines whether the target temperature is changed in step S506. When the target temperature is not changed, the control device 30 determines whether an operation stop instruction is issued in step S507. When the operation stop instruction is not issued, the process returns to step S503, and the feedback control on the compressor 11 and the expansion valve 13 in step S505 is repeated until it is detected in step S504 that the absolute value of the difference between the temperature of the fluid circulating downstream of the heat exchange unit 21E in the main flow path 21 and the target temperature is equal to or less than the determination threshold.

[0087]

When it is detected in step S504 that the absolute value of the difference between the temperature of the fluid circulating downstream of the heat exchange unit 21E in the main flow path 21 and the target temperature is equal to or less than the determination threshold or when it is detected that the control mode is in the return control state, in step S508, the control device 30 causes the compressor control unit 307 to maintain the rotation speed of the compressor 11 at a constant value, and continues the feedback control on the opening degree of the expansion valve 13 in the expansion valve control unit 308.

[0088]

In step S508, when the absolute value of the difference between the temperature of the fluid circulating downstream of the heat exchange unit 21E

through steps S504 and S505 and the target temperature is equal to or less than the determination threshold, the compressor control unit 307 maintains the rotation speed of the compressor 11 when it is detected that the absolute value of the difference between the temperature of the fluid and the target temperature is equal to or less than the determination threshold. On the other hand, when the process proceeds to step S508 in the steady control (return control) after the initial operation control, the rotation speed of the compressor 11 is maintained at a set value lowered by the initial operation control described later. In step S508, the compressor control unit 307 controls the opening degree of the expansion valve 13 so that the temperature of the fluid detected by the first temperature sensor 26 matches the target temperature by a feedback control based on the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature.

[0089]

After step S508, the control device 30 determines whether the target temperature is changed in step S506. When the target temperature is not changed, the control device 30 determines whether an operation stop instruction is issued in step S507. When the operation stop instruction is not issued, the process returns to step S503, and thereafter, the feedback control in step S508 is performed through step S504. In a state where the process of step S508 is repeated, the temperature of the fluid is basically controlled to the target temperature. However, when the transition from step S508 to step S504 is repeated in the steady control (return control) after the initial operation control, the process may proceed to step S505 when a predetermined condition is satisfied. For example, even in the return control, when it is detected in step S504 a predetermined number of times or more that the absolute value of the difference between the temperature of the fluid circulating downstream of the heat exchange unit 21E in the main flow path 21 and the target temperature is equal to or less than the determination threshold, the process may proceed to step S505. In this case, an appropriate temperature control state can be formed by finely adjusting the rotation speed of the compressor 11.

[0090]

When the target temperature is changed in step S506, the control device 30 causes the transition determination unit 306 to determine whether the changed target temperature corresponds to lowering from the current fluid temperature on the basis of the information on the temperature of the fluid detected by the first temperature sensor 26 in step S509. When it is

determined in step S509 that the target temperature is lowered, the process proceeds to step S503, and a feedback control toward the target temperature is performed.

[0091]

On the other hand, when it is determined in step S509 that the target temperature is not lowered, in other words, when it is determined that the target temperature is increased, the control device 30 causes the transition determination unit 306 to determine whether the target temperature corresponds to an increase from the current temperature by the temperature threshold or more in step S510. Specifically, the transition determination unit 306 determines whether the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or more than the temperature threshold.

[0092]

When it is determined in step S510 that the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is not equal to or more than the temperature threshold, the process proceeds to step S503, and a feedback control toward the target temperature is performed. On the other hand, when it is determined in step S510 that the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or more than the temperature threshold, the transition determination unit 306 determines to perform control by the initial operation control (step S511). When it is determined in step S507 that the operation stop instruction has been issued, the operation of the temperature control system 1 is stopped (END). Note that, in step S510, it may be determined whether or not the absolute value of the difference between the target temperatures before and after the change is equal to or more than the temperature threshold, and when the absolute value is equal to or more than the temperature threshold, the transition to the initial operation control may be determined (step S511).

[0093]

Fig. 6 is a flowchart for explaining an initial operation control. Hereinafter, the operation in the case of transition to the initial operation control will be described with reference to Fig. 6.

[0094]

First, in step S601, the control device 30 acquires information on the changed target temperature from the target temperature setting unit 302.

[0095]

Next, in step S602, the control device 30 causes the compressor control unit 307 to determine a relational expression corresponding to the target temperature. As described with reference to Figs. 3 and 4, in the present embodiment, the relational expression is determined on the basis of the basic expression and the coefficient eigenvalue held in the set value information holding unit 311. The determined relational expression defines a relationship between the thermal load for setting the temperature of the fluid before flowing into the heat exchange unit 21E to the target temperature and the set value (the rotation speed of the compressor 11).

[0096]

Next, in step S603, the compressor control unit 307 acquires information on the thermal load from the thermal load calculation unit 305. The thermal load is a thermal load for setting the temperature of the fluid before flowing into the heat exchange unit 21E to the target temperature, in other words, for setting the temperature of the fluid before temperature control to the target temperature. The thermal load calculation unit 305 calculates the thermal load using the target temperature, the temperature information of the fluid from the second temperature sensor 27, and the flow rate information of the fluid from the flow rate sensor 28.

[0097]

In step S604, the set value of the rotation speed of the compressor 11 to be the target rotation speed in the initial operation control, the lowering amount (predetermined amount) of the opening degree of the expansion valve 13, and the lowering amount (predetermined flow rate) of the fluid circulating in the heat exchange unit 21E in the main flow path 21 are specified. The set value of the rotation speed of the compressor 11 is specified by substituting the thermal load acquired in step S603 into the relational expression determined in step S602 in the present embodiment. On the other hand, in the present embodiment, the lowering amount (predetermined amount) of the opening degree of the expansion valve 13 and the lowering amount (predetermined flow rate) of the fluid circulating in the heat exchange unit 21E are determined by constant values regardless of the target temperature.

