(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 431 896 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
23.01.2019 Bulletin 2019/04

(21) Application number: **16894400.7**

(22) Date of filing: **17.03.2016**

(51) Int Cl.:
F24H 4/02 *(2006.01)*

(86) International application number:
PCT/JP2016/058439

(87) International publication number:
WO 2017/158782 (21.09.2017 Gazette 2017/38)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(71) Applicant: **Mitsubishi Electric Corporation**
Chiyoda-ku
Tokyo 100-8310 (JP)

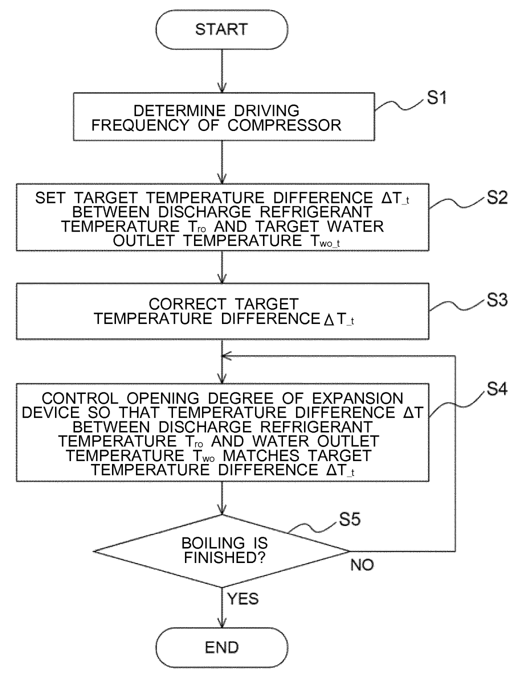
(72) Inventors:
- **HATANAKA, Kensaku**
  Tokyo 100-8310 (JP)
- **KOIDE, Toru**
  Tokyo 100-8310 (JP)

(74) Representative: **Mewburn Ellis LLP**
City Tower
40 Basinghall Street
London EC2V 5DE (GB)

(54) HEAT PUMP HOT WATER SUPPLIER

(57) Provided is a heat pump water heater apparatus having a water circuit and a refrigerant circuit thermally connected through a first heat exchanger, the refrigerant circuit circulating carbon dioxide, the first heat exchanger being configured to exchange heat between the water and the carbon dioxide, the refrigerant circuit including a compressor, a refrigerant passage of the first heat exchanger, an expansion valve, and a second heat exchanger, the water circuit including a water passage of the first heat exchanger and a tank, the heat pump water heater apparatus including: a first sensor configured to detect a temperature of the carbon dioxide discharged from the compressor, a second sensor configured to detect a temperature of the water flowing into the water passage; and a third sensor configured to detect a temperature of the water flowing out of the water passage; the expansion valve being opened to have an opening degree to reduce a difference between a first value and a target value, the first value being a difference between a temperature detected by the third sensor and a temperature detected by the first sensor, the target value being determined to be smaller in a case where the temperature detected by the second sensor is a first temperature, than in a case of a second temperature, the second temperature being lower than the first temperature.

FIG. 3



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Description

Technical Field

[0001] The present invention relates to a heat pump water heater apparatus having a water circuit and a refrigerant circuit using carbon dioxide as refrigerant, in which heat is exchanged between water flowing through the water circuit and the carbon dioxide flowing through the refrigerant circuit.

Background Art

[0002] Hitherto, the following technology has been proposed. In a heat pump water heater apparatus having a water circuit and a refrigerant circuit using hydrocarbon (HC) refrigerant, an opening degree of an expansion valve is controlled so that a temperature difference between a discharge temperature of refrigerant discharged from a compressor and an outflow water temperature of water flowing out of a water heating heat exchanger becomes a target value determined so that the coefficient of performance (COP) is maximized (for example, see Patent Literature 1).

Citation List

Patent Literature

[0003] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2012-233626 (Claim 1, Page 9)

Summary of Invention

Technical Problem

[0004] As one type of refrigerant circulating through the refrigerant circuit, carbon dioxide is known. Carbon dioxide has advantages such as incombustibility and low global warming potential, but has such a characteristic that a pressure in the refrigerant circuit is higher as compared to that of hydrocarbon refrigerant. In Patent Literature 1, there is a description that, in the heat pump water heater apparatus using hydrocarbon refrigerant, the opening degree of the expansion valve is controlled so that the temperature difference between the discharge refrigerant temperature of the refrigerant discharged from the compressor and the outflow water temperature becomes the target value determined so that the coefficient of performance (COP) is maximized. However, the control adopted in Patent Literature 1 could not be applied to the heat pump water heater apparatus using carbon dioxide. The reason is as follows. As described above, the carbon dioxide has a high pressure in the refrigerant circuit, and hence when the target temperature difference between the discharge refrigerant temperature and the outflow water temperature is determined so that the COP is maximized, the high-pressure-side pressure may exceed a design pressure. In this case, a heat pump operation cannot be continued, and the water heating is stopped. Further, there is also a characteristic in which the high pressure of the carbon dioxide tends to rise when the temperature of water to be heated by carbon dioxide is high, and hence management of the high pressure is important. A technology has been desired that enables the heat pump water heater apparatus using carbon dioxide to perform stable water heating operation while the rise of the high pressure is suppressed.

[0005] The present invention has been made in view of the above-mentioned problem, and provides a heat pump water heater apparatus using carbon dioxide as refrigerant and capable of performing stable water heating operation while rise of a high pressure is suppressed.

