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(54) **HOT WATER SUPPLY SYSTEM**

(57) Overall energy efficiency of a hot water supply system including a heat pump heating unit and an auxiliary heating unit is optimized. Provided are a hot water storage tank, a hot water delivery unit for supplying hot water from the hot water storage tank to a use side, a heat pump heating unit for boiling water in the hot water storage tank, and an auxiliary heating unit capable of heating the hot water supplied to the hot water delivery unit. Performed are a heat pump isolated operation that boils water in the hot water storage tank using the heat pump heating unit, and an auxiliary heating combined operation that simultaneously performs heating of hot water using the auxiliary heating unit as well as boiling when the amount of heat is insufficient only by boiling using the heat pump heating unit. Boiling in a first mode of the heat pump isolated operation has higher heating capability and lower heat pump efficiency than those of boiling in a second mode. The boiling in the first mode is performed in a condition where a shortage of the amount of heat is likely to be caused by the boiling in the second mode in a state where a large amount of delivery of hot water is estimated or a large amount of hot water is actually delivered.

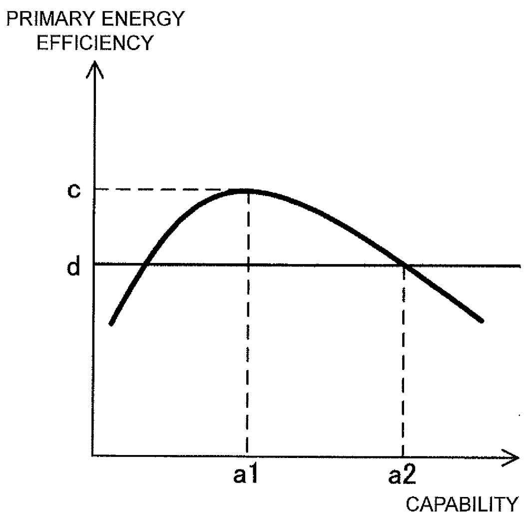

FIG. 4

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Description

TECHNICAL FIELD

[0001] The present invention relates to a hot water supply system that includes a heat pump heating unit capable of supplying hot water to a hot water storage tank.

BACKGROUND ART

[0002] A hot water supply system conventionally known is capable of storing, in a hot water storage tank, hot water generated using a heat pump heating unit, and further heating the hot water supplied from the hot water storage tank to a hot water supply terminal using a gas heater. For example, the hot water supply system disclosed in Patent Literature 1 (JP 2013-113495 A) performs a heating operation using the gas heater as well as boiling of water in a hot water storage tank using the heat pump heating unit when hot water in the hot water storage tank runs out. In this manner, supply of the hot water to the hot water supply terminal is secured even when the hot water in the hot water storage tank runs out.

SUMMARY OF THE INVENTION

<Technical Problem>

[0003] The heat pump heating unit is generally operated at a heating capability (frequency) that maximizes heat pump efficiency (COP) in accordance with an outside air temperature regardless of a required amount of heat. In other words, the heat pump heating unit is uniformly operated at the heating capability (frequency) that maximizes COP in both of a case where a sufficient amount of heat can be secured only by the boiling operation using the heat pump heating unit, and a case where heating by the gas heater is required due to a shortage of the amount of heat as a result of delivery of a large amount of hot water, for example.

[0004] Meanwhile, when COP of the heat pump heating unit is converted into primary energy efficiency and compared with primary energy efficiency of an auxiliary heating unit such as a gas heater, the efficiency of the heat pump heating unit is often higher than that of the auxiliary heating unit. Accordingly, when a shortage of the amount of heat occurs, i.e., hot water in the hot water storage tank runs out, for example, at the time of boiling by the heat pump heating unit having the heating capability described above, optimal overall energy efficiency of the system including the heat pump heating unit and the auxiliary heating unit is difficult to achieve in some cases by performing operation together with heating by the auxiliary heating unit.

[0005] An object of the present invention is to provide a hot water supply system including a heat pump heating unit and an auxiliary heating unit and capable of optimizing overall energy efficiency of the system.