[0098]

After step S604, in the present embodiment, in step S605, the compressor control unit 307 determines whether the difference between the set value of the rotation speed of the compressor 11, which becomes the target rotation speed in the initial operation control, and the current rotation speed is larger than the rotation speed threshold. When it is determined in step S604 that the difference between the set value specified in step S606

and the current rotation speed is larger than the rotation speed threshold, the compressor control unit 307 rewrites the set value of the rotation speed of the compressor 11, which is the target rotation speed in the initial operation control, to a value obtained by subtracting the rotation speed threshold from the current rotation speed. Thereafter, the compressor control unit 307 again determines whether the difference between the set value of the rotation speed of the compressor 11, which becomes the target rotation speed in the initial operation control, and the current rotation speed is larger than the rotation speed threshold. When it is detected in step S605 that the difference between the set value of the rotation speed of the compressor 11, which becomes the target rotation speed in the initial operation control, and the current rotation speed is not larger than the rotation speed threshold, the process proceeds to step S607.

[0099]

In step S607, the compressor control unit 307 lowers the rotation speed of the compressor 11 to the set value specified as described above. The expansion valve control unit 308 lowers the opening degree of the expansion valve 13 by a predetermined amount. The valve mechanism control unit 309 adjusts the flow rate so that the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 lowers by a predetermined flow rate. Specifically, the valve mechanism control unit 309 controls the valve mechanism 25 to lower the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 by a predetermined flow rate and increase the flow rate of the fluid circulating in the bypass flow path 24 by a predetermined flow rate. Steps S601 to S607 after steps S506, S509, and S510 correspond to an example of the control process (step).

[0100]

Thereafter, the control device 30 determines whether or not to transition to the preliminary steady control by the transition determination unit 306 in step S608. Specifically, when it is detected in step S608 that the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or less than the first predetermined value (YES in step S608), the transition determination unit 306 determines the transition to the preliminary steady control (S610). On the other hand, when it is not detected in step S608 that the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or less than the first predetermined value, the control device 30 determines in step S609 whether the operation stop instruction has been

issued. When the operation stop instruction is not issued, the process returns to step S608, and whether or not the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or less than the first predetermined value is monitored.

[0101]

In step S610 when the transition to the preliminary steady control is determined, the control device 30 causes the compressor control unit 307 to maintain the rotation speed of the compressor 11 at the set value lowered by the initial operation control. In step S610, the control device 30 causes the expansion valve control unit 308 to switch to a state where the opening degree of the expansion valve 13 is controlled by a feedback control.

[0102]

Thereafter, in step S611, the control device 30 determines whether the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature by the valve mechanism control unit 309 is equal to or less than the second predetermined value. When it is not detected in step S611 that the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or less than the second predetermined value, the control device 30 determines in step S612 whether the operation stop instruction has been issued. When the operation stop instruction is not issued, the process returns to step S610, the feedback control on the opening degree of the expansion valve 13 is repeated, and the monitoring of the temperature in step S611 is repeated.

[0103]

When it is detected in step S611 that the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or less than the second predetermined value, the control device 30 controls the valve mechanism 25 so that the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 returns to the flow rate before adjustment by the valve mechanism control unit 309 in step S613. At this time, the transition determination unit 306 determines the transition to the steady control (A). The process proceeds from "A" in Fig. 6 to step S503 via "A" in Fig. 5, and the process starts from step S503. When it is determined in step S609 or S612 that the operation stop instruction has been issued, the operation of the temperature control system 1 is stopped (END).

[0104]

Fig. 7 is a view showing a graph for explaining an operation of a constituent device of the temperature control system 1 and a temperature control state. Fig. 7 shows changes in the temperature of the fluid, the rotation speed of the compressor 11, the opening degree of the expansion valve 13, and the opening degree of the three-way valve 25V when the process transitions to the steady control → the initial operation control → the preliminary steady control → the steady control described above. In each graph, the horizontal axis is the time axis. Fig. 7(a) shows a state of the temperature of the fluid circulated by the fluid circulation apparatus 20 that changes with the lapse of time. Fig. 7(b) shows a state of the rotation speed of the compressor 11 that changes with the lapse of time (control mode). Fig. 7(c) shows a state of the opening degree of the expansion valve 13 that changes with the lapse of time (control mode). Fig. 7(d) shows a state of the opening degree of the three-way valve 25V (opening degree toward the heat exchange unit 21E) that changes with the lapse of time (control mode).

[0105]

The “old target temperature” shown in Fig. 7(a) means a target temperature of the fluid circulated by the fluid circulation apparatus 20 set at the start of operation. St1 in Fig. 7 indicates the steady control state. At this time, the control in the aspect (1) of feedback-controlling the compressor 11 and the expansion valve 13 is first performed, and then the control in the aspect (2) of feedback-controlling the expansion valve 13 with the rotation speed of the compressor 11 set to a constant value is performed. In Fig. 7, the aspect (1) corresponds to St1-1. The aspect (2) corresponds to St1-2. In the aspect (1), a large operation amount is input to the compressor 11 and the expansion valve 13, and in the aspect (2), the rotation speed of the compressor 11 becomes a constant value, the opening degree of the expansion valve 13 does not greatly change, and the temperature of the fluid is basically controlled to the target temperature (old target temperature). In steady control ST1, the pump control unit 310 controls the rotation speed so that the flow rate of the fluid specified by the flow rate information from the flow rate sensor 28 matches the target flow rate. In steady control ST1 in Fig. 7(d), the three-way valve 25V gradually closes the bypass flow path 24 by the valve mechanism 25, and forms a state where the fluid circulates only in the main flow path 21. “100%” in Fig. 7(d) indicates a state where the fluid circulates only in the main flow path 21.