Solution to Problem

[0006] According to one embodiment of the present invention, there is provided a heat pump water heater apparatus having a water circuit and a refrigerant circuit thermally connected through a first heat exchanger, the refrigerant circuit circulating carbon dioxide, the first heat exchanger being configured to exchange heat between the water and the carbon dioxide, the refrigerant circuit including a compressor, a refrigerant passage of the first heat exchanger, an expansion valve, and a second heat exchanger, the water circuit including a water passage of the first heat exchanger and a tank, the heat pump water heater apparatus including: a first sensor configured to detect a temperature of the carbon dioxide discharged from the compressor, a second sensor configured to detect a temperature of the water flowing into the water passage; and a third sensor configured to detect a temperature of the water flowing out of the water passage; the expansion valve being opened to have an opening degree to reduce a difference between a first value and a target value, the first value being a difference between a temperature detected by the third sensor and a temperature detected by the first sensor, the target value being determined to be smaller in a case where the temperature detected by the second sensor is a first temperature, than in a case of a second temperature, the second temperature being lower than the first temperature.

Advantageous Effects of Invention

[0007] According to one embodiment of the present invention, the heat pump water heater apparatus having the refrigerant circuit using carbon dioxide as refrigerant can perform stable water heating operation while the rise of the high pressure of the refrigerant discharged from the compressor is suppressed.

Brief Description of Drawings

[0008]

[Fig. 1] Fig. 1 is a circuit configuration diagram for illustrating a heat pump water heater apparatus according to Embodiment 1 of the present invention.

[Fig. 2] Fig. 2 is a functional block diagram for illustrating the heat pump water heater apparatus according to Embodiment 1.

[Fig. 3] Fig. 3 is a flow chart for illustrating control of a refrigerant circuit of the heat pump water heater apparatus according to Embodiment 1.

[Fig. 4] Fig. 4 is an example of a graph of a relationship between a water inlet temperature and a target temperature difference in the heat pump water heater apparatus according to Embodiment 1.

[Fig. 5] Fig. 5 is another example of the graph of the relationship between the water inlet temperature and the target temperature difference in the heat pump water heater apparatus according to Embodiment 1.

[Fig. 6] Fig. 6 is a configuration diagram for illustrating an accumulator in Embodiment 2 of the present invention.

[Fig. 7] Fig. 7 is a functional block diagram for illustrating a heat pump water heater apparatus according to Embodiment 2.

Description of Embodiments

[0009] Heat pump water heater apparatus according to embodiments of the present invention are described with reference to the drawings. In the drawings, relative dimensional relationships or shapes of respective components may differ from actual ones.

Embodiment 1

[0010] Fig. 1 is a circuit configuration diagram for illustrating a heat pump water heater apparatus according to Embodiment 1 of the present invention. A heat pump water heater apparatus 100 has a refrigerant circuit 10 circulating carbon dioxide serving as refrigerant, and a water circuit 20. The refrigerant circuit 10 and the water circuit 20 are thermally connected through a first heat exchanger 12 serving as a water-refrigerant heat exchanger, and the first heat exchanger 12 exchanges heat between the refrigerant circulating through the refrigerant circuit 10 and water circulating through the water circuit 20.

[0011] The refrigerant circuit 10 includes a compressor 11 configured to compress and discharge the refrigerant, a refrigerant passage 12a of the first heat exchanger 12 through which the refrigerant discharged from the compressor 11 passes, an expansion valve 13 configured to decompress the refrigerant, and a second heat exchanger 14, which are annularly connected in the stated order by a refrigerant pipe 18. The compressor 11 is driven by a driver including, for example, an inverter-controlled DC brushless motor, and has a function of varying the pressure and the temperature of the refrigerant discharged from the compressor 11. The expansion valve 13 has a variable opening degree, and has a function of varying a decompression state of the refrigerant passing therethrough. Further, in Embodiment 1, an accumulator 15, which is a container for accumulating surplus refrigerant, is connected on the downstream side of the second heat exchanger 14 and on the upstream side of the compressor 11. The second heat exchanger 14 is an air heat exchanger configured to exchange heat between the refrigerant circuiting through the refrigerant circuit 10 and outdoor air. A fan 16 configured to send the outdoor air to the second heat exchanger 14 is arranged in the vicinity of the second heat exchanger 14.

[0012] At a discharge portion of the compressor 11, a first sensor 17 that is a temperature sensor configured to detect a temperature of the refrigerant discharged from the compressor 11 is provided. The first sensor 17 is a temperature sensor configured to detect the temperature of the refrigerant directly or indirectly via a pipe.

[0013] The water circuit 20 includes a tank 21 for storing water and a water passage 12b of the first heat exchanger 12, which are connected by a water circulating pipe 25. In the water circulating pipe 25, a pump 22 configured to send water is arranged. The pump 22 is operated to circulate water in the water circuit 20. One end of the water circulating pipe 25 is connected to a lower portion of the tank 21, and an other end of the water circulating pipe 25 is connected to an upper portion of the tank 21. Water having a relatively low temperature at the lower portion of the tank 21 is heated by the first heat exchanger 12 to flow into the tank 21 from the upper portion of the tank 21.

[0014] To the lower portion of the tank 21, a water supply pipe 26 that is different from the water circulating pipe 25 is connected. Water from a water supply source is stored in the tank 21 via the water supply pipe 26. To the upper portion of the tank 21, an outflow water pipe 27 that is different from the water circulating pipe 25 is connected. Water having a relatively high temperature at the upper portion of the tank 21 is supplied to, for example, a bathtub. The pipe configurations related to water supply to the tank 21 and water outflow from the tank 21 are merely an example, and the present invention is not limited to those pipe configurations.

[0015] At an inlet of the water passage 12b of the first heat exchanger 12, a second sensor 23 that is a temperature sensor configured to detect a temperature of water flowing into the first heat exchanger 12 is provided. Further, at an outlet of the water passage 12b of the first heat exchanger 12, a third sensor 24 that is a temperature sensor configured to detect a temperature of water flowing out of the first heat exchanger 12 is provided. A water inlet temperature T_{wi} detected by the second sensor 23 is a temperature of water before being heated by the first heat exchanger 12, and a water outlet temperature T_{wo} detected by the third sensor 24 is a temperature of water after being heated by the first heat exchanger 12. The second sensor and the third sensor are temperature sensors configured to detect the temperature of the water directly or indirectly via a pipe.