<Solution to Problem>

[0006] A hot water supply system of the present invention includes a hot water storage tank that stores hot water, a hot water delivery unit that supplies the hot water from the hot water storage tank to a use side, a heat pump heating unit that boils the hot water in the hot water storage tank, and an auxiliary heating unit capable of heating the hot water supplied from the hot water storage tank to the hot water delivery unit. The hot water supply system is configured to perform a heat pump isolated operation that boils the hot water in the hot water storage tank using the heat pump heating unit, and an auxiliary heating combined operation that simultaneously performs boiling of the hot water in the hot water storage tank and heating of the hot water using the auxiliary heating unit when an amount of heat is insufficient only by the boiling of the hot water in the hot water storage tank using the heat pump heating unit. The heat pump isolated operation includes boiling in a first mode and boiling in a second mode having different heating capabilities. The heating capability of the boiling in the first mode is higher than the heating capability of the boiling in the second mode, and heat pump efficiency of the boiling in the first mode is lower than heat pump efficiency of the boiling in the second mode. In addition, the boiling in the first mode is performed in a predetermined condition where a shortage of the amount of heat is likely to be caused by the boiling in the second mode in a state where a large amount of delivery of the hot water is estimated or a large amount of the hot water is actually delivered.

[0007] According to this configuration, total energy efficiency of the entire hot water supply system can be optimized by reducing the proportion of the heating amount generated by the auxiliary heating unit in the heating amount of the entire system.

[0008] In the hot water supply system described above, the heating capability of the boiling in the first mode may be higher than a heating capability at which COP may be maximized at an outside air temperature at that time. In addition, primary energy efficiency of the boiling in the first mode may be equal to or higher than primary energy efficiency during isolated operation of the auxiliary heating unit.

[0009] This configuration reduces a decrease in the primary energy efficiency of the heat pump heating unit to efficiency lower than the primary energy efficiency of the auxiliary heating unit, thereby reducing a drop of the overall energy efficiency of the hot water supply system.

[0010] The hot water supply system described above may further include a hot water storage amount detection unit that detects a hot water storage amount in the hot water storage tank. The boiling in the second mode may be started when the hot water storage amount detected by the hot water storage amount detection unit becomes smaller than a first hot water storage amount. The boiling in the second mode may be switched to the boiling in the first mode when the hot water storage amount becomes a second hot water storage amount smaller than the first hot water storage amount.

[0011] This configuration can reduce operation of the auxiliary heating unit performed in accordance with a decrease in the amount of hot water in the hot water storage tank, thereby optimizing the overall energy efficiency of the hot water supply system.

[0012] The above hot water supply system may further include a bathtub 10a to which the hot water is supplied from the hot water delivery unit. The boiling in the first mode may be performed when a hot water filling instruction for supplying the hot water at a target temperature to the bathtub 10a is issued.

[0013] This configuration can reduce operation of the auxiliary heating unit performed in accordance with a decrease in the amount of hot water in the hot water storage tank as a result of delivery of a large amount of hot water during filling of hot water, thereby optimizing the overall energy efficiency of the hot water supply system.

[0014] The hot water supply system described above may further include: a hot water delivery amount detection unit that detects a hot water delivery amount supplied from the hot water storage tank to the hot water delivery unit; a history information storage unit that stores history information indicating a hot water delivery amount detected by the hot water delivery amount detection unit, and a hot water delivery time; and a hot water delivery prediction unit that predicts a scheduled hot water delivery amount and a scheduled hot water delivery time based on the history information stored in the history information storage unit. In this case, the boiling in the first mode is performed when delivery of the hot water not predicted by the hot water delivery prediction unit is executed at a time of operation of the heat pump heating unit for storing the scheduled hot water delivery amount predicted by the hot water delivery prediction unit in the hot water storage tank by the scheduled hot water delivery time.

[0015] This configuration can reduce operation of the auxiliary heating unit performed in accordance with a decrease in the amount of hot water in the hot water storage tank, thereby optimizing the overall energy efficiency of the hot water supply system.