[0106]

The “new target temperature” in Fig. 7 indicates the changed target temperature. The change to the new target temperature is performed at a

time point indicated by a reference sign  $E_v$  in the drawing, and initial operation control  $St_2$  is performed accordingly. In initial operation control  $St_2$ , the rotation speed of the compressor 11 is lowered to a set value  $R$  derived on the basis of the target temperature. In initial operation control  $St_2$ , the opening degree of the expansion valve 13 is lowered by a predetermined amount  $D$ . In initial operation control  $St_2$ , the valve mechanism 25 is adjusted so that the flow rate of the fluid circulating in the heat exchange unit 21E lowers by a predetermined flow rate  $F$ . In the initial operation control, the rotation speed of the compressor 11 is lowered to the set value  $R$ , the opening degree of the expansion valve 13 is lowered by the predetermined amount  $D$ , and the flow rate of the fluid circulating in the heat exchange unit 21E is lowered by the predetermined flow rate  $F$  in a linear function manner or in a step input manner. [0107]

Thereafter, when the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or less than the first predetermined value and equal to or less than the second predetermined value, the state transitions to steady control  $St_4$  simultaneously with preliminary steady control  $St_3$  in the present embodiment. At this time, the flow rate of the fluid circulating in the heat exchange unit 21E is returned to the state before adjustment. In steady control  $St_4$ , the temperature of the fluid is controlled to the new target temperature. The inventors of the present application have confirmed that an arrival time  $T_r$  can be significantly shortened by performing the initial operation control when the target temperature is greatly raised as described above.

[0108]

The temperature control system 1 according to the present embodiment described above includes the refrigeration apparatus 10, the fluid circulation apparatus 20 including the main flow path 21 having the heat exchange unit 21E between the inlet 21U and the outlet 21D and allowing the fluid received at the inlet 21U to circulate to the outlet 21D through the heat exchange unit 21E, the fluid circulation apparatus 20 allowing the fluid in the heat exchange unit 21E to exchange heat with the refrigerant in the evaporator 14 of the refrigeration apparatus 10, the first temperature sensor 26 detecting the temperature of the fluid circulating in the downstream portion of the heat exchange unit 21E in the main flow path 21, and the control device 30 controlling the refrigeration apparatus 10 and the fluid circulation apparatus 20. The control device 30 controls the compressor 11 so that the rotation speed of the compressor 11 lowers to a set value derived on the basis

of the target temperature when the target temperature of the fluid higher than the temperature of the fluid detected by the first temperature sensor 26 is set, and performs an initial operation control of lowering the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 simultaneously with, before, or after the control of the compressor 11.

[0109]

In the temperature control system 1, when the target temperature of the fluid is increased, the rotation speed of the compressor 11 is lowered to a set value corresponding to the target temperature. In this case, the responsiveness of the control to the refrigeration capacity of the evaporator 14 that meets the target temperature can be improved as compared with the case of the feedback control. That is, in the feedback control, the control operation amount of the compressor up to the target temperature is derived stepwise by a plurality of calculations based on the difference between the target temperature and the current temperature. Since the temperature of the fluid gradually approaches the target temperature, the responsiveness may not be necessarily favorable. On the other hand, in the temperature control system 1, when the target temperature is set value, the control operation amount of the compressor 11 is changed toward a single set value in a linear function manner or in a step input manner. Therefore, the responsiveness of the control to the refrigeration capacity of the evaporator 14 that meets the target temperature can be improved.

On the other hand, the temperature of the fluid circulated by the fluid circulation apparatus 20 does not change drastically even when the target temperature is increased. When the rotation speed of the compressor 11 is rapidly lowered without a change or a large change in the temperature of the fluid, for example, the degree of superheating of the refrigerant flowing out from the evaporator 14 increases, which may make the operation of the compressor 11 unstable. On the other hand, in the temperature control system 1, when the rotation speed of the compressor 11 is lowered, the valve mechanism 25 is controlled so that the flow rate of the fluid circulating in the heat exchange unit 21E lowers, whereby the state of the refrigerant flowing out from the evaporator 14 can be optimized. As a result, an unstable operation of the compressor 11 is suppressed.

[0110]

Therefore, according to the temperature control system 1, it is possible to suppress an undesirable influence on an operation state and a constituent device while improving the responsiveness of the temperature control.

[0111]

The fluid circulation apparatus 20 in the present embodiment further includes the valve mechanism 25 that adjusts the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21. In this configuration, the responsiveness of the flow rate change can be enhanced by the valve mechanism 25.

[0112]

Specifically, the fluid circulation apparatus 20 further includes the bypass flow path 24 that connects the upstream portion and the downstream portion of the heat exchange unit 21E in the main flow path 21 and allows the fluid received from the main flow path 21 to circulate. The valve mechanism 25 adjusts the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 and the flow rate of the fluid circulating in the bypass flow path 24. In the initial operation control, the control device 30 adjusts the valve mechanism 25 to lower the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 and increase the flow rate of the fluid circulating in the bypass flow path 24. In this configuration, the pressure fluctuation of the fluid circulating in the fluid circulation apparatus 20 can be suppressed by using the bypass flow path 24, and the responsiveness of the flow rate change and the responsiveness of the temperature control can be enhanced.

[0113]

In particular, in the initial operation control, by opening the bypass flow path 24 in a state of being closed by the valve mechanism 25, the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 lowers, and the flow rate of the fluid circulating in the bypass flow path 24 increases. In the initial operation control, the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 is lowered by 5% or more and 15% or less. In this configuration, the state of the refrigerant flowing out from the evaporator 14 after heat exchange with the fluid can be stably optimized.

[0114]

The control device 30 determines a relational expression according to the changed target temperature, and derives a set value for the rotation speed of the compressor 11 in the above initial operation control on the basis of the determined relational expression. In the present embodiment, as described above with reference to Figs. 3 and 4, the control device 30 causes the set value information holding unit 311 to hold, as information for determining a relational expression, a basic expression and a coefficient eigenvalue table for specifying the relationship between the plurality of target temperature

candidate values and the coefficient eigenvalues corresponding to the plurality of target temperature candidate values. The control device 30 determines the coefficient eigenvalue on the basis of the comparison between the target temperature and the above target temperature candidate value, and determines the relational expression by substituting the coefficient eigenvalue into the basic expression.

[0115]

In this configuration, the relational expression for deriving a set value for the rotation speed of the compressor 11 to be used in the initial operation control is determined according to the target temperature. As a result, since a specific value with respect to the target temperature can be adopted as the set value, the responsiveness of the temperature control can be improved.

[0116]

More specifically, when the target temperature is set, the control device 30 calculates a thermal load for setting the temperature of the fluid before flowing into the heat exchange unit 21E to the target temperature. The relational expression defines the relationship between the thermal load and the set value. The set value is determined on the basis of the target temperature, the thermal load, and the relational expression determined according to the target temperature.