[0016] Further, the heat pump water heater apparatus 100 includes an outdoor air temperature detection device 28 that is a temperature sensor. The outdoor air temperature detection device 28 is arranged at a place at which an outdoor air temperature in the vicinity of the heat pump water heater apparatus 100 can be measured.

[0017] Fig. 2 is a functional block diagram for illustrating the heat pump water heater apparatus according to Embodiment 1. The heat pump water heater apparatus 100 includes a controller 30 configured to control the entirety of the apparatus, and the controller 30 includes a memory 31. The controller 30 receives input such as output of the first sensor 17, the second sensor 23, the third sensor 24, and the outdoor air temperature detection device 28 and information from operation means operated by a user. The controller 30 outputs commands to the compressor 11, the expansion valve 13, the fan 16, and the pump 22 based on those pieces of input information to control the operation of those actuators. Specifically, the controller 30 controls a frequency of the driver for the compressor 11 to control the operation state of the compressor 11 so that the pressure and the temperature of the discharged refrigerant are adjusted. Further, the controller 30 controls the opening degree of the expansion valve 13 so that the refrigerant attains a target decompression state in the expansion valve 13. Further, the controller 30 controls the operation states of the fan 16 and the pump 22.

[0018] The controller 30 is constructed of dedicated hardware or a central processing unit (CPU, also referred to as central processing device, processing device, calculation device, microprocessor, microcomputer, and processor) configured to execute a program stored in the memory 31.

[0019] When the controller 30 is dedicated hardware, the controller 30 corresponds to, for example, a single circuit, a composite circuit, an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or a combination of those circuits. Each functional unit to be implemented by the controller 30 may be implemented by individual hardware, or the functional units may be implemented by single hardware.

[0020] When the controller 30 is a CPU, each function executed by the controller 30 is implemented by software, firmware, or a combination of software and firmware. The software or the firmware is described as a program, and stored in the memory 31. The CPU loads and executes the program stored in the memory 31 to implement the functions of the controller 30. In this case, the memory 31 is a non-volatile or volatile semiconductor memory, for example, a RAM, a ROM, a flash memory, an EPROM, or an EEPROM.

[0021] A part of the functions of the controller 30 may be implemented by dedicated hardware, and a part may be implemented by software or firmware. Further, in Fig. 2, the respective actuators are controlled collectively by the controller 30, but the controller 30 is not necessarily required to be physically configured as illustrated in Fig. 2. That is, specific forms of dispersion and integration of the controller 30 are not limited to those illustrated in Fig. 2, and the whole or a part thereof may be functionally or physically dispersed or integrated in any unit in accordance with various loads or use conditions, for example.

[0022] The overall description of water heating operation of the heat pump water heater apparatus 100 is provided below. When the compressor 11, whose operation frequency is controlled, is operated, the compressed refrigerant is discharged from the compressor 11. The high-temperature and high-pressure refrigerant discharged from the compressor 11 flows into the refrigerant passage 12a of the first heat exchanger 12. Meanwhile, in the water circuit 20, the pump 22 is driven, and the action of the pump 22 causes water in the tank 21 to pass through the water circulating pipe 25 to flow into the water passage 12b of the first heat exchanger 12. The high-temperature and high-pressure refrigerant passing through the refrigerant passage 12a and the water passing through the water passage 12b exchange heat in the first heat exchanger 12, and the refrigerant decreased in temperature and the high-temperature water increased in temperature respectively flow out of the first heat exchanger 12. The high-temperature water increased in temperature in the first heat exchanger 12 passes through the water circulating pipe 25 to flow into the tank 21.

[0023] The refrigerant decreased in temperature through heat exchange with water in the first heat exchanger 12 flows into the expansion valve 13. The refrigerant flowing into the expansion valve 13 is decompressed to a state corresponding to the opening degree of the expansion valve 13, and transitions to the low-pressure refrigerant to flow into the second heat exchanger 14. The refrigerant flowing into the second heat exchanger 14 exchanges heat with the outdoor air in the process of passing through the second heat exchanger 14 and is increased in temperature. The operation state of the fan 16 is controlled so as to obtain a desired heat exchange amount between the outdoor air and the refrigerant. The refrigerant increased in temperature through heat exchange with the outdoor air in the second heat exchanger 14 is sucked into the compressor 11 via the accumulator 15. The controller 30 monitors the high-pressure-side refrigerant pressure output from the first sensor 17, and when the high-pressure-side refrigerant pressure exceeds an upper limit value determined at the time of design, the controller 30 temporarily stops the water heating operation.

[0024] Next, details of control of the operation of the refrigerant circuit 10 in the water heating operation of the heat pump water heater apparatus 100 are described. Fig. 3 is a flow chart for illustrating the control of the refrigerant circuit of the heat pump water heater apparatus according to Embodiment 1.

(S1)

[0025] The controller 30 determines a driving frequency of the compressor 11, and operates the compressor 11 at the determined driving frequency. Specifically, the controller 30 determines the driving frequency of the compressor 11 based on an outdoor air temperature T_a output from the outdoor air temperature detection device 28 and the water inlet temperature T_{wi} output from the second sensor 23. The driving frequency of the compressor 11 is set higher in a case where the outdoor air temperature T_a is low, than in a case where the outdoor air temperature T_a is high. Further, the driving frequency of the compressor 11 is set higher in a case where the water inlet temperature T_{wi} is low, than in a case where the water inlet temperature T_{wi} is high. For example, a correspondence table between a combination of the outdoor air temperature T_a and the water inlet temperature T_{wi} and the driving frequency of the compressor 11 is obtained through experiments or other methods in advance, and the correspondence table is stored in the memory 31. The controller 30 can determine the driving frequency based on the correspondence table stored in the memory 31. Instead of determining the driving frequency based on the correspondence table as described above, the controller 30 may determine the driving frequency by applying the detected outdoor air temperature T_a and water inlet temperature T_{wi} to a predetermined calculation formula.