[0117]

In this configuration, by determining the relationship between the thermal load and the rotation speed of the compressor 11 in the relational expression, the set value related to the rotation speed of the compressor 11 that can enhance the responsiveness to the target temperature can be set according to the thermal load. As a result, it is possible to improve the responsiveness of the control to the refrigeration capacity of the evaporator 14 that meets the target temperature. Note that the relational expression in this configuration can be created by specifying the relationship between the refrigeration capacity of the evaporator 14 for controlling the fluid before flowing into the heat exchange unit 21E to the target temperature in consideration of the presence or absence and the magnitude of the thermal load and the rotation speed of the compressor 11 corresponding to the refrigeration capacity.

[0118]

In the present embodiment, the control device 30 causes the set value information holding unit 311 to hold, as information for determining a relational expression, a basic expression and a coefficient eigenvalue table for specifying the relationship between the plurality of target temperature

candidate values and the coefficient eigenvalues corresponding to the plurality of target temperature candidate values. The control device 30 determines the coefficient eigenvalue on the basis of the comparison between the target temperature and the above target temperature candidate value, and determines the relational expression by substituting the coefficient eigenvalue into the basic expression. As a result, the amount of information held inside can be suppressed.

[0119]

As a modification, the control device 30 may determine the set value to be used in the initial operation control on the basis of a set value table that defines a relationship between the thermal load set for each target temperature candidate value and the rotation speed of the compressor 11 to be the set value. Fig. 8 shows an example of a set value table. In the case of using the set value table shown in Fig. 8, for example, when the target temperature is -20 degrees (°C), an element table T20 is selected. When the thermal load is, for example, 1.5 Kw, "◆△ Hz" is selected. The rotation speed corresponding to "◆△ Hz" is determined as the set value. Although Fig. 8 shows the frequency of an input voltage to an inverter that controls the rotation of the compressor 11 in a set value table, the rotation speed of the compressor 11 may be stored in the set value table.

[0120]

In the present embodiment, the control device 30 also lowers the opening degree of the expansion valve 13 by a predetermined amount in the initial operation control. In this configuration, the state of the refrigerant flowing out from the evaporator 14 after heat exchange with the fluid can be more remarkably optimized than when the opening degree of the expansion valve 13 is maintained constant. As a result, an unstable operation of the compressor 11 is effectively suppressed. As a result of ensuring the stability of the operation, the responsiveness of the temperature control can also be improved. Specifically, the control device 30 lowers the opening degree of the expansion valve 13 by a range of 5% or more and 10% or less from the current opening degree. By lowering the opening degree of the expansion valve 13 within a range not too small and not too large as described above, it is possible to effectively suppress an unstable operation of the compressor 11.

[0121]

The control device 30 in the present embodiment lowers the rotation speed of the compressor 11 and the opening degree of the expansion valve 13 in the initial operation control, and then transitions to the preliminary steady control. In the preliminary steady control, the control device 30

adjusts the opening degree of the expansion valve 13 by a feedback control based on the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature, and maintains the rotation speed of the compressor 11 in a lowered state in the initial operation control. In this configuration, favorable responsiveness to the target temperature and favorable control accuracy can be secured by performing the preliminary steady control accompanied by the feedback control after the initial operation control focusing on responsiveness.

[0122]

The control device 30 adjusts the valve mechanism 25 in the initial operation control so that the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 lowers, and then controls the valve mechanism 25 so that the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 returns to the flow rate before adjustment before the temperature of the fluid detected by the first temperature sensor 26 reaches the target temperature. In this configuration, it is possible to avoid a situation in which the responsiveness is deteriorated due to the temperature of the fluid exceeding the target temperature.

[0123]

When the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or more than the temperature threshold, the control device 30 performs an initial operation control. When the increasing amount from the current fluid temperature to the target temperature is relatively small, the initial operation control may not be necessarily effective from the viewpoint of responsiveness. By determining whether or not to perform the initial operation control using the temperature threshold from such a viewpoint, not only when the target temperature is greatly increased, but also favorable responsiveness of the temperature control can be secured as the entire system.

[0124]

<Modification>

The fluid circulation apparatus 20 in the embodiment described above includes the bypass flow path 24 that connects the upstream portion and the downstream portion of the heat exchange unit 21E in the main flow path 21 and allows the fluid received from the main flow path 21 to circulate. Figs. 9 and 10 each illustrate a modification in which the configuration of the fluid circulation apparatus 20 is different from that of the above-described embodiment. Note that the same components as those of the above-

described embodiment among the components of the temperature control system according to the modification described below including Figs. 9 and 10 are denoted by the same reference numerals, and redundant description will be omitted.

[0125]

In the modification illustrated in Fig. 9, the fluid circulation apparatus 20 does not include the bypass flow path 24. In this configuration, when the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 is lowered in the initial operation control, the discharge amount of the pump 22 is lowered. Note that a configuration in which a throttle valve is provided upstream of the heat exchange unit 21E and the opening degree of the throttle valve is lowered at the time of initial operation control may be adopted. In the modification illustrated in Fig. 10, the bypass flow path 24 connects an upstream portion of the heat exchange unit 21E in the main flow path 21 and a further upstream portion of this portion.

[0126]

Fig. 11 is a flowchart for explaining an operation of a temperature control system according to a modification. In the above-described embodiment, when the target temperature of the fluid higher than the temperature of the fluid detected by the first temperature sensor 26 is set and the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or more than the temperature threshold, it is determined to transition to the initial operation control. On the other hand, in the operation of the modification illustrated in Fig. 11, when the target temperature is lowered or increased and the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or more than the temperature threshold, it is determined to transition to the initial operation control. That is, in the above-described embodiment, the initial operation control is performed when the target temperature is greatly increased, but in this modification, the initial operation control is also performed when the target temperature is greatly lowered.

[0127]

The processes in steps S501 to S508 in the operation illustrated in Fig. 11 are the same as the processes in Fig. 5. In the operation in Fig. 11, when it is determined in step S506 that the target temperature has been changed, the control device 30 determines in step S510R whether the target temperature corresponds to an increase or decrease in the temperature from

the current temperature by the temperature threshold or more. Specifically, the transition determination unit 306 determines whether the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or more than the temperature threshold. When it is determined in step S510R that the target temperature corresponds to an increase or decrease from the current temperature by the temperature threshold or more, the transition determination unit 306 determines the transition to the initial operation control in step S511. Note that, in Fig. 11, step S509 (a process of determining whether or not the target temperature is lowered) illustrated in Fig. 5 is not performed.

[0128]

Fig. 12 is a flowchart for explaining an operation when the operation of Fig. 11 is transitioned to the initial operation control. In the operation of Fig. 12, similarly to the operation of Fig. 6, the control device 30 first acquires information on the target temperature from the target temperature setting unit 302 in step S601. Next, in step S602, the control device 30 causes the compressor control unit 307 to determine a relational expression corresponding to the target temperature. In step S602, for example, when the target temperature is lowered from -20 degrees to -30 degrees, the relational expression indicated by F30 in Fig. 4 is selected. Note that, in step S602, a set value table as shown in Fig. 8 may be used instead of the relational expression.

[0129]

After the relational expression is determined in step S602, the compressor control unit 307 acquires information on the thermal load from the thermal load calculation unit 305 in step S603. The thermal load is a thermal load for setting the temperature of the fluid before flowing into the heat exchange unit 21E to the target temperature, in other words, for setting the temperature of the fluid before temperature control to the target temperature.

[0130]

In step S604R, the set value of the rotation speed of the compressor 11 to be the target rotation speed in the initial operation control, the adjustment amount of the opening degree of the expansion valve 13, and the adjustment amount of the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 are specified. The set value of the rotation speed of the compressor 11 is specified by substituting the thermal load acquired in step S603 into the relational expression determined

in step S602 in the present embodiment. On the other hand, even in the present modification, the adjustment amount of the opening degree of the expansion valve 13 and the adjustment amount of the flow rate of the fluid circulating in the heat exchange unit 21E are determined by constant values regardless of the target temperature. However, when the target temperature is increases, the lowering amount of the opening degree of the expansion valve 13 and the lowering amount of the flow rate of the fluid circulating in the heat exchange unit 21E are specified. When the target temperature is lowered, the rotation speed of the compressor 11 is increased, and the increasing amount of the opening degree of the expansion valve 13 and the increasing amount of the fluid circulating in the heat exchange unit 21E are specified.

[0131]

That is, in the present modification, when the target temperature is lowered, in the initial operation control, the rotation speed of the compressor 11 is increased, the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 is increased, and the opening degree of the expansion valve 13 is also increased. However, at this time, the opening degree of the expansion valve 13 may not be increased. When the flow rate of the fluid circulating in the heat exchange unit 21E is increased in the initial operation control, the valve mechanism 25 may be adjusted so that the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 increases by 5% or more and 15% or less from the current flow rate. In this case, in the steady control, a state where the fluid circulates in both the main flow path 21 and the bypass flow path 24 may be formed, and in the initial operation control, the bypass flow path 24 may be closed, and the flow rate of the fluid circulating in the heat exchange unit 21E may be increased. When the opening degree of the expansion valve 13 is increased in the initial operation control, the opening degree of the expansion valve 13 may be increased by a range of 5% or more and 10% or less from the current opening degree (at the time of transition to the initial operation control).

[0132]

The process after step S604R is similar to the process described with reference to Fig. 6. However, when the target temperature is lowered, as described above in step S607, the rotation speed of the compressor 11 is increased, the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 is increased, and the opening degree of the expansion valve 13 is also increased.

[0133]

Fig. 13 is a view showing a graph for explaining an operation of a constituent device of the temperature control system that performs the operation illustrated in Figs. 11 and 12 and a temperature control state. Fig. 13 shows changes in the temperature of the fluid, the rotation speed of the compressor 11, the opening degree of the expansion valve 13, and the opening degree of the three-way valve 25V when the process transitions to the steady control → the initial operation control → the preliminary steady control → the steady control. Specifically, Fig. 13 shows an operation when the process transitions from the steady control to the initial operation control by lowering the target temperature. In each graph, the horizontal axis is the time axis. Fig. 13(a) shows a state of the temperature of the fluid circulated by the fluid circulation apparatus 20 that changes with the lapse of time. Fig. 13(b) shows a state of the rotation speed of the compressor 11 that changes with the lapse of time (control mode). Fig. 13(c) shows a state of the opening degree of the expansion valve 13 that changes with the lapse of time (control mode). Fig. 13(d) shows a state of the opening degree of the three-way valve 25V (opening degree toward the heat exchange unit 21E) that changes with the lapse of time (control mode).

[0134]

The “old target temperature” shown in Fig. 13(a) means a target temperature of the fluid circulated by the fluid circulation apparatus 20 set at the start of operation. St1 in Fig. 13 indicates the steady control state. At this time, the control in the aspect (1) of feedback-controlling the compressor 11 and the expansion valve 13 is first performed, and then the control in the aspect (2) of feedback-controlling the expansion valve 13 with the rotation speed of the compressor 11 set to a constant value is performed.

[0135]

The “new target temperature” in Fig. 13 indicates the changed target temperature. The change to the new target temperature is performed at a time point indicated by a reference sign Ev in the drawing, and initial operation control St2 is performed accordingly. In initial operation control St2, the rotation speed of the compressor 11 is increased to the set value R derived on the basis of the target temperature. In initial operation control St2, the opening degree of the expansion valve 13 is increased by the predetermined amount D. In initial operation control St2, the valve mechanism 25 is adjusted so that the flow rate of the fluid circulating in the heat exchange unit 21E increases by the predetermined flow rate F. In the initial operation control, the rotation speed of the compressor 11 is increased to the set value R, the opening degree of the expansion valve 13 is increased by the predetermined

amount  $D$ , and the flow rate of the fluid circulating in the heat exchange unit 21E is increased by the predetermined flow rate  $F$  in a linear function manner or in a step input manner.

[0136]

Thereafter, when the absolute value of the difference between the temperature of the fluid detected by the first temperature sensor 26 and the target temperature is equal to or less than the first predetermined value and equal to or less than the second predetermined value, the state transitions to steady control St4 simultaneously with preliminary steady control St3 in this example. In steady control St4, the temperature of the fluid is controlled to the new target temperature. In the process as described above, the arrival time  $T_r$  can be significantly shortened.