(S2)

[0026] The controller 30 sets a target temperature difference $\Delta T_{\_t}$ that is a target value of a temperature difference between a discharge refrigerant temperature T_{ro} and a target water outlet temperature T_{wo_t}. In this case, the target water outlet temperature T_{wo_t} is set based on a predetermined temperature of the water to be stored in the tank 21. The discharge refrigerant temperature T_{ro} is set as a temperature that is higher than the target water outlet temperature T_{wo_t} by an amount of a margin so that the temperature of the water to be heated by the refrigerant in the first heat exchanger 12 reaches the target water outlet temperature T_{wo_t}. The value of the amount of the margin corresponds to the target temperature difference $\Delta T_{\_t}$. In Step S2, the target temperature difference $\Delta T_{\_t}$ is set to a value corresponding to the target water outlet temperature T_{wo_t}. For example, a correspondence table between the target water outlet temperature T_{wo_t} and the target temperature difference $\Delta T_{\_t}$ can be stored in the memory 31 in advance.

(S3)

[0027] The controller 30 corrects the target temperature difference $\Delta T_{\_t}$ set in Step S2. Specifically, the controller 30 corrects the target temperature difference $\Delta T_{\_t}$ so that the target temperature difference $\Delta T_{\_t}$ is smaller in a case where the water inlet temperature T_{wi} output from the second sensor 23 is a first temperature V_1, than in a case of a second temperature V_2 (provided that $V_1>V_2$). That is, even at the same target water outlet temperature T_{wo_t}, the target temperature difference $\Delta T_{\_t}$ is changed depending on the water inlet temperature T_{wi}, and the target temperature difference $\Delta T_{\_t}$ is determined to be smaller in a case where the water inlet temperature T_{wi} is large, than in a case where the water inlet temperature T_{wi} is small.

[0028] Fig. 4 is an example of a graph of a relationship between the water inlet temperature and the target temperature difference in the heat pump water heater apparatus according to Embodiment 1. Fig. 4 shows an example in which the correction value of the target temperature difference $\Delta T_{\_t}$ is changed stepwise so that the target temperature difference $\Delta T_{\_t}$ is decreased as the water inlet temperature T_{wi} is increased. In addition to the example shown in Fig. 4, the target temperature difference $\Delta T_{\_t}$ may be corrected by determining one threshold value for the water inlet temperature T_{wi} in advance, and subtracting a predetermined correction value from the target temperature difference $\Delta T_{\_t}$ when the water inlet temperature T_{wi} exceeds the threshold value.

[0029] Fig. 5 is another example of the graph of the relationship between the water inlet temperature and the target temperature difference in the heat pump water heater apparatus according to Embodiment 1. As shown in Fig. 5, the target temperature difference $\Delta T_{\_t}$ may be corrected by adjusting the correction value in accordance with the outdoor air temperature T_a in addition to the adjustment to the water inlet temperature T_{wi}. Specifically, the target temperature difference $\Delta T_{\_t}$ is determined to be smaller in a case where the outdoor air temperature T_a is high ($T_a=\beta$ degrees Celsius), than in a case where the outdoor air temperature T_a is low ($T_a=\alpha$ degrees Celsius). When the outdoor air temperature T_a is high, the amount of heat rejection of water in the water circuit 20 is small. Therefore, a desired water outlet temperature T_{wo} can be obtained even when the target temperature difference $\Delta T_{\_t}$ is decreased in a case where the outdoor air temperature T_a is high.

(S4)

[0030] The controller 30 controls the opening degree of the expansion valve 13 so that a temperature difference ΔT between the discharge refrigerant temperature T_{ro} detected by the first sensor 17 and the water outlet temperature T_{wo} detected by the third sensor 24 approaches the target temperature difference $\Delta T_{\_t}$ corrected in Step S3.

[0031] While the operation of Step S4 is executed, the pump 22 is operated to cause the water from the lower portion of the tank 21 to pass through the water passage 12b of the first heat exchanger 12. In this process, the water is heated by the refrigerant, and the heated water is returned into the tank 21 from the upper portion of the tank 21. In this manner, the boiled high-temperature water is stored in the tank 21. The rotation speed of the pump 22 is controlled so that the output value of the third sensor 24 becomes the target water outlet temperature T_{wo_t}. The opening degree of the expansion valve 13 is controlled so as to obtain the target temperature difference $\Delta T_{\_t}$ in Step S4, that is, the heating capacity is maintained constant in the heat pump cycle, and hence the water outlet temperature T_{wo} can be secured by adjusting the rotation speed of the pump 22.

(S5)

[0032] The controller 30 continuously performs the processing of Step S4 until the boiling is finished. When a predetermined amount of hot water having a target temperature is stored in the tank 21, the controller 30 determines that the boiling is finished, and ends the operation.

[0033] As described above, according to Embodiment 1, the opening degree of the expansion valve 13 is controlled so that the difference between the target temperature difference $\Delta T_{\_t}$ and the temperature difference ΔT between the discharge refrigerant temperature T_{ro} and the water outlet temperature T_{wo} is decreased. The value of the target temperature difference $\Delta T_{\_t}$ is set to be smaller in a case where the water inlet temperature T_{wi} is the first temperature, than in a case of the second temperature that is smaller than the first temperature. Therefore, the opening degree of the expansion valve 13 is controlled so that the degree of superheat of carbon dioxide serving as the refrigerant is lower in a case where the water inlet temperature T_{wi} is high, than in a case where the water inlet temperature T_{wi} is low. In this manner, the amount of liquid refrigerant stored in the accumulator 15 is increased. When the amount of liquid refrigerant in the accumulator 15 is increased, the rise of the high pressure of the refrigerant discharged from the compressor 11 is suppressed. As described above, the controller 30 temporarily stops the water heating operation when the high-pressure-side refrigerant pressure exceeds the upper limit value determined at the time of design, but the high pressure of the refrigerant is prevented from excessively rising according to Embodiment 1. Therefore, the water heating operation can be continued stably, and the heat pump water heater apparatus 100 having high reliability can be obtained. The first value of the invention of the subject application corresponds to the temperature difference ΔT in Embodiment 1.