[0137]

In the temperature control system described with reference to Figs. 11 to 13, the control device 30 controls the compressor 11 so that the rotation speed of the compressor 11 is changed to a set value derived on the basis of the changed target temperature (target temperature after changing) when the target temperature of the fluid is changed, and performs an initial operation control of changing the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 simultaneously with, before, or after the control of the compressor 11. In this configuration, the responsiveness of the temperature control when the target temperature is lowered can also be improved.

[0138]

Fig. 14 is a flowchart for explaining an operation of a temperature control system according to another modification. In the above-described embodiment and the modification illustrated in Fig. 11, whether or not to transition to the initial operation control is determined according to the target temperature. On the other hand, in the operation of the modification illustrated in Fig. 14, whether or not to transition to the initial operation control is determined according to the change in the temperature of the fluid before flowing into the heat exchange unit 21E in the main flow path 21. Specifically, whether or not to transition to the initial operation control is determined according to the magnitude of the change in the temperature of the fluid detected by the second temperature sensor 27.

[0139]

The processes in steps S501 to S505 and S508 in the operation illustrated in Fig. 14 are the same as the processes in Fig. 5. In this modification, in step S506R after the feedback control is performed in steps

S505 and S508, the control device 30 determines whether the temperature of the fluid before flowing into the heat exchange unit 21E (fluid temperature before temperature adjustment) has changed. The determination in step S506R is made by comparing the temperatures of the fluids detected by the second temperature sensor 27 at different detection timings. More specifically, for example, the temperature of the fluid detected by the second temperature sensor 27 during the process in step S506R may be compared with the temperature of the fluid detected by the second temperature sensor 27 before the process. The temperature of the fluid detected by the second temperature sensor 27 before the above process may be a moving average value. The temperature of the fluid detected by the second temperature sensor 27 during the above process may be a moving average value. When the change in the temperature of the fluid is not detected in step S506R, the process returns to step S503, and the feedback control is repeated.

[0140]

On the other hand, when the change in the temperature of the fluid is detected in step S506R, in step S510R2, the control device 30 determines whether the absolute value of the difference between the temperatures of the fluids before and after the change is equal to or more than the threshold. The temperature difference is obtained from the temperature of the fluid compared in step S506R. When it is determined in step S510R that the absolute value of the difference between the temperatures of the fluids before and after the change is equal to or more than the threshold, the transition to the initial operation control is determined (step S511). In the initial operation control, the same process as the operation illustrated in Fig. 12 is performed. Note that, as the target temperature acquired in step S601 in Fig. 12, the currently set target temperature is acquired, and then a set value to be the rotation speed of the compressor 11 is specified according to the thermal load based on the temperature of the fluid detected by the second temperature sensor 27. That is, in this modification, when the temperature of the fluid detected by the second temperature sensor 27 changes, the process for maintaining the target temperature at an early stage by the initial operation control is performed. Note that, in step S510R2, the transition to the initial operation control may be determined when the thermal load is equal to or more than a predetermined value.

[0141]

In the temperature control system described with reference to Fig. 14, when the temperature of the fluid before flowing into the heat exchange unit 21E is changed, the control device 30 controls the compressor 11 so that the

rotation speed of the compressor 11 is changed to a set value described on the basis of the changed temperature of the fluid (specifically, the thermal load is calculated on the basis of the changed temperature of the fluid), and performs an initial operation control of changing the flow rate of the fluid circulating in the heat exchange unit 21E in the main flow path 21 simultaneously with, before, or after the control of the compressor 11. For example, when the temperature of the fluid before flowing into the heat exchange unit 21E increases, the rotation speed of the compressor 11 increases, and the flow rate of the fluid circulating in the heat exchange unit 21E increases. When the temperature of the fluid before flowing into the heat exchange unit 21E is lowered, the rotation speed of the compressor 11 is lowered, and the flow rate of the fluid circulating in the heat exchange unit 21E is lowered. In this configuration, when the temperature of the fluid returned from the temperature control target T greatly changes, the responsiveness of the temperature control for maintaining the target temperature can be improved.

[0142]

Fig. 15 is a diagram for explaining an application example of a temperature control system according to an embodiment or a modification. In Fig. 15, the temperature control system 1 is connected to an etching apparatus 7 as the temperature control target T. The etching apparatus of Fig. 15 includes an electrostatic chuck 71. The fluid whose temperature is controlled from the temperature control system 1 passes through the electrostatic chuck 71 and returns to the temperature control system 1. A wafer 72 is held by the electrostatic chuck 71. The electrostatic chuck 71 is connected to the inlet 21U and the outlet 21D of the main flow path 21 in the temperature control system 1 via a flow path inside the etching apparatus. The etching apparatus further includes an internal temperature sensor 73 that detects the temperature of the fluid flowing out from the electrostatic chuck 71 inside the apparatus. Strictly speaking, the temperature control target T in this example is the electrostatic chuck 71 or the wafer 71 in the etching apparatus 7.

[0143]

Note that the operation described with reference to Fig. 14 may be performed on the basis of a change in the temperature of the fluid detected by the internal temperature sensor 73. That is, whether or not to perform the initial operation control may be determined according to the temperature of the fluid detected by the internal temperature sensor 73. Specifically, whether or not to perform the initial operation control may be determined according to

the temperature of the fluid in the etching apparatus 7 as an external device after heat exchange with the electrostatic chuck 71 in the etching apparatus 7 which is an external apparatus and before flowing into the heat exchange unit 21E detected by the internal temperature sensor 73. Note that the internal temperature sensor 73 may detect the temperature of the inside or the outer surface of the electrostatic chuck 71. In the example of Fig. 15, the temperature control system 1 integrally includes the etching apparatus 7 which is an external device as the temperature control target T, but the temperature control system 1 may be integrated with another external device. For example, the temperature control system 1 may be integrated with another semiconductor manufacturing apparatus such as a resist processing apparatus, an inspection apparatus such as a semiconductor tester, a molding apparatus including a mold other than the semiconductor field, or the like. Even in such another configuration, whether or not to perform the initial operation control may be determined on the basis of the temperature detected by an element corresponding to the internal temperature sensor 73 in the external device.