Embodiment 2

[0034] In Embodiment 2 of the present invention, a modification example of above-mentioned Embodiment 1 is described. In above-mentioned Embodiment 1, description is given of correcting the target temperature difference $\Delta T_{\_t}$ based on the water inlet temperature T_{wi}, but in Embodiment 2, description is given of controlling the minimum value of the target temperature difference $\Delta T_{\_t}$ after the correction. Embodiment 2 is achieved by adding a configuration to Embodiment 1, and the difference from Embodiment 1 is mainly described below.

[0035] Fig. 6 is a configuration diagram for illustrating an accumulator according to Embodiment 2. As illustrated in Fig. 6, pipes of the refrigerant circuit 10 are inserted to an upper portion and a lower portion of the accumulator 15. The refrigerant flows into the accumulator 15 from the pipe at the upper portion, and gas refrigerant flows out of the pipe at the lower portion. As illustrated in Fig. 1, the refrigerant flowing out of the accumulator 15 is sucked into the compressor 11.

[0036] The accumulator 15 includes a liquid level gauge 19 configured to detect the liquid level of the liquid refrigerant in the accumulator 15. The specific configuration of the liquid level gauge 19 is not particularly limited as long as the liquid level gauge has a function of detecting the liquid level of the liquid refrigerant. Any liquid level gauge of, for example, a magnet float type, a capacitive type, or an ultrasonic type can be used.

[0037] Fig. 7 is a functional block diagram for illustrating a heat pump water heater apparatus according to Embodiment 2. As illustrated in Fig. 7, the liquid level gauge 19 is connected to the controller 30 so that communication is enabled therebetween, and the output of the liquid level gauge 19 is input to the controller 30.

[0038] The operation control related to the water heating capacity in the refrigerant circuit 10 of the heat pump water heater apparatus 100 is performed similarly to that illustrated in Fig. 3 in Embodiment 1. That is, the target temperature difference $\Delta T_{\_t}$ between the discharge refrigerant temperature T_{ro} and the target water outlet temperature T_{wo_t} is corrected based on the water inlet temperature T_{wi}. Then, the opening degree of the expansion valve 13 is controlled so that the temperature difference ΔT between the detected discharge refrigerant temperature T_{ro} and the water outlet temperature T_{wo} becomes the target temperature difference $\Delta T_{\_t}$ after the correction.

[0039] Also in Embodiment 2, the value of the target temperature difference $\Delta T_{\_t}$ is corrected so that the value is smaller as the water inlet temperature T_{wi} is higher, but when the liquid level gauge 19 detects that the liquid level in the accumulator 15 exceeds a threshold value, the downward correction of the target temperature difference $\Delta T_{\_t}$ is not performed. That is, when the liquid level gauge 19 detects the threshold value, the controller 30 maintains the value of the target temperature difference $\Delta T_{\_t}$ at the current state or increases the value to be larger than the current value irrespective of the detected water inlet temperature T_{wi}.

[0040] As described above, according to Embodiment 2, the controller 30 performs correction of decreasing the target temperature difference $\Delta T_{\_t}$ as the water inlet temperature T_{wi} is increased until the amount of the liquid refrigerant in the accumulator 15 reaches the threshold value. Thus, similarly to Embodiment 1, the rise of the high pressure of the refrigerant discharged from the compressor 11 can be suppressed. Further, when the amount of the liquid refrigerant in the accumulator 15 exceeds the threshold value, the controller 30 does not perform correction of decreasing the target temperature difference $\Delta T_{\_t}$, and hence the shortage of the amount of refrigerant circulating through the refrigerant circuit 10 can be prevented.

Reference Signs List

[0041] 10 refrigerant circuit 11 compressor 12 first heat exchanger 12a refrigerant passage 12b water passage 13 expansion valve 14 second heat exchanger 15 accumulator 16 fan 17 first sensor 18 refrigerant pipe 19 liquid level gauge 20 water circuit 21 tank 22 pump 23 second sensor 24 third sensor 25 water circulating pipe 26 water supply pipe 27 outflow water pipe 28 outdoor air temperature detection device 30 controller 31 memory 100 heat pump water heater apparatus

Claims

1. A heat pump water heater apparatus having a water circuit and a refrigerant circuit thermally connected through a first heat exchanger, the refrigerant circuit circulating carbon dioxide, the first heat exchanger being configured to exchange heat between the water and the carbon dioxide,
the refrigerant circuit including a compressor, a refrigerant passage of the first heat exchanger, an expansion valve, and a second heat exchanger,
the water circuit including a water passage of the first heat exchanger and a tank,
the heat pump water heater apparatus comprising:

   a first sensor configured to detect a temperature of the carbon dioxide discharged from the compressor;
   a second sensor configured to detect a temperature of the water flowing into the water passage; and
   a third sensor configured to detect a temperature of the water flowing out of the water passage,

   the expansion valve being opened to have an opening degree to reduce a difference between a first value and a target value, the first value being a difference between a temperature detected by the third sensor and a temperature detected by the first sensor, the target value being determined to be smaller in a case where the temperature detected by the second sensor is a first temperature, than in a case of a second temperature, the second temperature being lower than the first temperature.

2. The heat pump water heater apparatus of claim 1, wherein the target value is smaller when an outdoor air temperature is high, than in a case where the outdoor air temperature is low.

3. The heat pump water heater apparatus of claim 1 or 2, further comprising:

   an accumulator provided in the refrigerant circuit on a downstream side of the second heat exchanger and on an upstream side of the compressor;
   a liquid level gauge configured to detect a liquid level of the carbon dioxide in the accumulator; and
   a controller configured to correct the target value so as to be smaller in a case where the temperature detected by the second sensor is high, than in a case where the temperature detected by the second sensor is low,

   wherein the controller is configured to prevent the target value from being corrected to be smaller under a state in which the liquid level detected by the liquid level gauge exceeds a threshold value, irrespective of the temperature detected by the second sensor.

FIG. 1

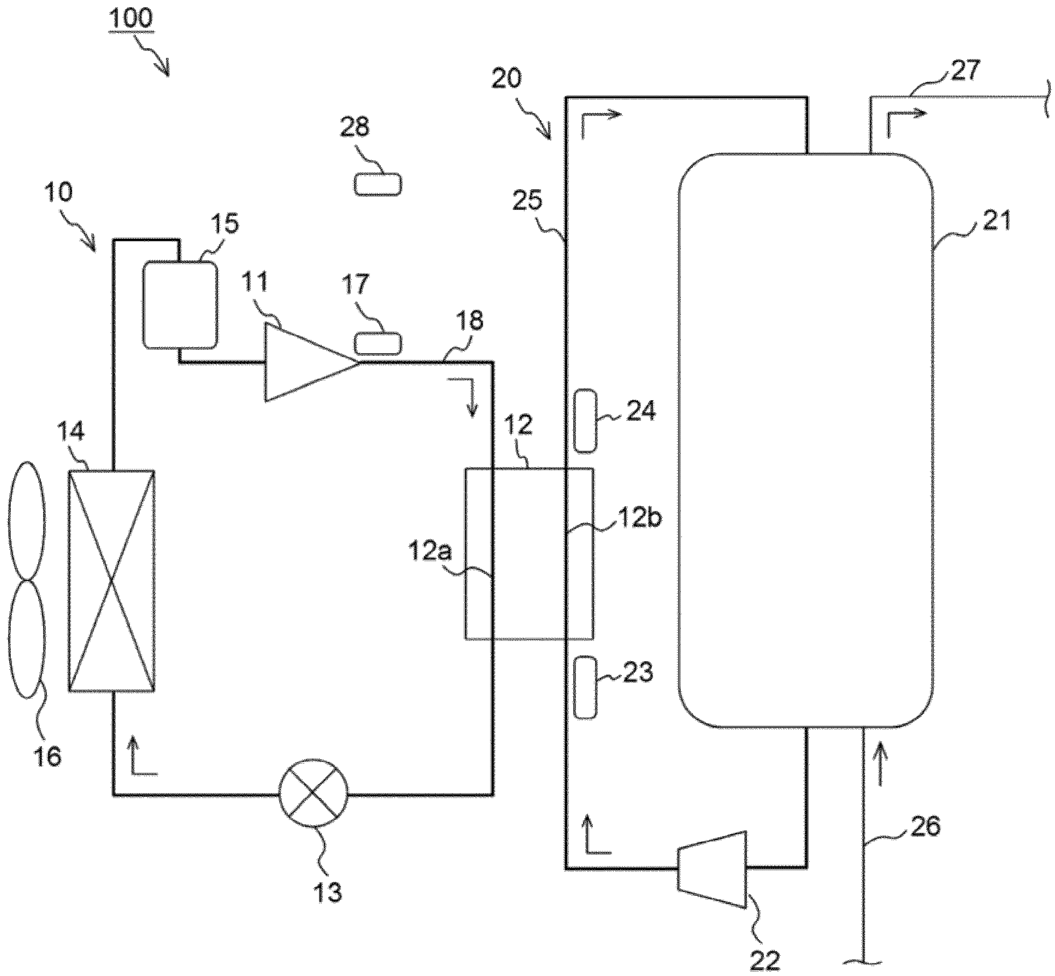

100
10
11
12
12a
12b
13
14
15
16
17
18
20
21
22
23
24
25
26
27
28

FIG. 2

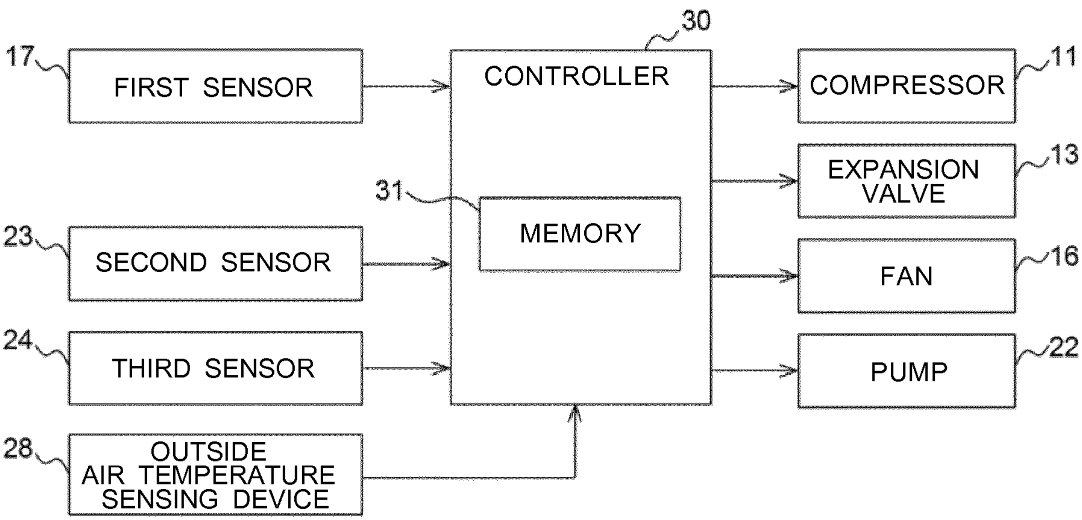

17
FIRST SENSOR
23
SECOND SENSOR
24
THIRD SENSOR
28
OUTSIDE AIR TEMPERATURE SENSING DEVICE
30
CONTROLLER
31
MEMORY
11
COMPRESSOR
13
EXPANSION VALVE
16
FAN
22
PUMP