[0144]

Although the embodiments and modifications of the present invention have been described above, the present invention is not limited to the above-described embodiments, and various modifications can be further made to the above-described embodiments and modifications.

## Claims

## [Claim 1]

A temperature control system comprising:

a refrigeration apparatus including a compressor, a condenser, an expansion valve, and an evaporator, a refrigerant flowing out from the compressor passing through the condenser, the expansion valve, and the evaporator in this order and then returning to the compressor;

a fluid circulation apparatus including a main flow path having a heat exchange unit between an inlet and an outlet and allowing a fluid received at the inlet to circulate to the outlet through the heat exchange unit, the fluid circulation apparatus allowing the fluid in the heat exchange unit to exchange heat with the refrigerant in the evaporator; and

a control device controlling the refrigeration apparatus and the fluid circulation apparatus,

wherein the control device controls the compressor so that a rotation speed of the compressor is changed to a set value derived based on a changed target temperature or a changed temperature of the fluid when the target temperature of the fluid is changed or the temperature of the fluid before flowing into the heat exchange unit is changed, and performs an initial operation control of changing a flow rate of the fluid circulating in the heat exchange unit in the main flow path simultaneously with, before, or after the control of the compressor.

## [Claim 2]

The temperature control system according to claim 1, wherein in the initial operation control, when the rotation speed of the compressor is lowered, the flow rate of the fluid circulating in the heat exchange unit in the main flow path is lowered.

## [Claim 3]

The temperature control system according to claim 2, wherein when the target temperature is changed to a temperature higher than a temperature of the fluid detected by a temperature sensor detecting a temperature of the fluid circulating in a downstream portion of the heat exchange unit in the main flow path, the control device lowers the rotation speed of the compressor by the initial operation control.

## [Claim 4]

The temperature control system according to claim 1, wherein in the initial operation control, when the rotation speed of the compressor is increased, the flow rate of the fluid circulating in the heat exchange unit in the main flow path is increased.

[Claim 5]

The temperature control system according to claim 1, wherein the fluid circulation apparatus further includes a valve mechanism adjusting the flow rate of the fluid circulating in the heat exchange unit in the main flow path.

[Claim 6]

The temperature control system according to claim 5, wherein the fluid circulation apparatus further includes a bypass flow path connecting an upstream portion and a downstream portion of the heat exchange unit in the main flow path and allowing the fluid received from the main flow path to circulate,

the valve mechanism adjusts the flow rate of the fluid circulating in the heat exchange unit in the main flow path and a flow rate of the fluid circulating in the bypass flow path, and

in the initial operation control, the control device adjusts the valve mechanism to lower the flow rate of the fluid circulating in the heat exchange unit in the main flow path and increase the flow rate of the fluid circulating in the bypass flow path, or to increase the flow rate of the fluid circulating in the heat exchange unit in the main flow path and lower the flow rate of the fluid circulating in the bypass flow path.

[Claim 7]

The temperature control system according to any one of claims 1 to 6, wherein the control device determines a relational expression or a table according to the changed target temperature or a target temperature set when the temperature of the fluid before flowing into the heat exchange unit is changed, and derives the set value based on the determined relational expression or table.

[Claim 8]

The temperature control system according to claim 7, wherein when the target temperature is changed, the control device calculates a thermal load for setting the temperature of the fluid before flowing into the heat exchange unit to the target temperature,

the relational expression or table defines a relationship between the thermal load and the set value, and

the set value is determined based on the target temperature, the thermal load, and the relational expression or table determined according to the target temperature.

[Claim 9]

The temperature control system according to claim 2, wherein when the rotation speed of the compressor is lowered in the initial operation control, the control device also lowers an opening degree of the expansion valve by a predetermined amount.

[Claim 10]

The temperature control system according to claim 4, wherein when the rotation speed of the compressor is increased in the initial operation control, the control device also increases an opening degree of the expansion valve by a predetermined amount.

[Claim 11]

The temperature control system according to claim 9 or 10, wherein when the opening degree of the expansion valve is changed in the initial operation control, the control device lowers or increases the opening degree of the expansion valve by a range of 5% or more and 10% or less from a current opening degree.

[Claim 12]

The temperature control system according to claim 9, wherein when the target temperature is changed to a temperature higher than a temperature of the fluid detected by a temperature sensor detecting a temperature of the fluid circulating in a downstream portion of the heat exchange unit in the main flow path, the control device lowers the rotation speed of the compressor and the opening degree of the expansion valve in the initial operation control and then transitions to a preliminary steady control, and

in the preliminary steady control, the control device adjusts the opening degree of the expansion valve by a feedback control based on a difference between the temperature of the fluid detected by the temperature sensor and the target temperature, and maintains the rotation speed of the compressor in a lowered state in the initial operation control.

[Claim 13]

The temperature control system according to claim 12, wherein when an absolute value of the difference between the temperature of the fluid detected by the temperature sensor and the target temperature is equal to or less than a first predetermined value after the rotation speed of the compressor and the opening degree of the expansion valve are lowered in the initial operation control, the control device transitions to the preliminary steady control.

[Claim 14]

The temperature control system according to claim 12, wherein the feedback control is P control, PI control, PD control, or PID control.

[Claim 15]

The temperature control system according to claim 12, wherein the control device adjusts the flow rate so that the flow rate of the fluid circulating in the heat exchange unit in the main flow path lowers in the initial operation control, and then adjusts the flow rate so that the flow rate of the fluid circulating in the heat exchange unit in the main flow path returns to the flow rate before adjustment before the temperature of the fluid detected by the temperature sensor reaches the target temperature.

[Claim 16]

The temperature control system according to claim 15, wherein the control device adjusts the flow rate so that the flow rate of the fluid circulating in the heat exchange unit in the main flow path lowers, and then adjusts the flow rate so that the flow rate of the fluid circulating in the heat exchange unit in the main flow path returns to the flow rate before adjustment when the absolute value of the difference between the temperature of the fluid detected by the temperature sensor and the target temperature is equal to or less than a second predetermined value.