FIG. 3

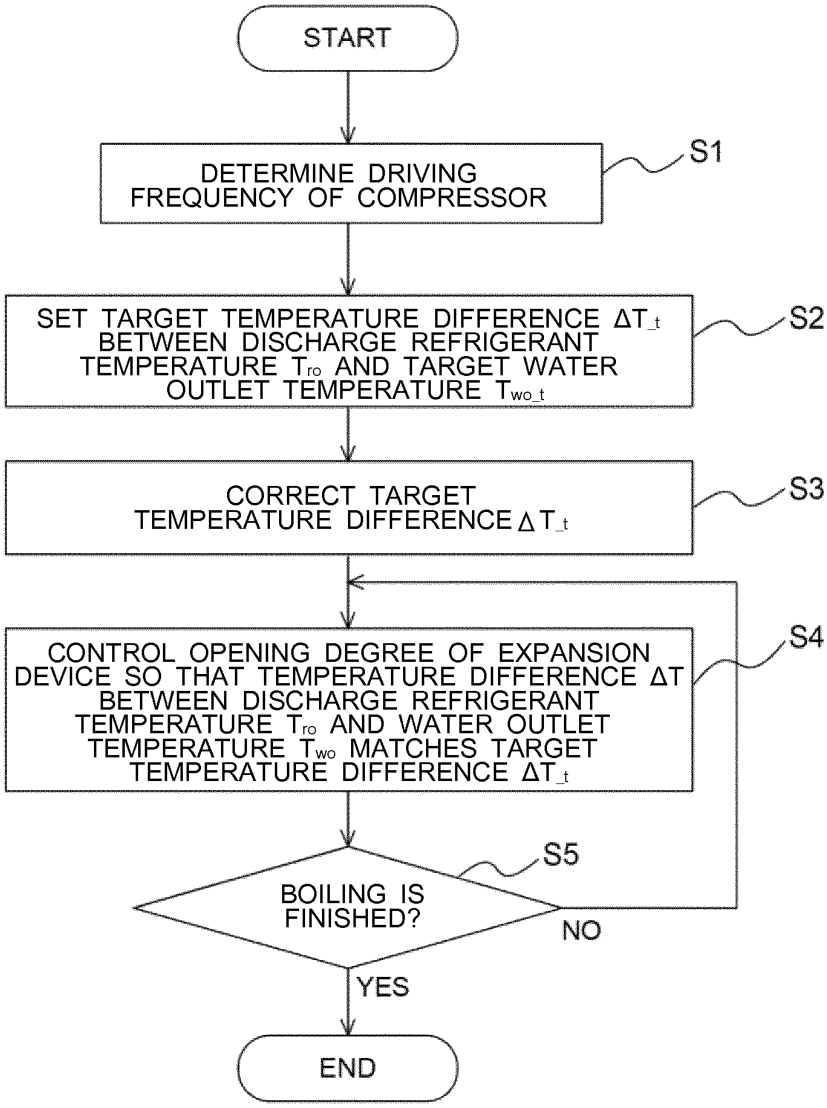

START
DETERMINE DRIVING FREQUENCY OF COMPRESSOR
S1
SET TARGET TEMPERATURE DIFFERENCE $\Delta T_{\_t}$ BETWEEN DISCHARGE REFRIGERANT TEMPERATURE T_{ro} AND TARGET WATER OUTLET TEMPERATURE T_{wo_t}
S2
CORRECT TARGET TEMPERATURE DIFFERENCE $\Delta T_{\_t}$
S3
CONTROL OPENING DEGREE OF EXPANSION DEVICE SO THAT TEMPERATURE DIFFERENCE ΔT BETWEEN DISCHARGE REFRIGERANT TEMPERATURE T_{ro} AND WATER OUTLET TEMPERATURE T_{wo} MATCHES TARGET TEMPERATURE DIFFERENCE $\Delta T_{\_t}$
S4
BOILING IS FINISHED?
S5
NO
YES
END

FIG. 4

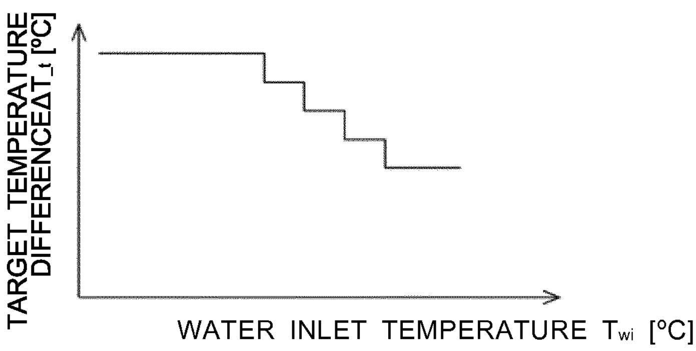

TARGET TEMPERATURE DIFFERENCE$\Delta T_{_t}$ [ºC]
WATER INLET TEMPERATURE T_{wi} [ºC]

FIG. 5

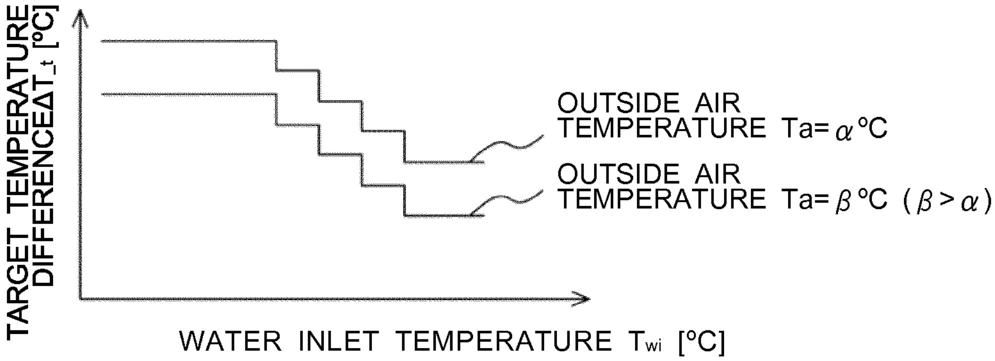

TARGET TEMPERATURE DIFFERENCEΔT_t [°C]
OUTSIDE AIR TEMPERATURE Ta=α°C
OUTSIDE AIR TEMPERATURE Ta=β°C (β>α)
WATER INLET TEMPERATURE Twi [°C]

FIG. 6

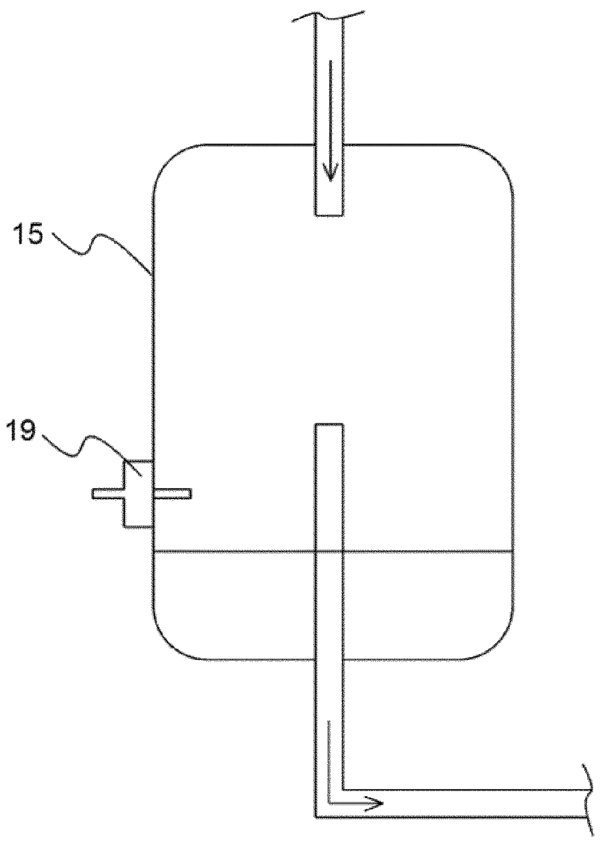
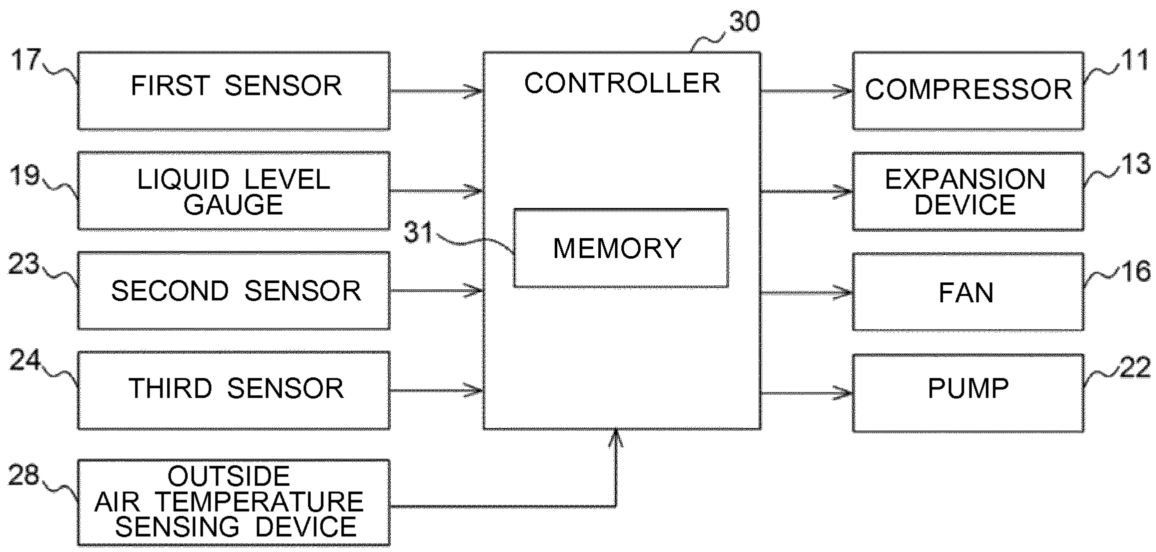

15
19

FIG. 7


17
FIRST SENSOR
19
LIQUID LEVEL GAUGE
23
SECOND SENSOR
24
THIRD SENSOR
28
OUTSIDE AIR TEMPERATURE SENSING DEVICE
30
CONTROLLER
31
MEMORY
COMPRESSOR
11
EXPANSION DEVICE
13
FAN
16
PUMP
22

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2016/058439

A. CLASSIFICATION OF SUBJECT MATTER
F24H4/02(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F24H4/02

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2012-112568 A (Mitsubishi Electric Corp.), 14 June 2012 (14.06.2012), paragraphs [0014], [0024] to [0025], [0045]; fig. 1 (Family: none)	1-2 3
Y	JP 2005-147608 A (Matsushita Electric Industrial Co., Ltd.), 09 June 2005 (09.06.2005), paragraphs [0022] to [0023], [0050]; fig. 1, 4 (Family: none)	1-2
Y	JP 2005-188923 A (Matsushita Electric Industrial Co., Ltd.), 14 July 2005 (14.07.2005), paragraphs [0012] to [0015]; fig. 3 (Family: none)	2

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

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"&" document member of the same patent family

Date of the actual completion of the international search 25 May 2016 (25.05.16)	Date of mailing of the international search report 07 June 2016 (07.06.16)
Name and mailing address of the ISA/ Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Authorized officer Telephone No.

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Patent documents cited in the description

- JP 2012233626 A **[0003]**