[Claim 17]

The temperature control system according to claim 15, wherein the control device transitions to the preliminary steady control, adjusts the flow rate so that the flow rate of the fluid circulating in the heat exchange unit in the main flow path returns to the flow rate before adjustment, and then transitions to a steady control, and

in the steady control, the control device adjusts the opening degree of

the expansion valve by the feedback control based on the difference between the temperature of the fluid detected by the temperature sensor and the target temperature, and maintains the rotation speed of the compressor in a lowered state in the initial operation control or controls the rotation speed of the compressor and the opening degree of the expansion valve by the feedback control based on the difference between the temperature of the fluid detected by the temperature sensor and the target temperature.

[Claim 18]

The temperature control system according to claim 6, wherein in the initial operation control, when the flow rate of the fluid circulating in the heat exchange unit in the main flow path is lowered and the flow rate of the fluid circulating in the bypass flow path is increased by adjusting the valve mechanism, the flow rate of the fluid circulating in the heat exchange unit in the main flow path lowers and the flow rate of the fluid circulating in the bypass flow path increases by opening the bypass flow path in a state of being closed by the valve mechanism.

[Claim 19]

The temperature control system according to claim 1, wherein in the initial operation control, the flow rate of the fluid circulating in the heat exchange unit in the main flow path is lowered by 5% or more and 15% or less.

[Claim 20]

The temperature control system according to claim 1, wherein the control device performs the initial operation control when an absolute value of a difference between a temperature of the fluid detected by a temperature sensor detecting a temperature of the fluid circulating in a downstream portion of the heat exchange unit in the main flow path and the target temperature or an absolute value of a difference between target temperatures before and after change is equal to or more than a temperature threshold.

[Claim 21]

The temperature control system according to claim 1, wherein when the initial operation control is performed, the rotation speed of the compressor is changed by a rotation speed corresponding to a refrigeration capacity of at least 5 Kw.

## [Claim 22]

The temperature control system according to claim 1, wherein when the rotation speed of the compressor is lowered to the set value in the initial operation control, in a case where a difference between the set value and a current rotation speed is larger than a rotation speed threshold, a value obtained by subtracting the rotation speed threshold from the current rotation speed is set as the set value.

## [Claim 23]

The temperature control system according to claim 8, wherein the control device holds a basic expression including at least a variable to which the thermal load is substituted and a coefficient for increasing or decreasing the variable and a plurality of coefficient eigenvalues held in advance corresponding to a plurality of target temperature candidate values, and

the relational expression is determined by substituting the coefficient eigenvalue determined based on a comparison between the target temperature and the target temperature candidate value into the basic expression.

## [Claim 24]

The temperature control system according to claim 1, further comprising an external device receiving the fluid from the outlet, performing heat exchange with the fluid, and causing the fluid after the heat exchange to flow into the inlet,

wherein when the temperature of the fluid, which is the fluid after the heat exchange in the external device and before flowing into the heat exchange unit, is changed, the control device controls the compressor so that the rotation speed of the compressor is changed to a set value derived based on the changed temperature of the fluid, and performs an initial operation control of changing a flow rate of the fluid circulating in the heat exchange unit in the main flow path simultaneously with, before, or after the control of the compressor.

## [Claim 25]

A temperature control method in a temperature control system including: a refrigeration apparatus including a compressor, a condenser, an expansion valve, and an evaporator, a refrigerant flowing out from the compressor passing through the condenser, the expansion valve, and the evaporator in this order and then returning to the compressor; and a fluid

circulation apparatus including a main flow path having a heat exchange unit between an inlet and an outlet and allowing a fluid received at the inlet to circulate to the outlet through the heat exchange unit, the fluid circulation apparatus allowing the fluid in the heat exchange unit to exchange heat with the refrigerant in the evaporator, the temperature control method comprising:

- a detection process of detecting a change in a target temperature of the fluid or a change in a temperature of the fluid before flowing into the heat exchange unit; and

- a control process of controlling the compressor so that a rotation speed of the compressor is changed to a set value derived based on a changed target temperature or a changed temperature of the fluid when the change in a target temperature of the fluid or the change in a temperature of the fluid before flowing into the heat exchange unit is detected in the detection process, and changing a flow rate of the fluid circulating in the heat exchange unit in the main flow path simultaneously with, before, or after the control of the compressor.

[Claim 26]

A control device controlling a temperature control system including: a refrigeration apparatus including a compressor, a condenser, an expansion valve, and an evaporator, a refrigerant flowing out from the compressor passing through the condenser, the expansion valve, and the evaporator in this order and then returning to the compressor; and a fluid circulation apparatus including a main flow path having a heat exchange unit between an inlet and an outlet and allowing a fluid received at the inlet to circulate to the outlet through the heat exchange unit, the fluid circulation apparatus allowing the fluid in the heat exchange unit to exchange heat with the refrigerant in the evaporator,

the control device controlling the compressor so that a rotation speed of the compressor is changed to a set value derived based on a changed target temperature or a changed temperature of the fluid when the target temperature of the fluid is changed or the temperature of the fluid before flowing into the heat exchange unit is changed, and performing an initial operation control of changing a flow rate of the fluid circulating in the heat exchange unit in the main flow path simultaneously with, before, or after the control of the compressor.

[Claim 27]

A computer program for controlling a refrigeration apparatus including

a compressor, a condenser, an expansion valve, and an evaporator, a refrigerant flowing out from the compressor passing through the condenser, the expansion valve, and the evaporator in this order and then returning to the compressor, and a fluid circulation apparatus including a main flow path having a heat exchange unit between an inlet and an outlet and allowing a fluid received at the inlet to circulate to the outlet through the heat exchange unit, the fluid circulation apparatus allowing the fluid in the heat exchange unit to exchange heat with the refrigerant in the evaporator, the computer program configured to cause a computer to execute:

- a detection step of detecting a change in a target temperature of the fluid or a change in a temperature of the fluid before flowing into the heat exchange unit; and

- a control step of controlling the compressor so that a rotation speed of the compressor is changed to a set value derived based on a changed target temperature or a changed temperature of the fluid when the change in a target temperature of the fluid or the change in a temperature of the fluid before flowing into the heat exchange unit is detected in the detection step, and changing a flow rate of the fluid circulating in the heat exchange unit in the main flow path simultaneously with, before, or after the control of the compressor.