[0016] The hot water supply system may further include: a hot water storage amount detection unit that detects a hot water storage amount in the hot water storage tank; a hot water delivery amount detection unit that detects a hot water delivery amount supplied from the hot water storage tank to the hot water delivery unit; a history information storage unit that stores history information indicating a hot water delivery amount detected by the hot water delivery amount detection unit, and a hot water delivery time; and a hot water delivery prediction unit that predicts a scheduled hot water delivery amount and a scheduled hot water delivery time based on the history information stored in the history information storage unit. In this case, the boiling in the first mode is performed when the scheduled hot water delivery amount is larger than a total value of the hot water storage amount detected by the hot water storage amount detection unit and a scheduled hot water storage amount at the scheduled hot water delivery time of an operation by the boiling in the second mode.

[0017] This configuration can reduce operation of the auxiliary heating unit performed in accordance with a decrease in the amount of hot water in the hot water storage tank, thereby optimizing the overall energy efficiency of the hot water supply system.

[0018] In the hot water supply system, the heat pump heating unit may include a refrigerant circuit through which a refrigerant circulates, the refrigerant circuit including a compressor, a radiator, an expansion mechanism, and an evaporator each connected to the refrigerant circuit. A frequency of the compressor in the boiling in the first mode may be higher than a frequency of the compressor in the boiling in the second mode at a same outside air temperature.

[0019] This configuration can produce a heating capability necessary for the boiling in the first mode by increasing the frequency of the compressor.

[0020] In the hot water supply system, the heat pump heating unit may include a refrigerant circuit through which a refrigerant circulates, the refrigerant circuit including a compressor, a heat source side heat exchanger, an expansion mechanism, and a usage-side heat exchanger each connected to the refrigerant circuit. The heat pump heating unit may further include a fan that feeds air to the heat source side heat exchanger to cause heat exchange. In this case, a number of revolutions of the fan in the boiling in the first mode may be larger than a number of revolutions of the fan in the boiling in the second mode at a same outside air temperature.

[0021] This configuration can produce a heating capability necessary for the boiling in the first mode by increasing the number of revolutions of the fan.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022]

FIG. 1 is a configuration diagram of a hot water supply system according to an embodiment of the present invention.

FIG. 2 is a configuration diagram of a control unit of the hot water supply system in FIG. 1.

FIG. 3 is a diagram showing a change in COP in accordance with a change in a heating capability of a heat pump unit.

FIG. 4 is a diagram showing a change in primary energy efficiency in accordance with the change in the heating capability of the heat pump unit.

FIG. 5 is a flowchart for describing an operation of the hot water supply system in FIG. 1.

FIG. 6 is a time chart for describing the operation of the hot water supply system in FIG. 1.

FIG. 7 is a flowchart for describing an operation of a

hot water supply system according to Modification A.
FIG. 8 is a flowchart for describing an operation of a hot water supply system according to Modification B.
FIG. 9 is a diagram showing a change in a usage charge per unit capability in accordance with a change in the heating capability of the heat pump unit.
FIG. 10 is a diagram showing a change in a carbon emission amount per unit capability in accordance with a change in the heating capability of the heat pump unit.

DESCRIPTION OF EMBODIMENTS

(1) Configuration of hot water supply system 1

[0023] FIG. 1 is a configuration diagram of a hot water supply system 1 according to an embodiment of the present invention. The hot water supply system 1 includes a heat pump unit 2 (heat pump heating unit), a hot water circuit unit 3 having a hot water storage tank 5, and a gas heater 6 (one example of auxiliary heating unit). The heat pump unit 2 generates hot water to be stored in the hot water storage tank 5. A hot water supply terminal 10 (one example of hot water delivery unit) delivers hot water from the hot water storage tank 5. The hot water in the hot water storage tank 5 is further heated by the gas heater 6 as needed before delivery.

(1-1) Configuration of heat pump unit 2

[0024] The heat pump unit 2 includes a refrigerant circuit 41 where a refrigerant circulates. The refrigerant circuit 41 is constituted by a compressor 11, an outdoor heat exchanger (heat source side heat exchanger) 12, an expansion valve (one example of expansion mechanism) 13, and a hot water supply heat exchanger (usage-side heat exchanger) 16 connected to each other via a refrigerant pipe 40. A fan 15 is disposed in such a position as to face the outdoor heat exchanger 12. An outside air temperature sensor 21 detects an outside air temperature.

[0025] In a boiling operation for storing hot water in the hot water storage tank 5, the refrigerant discharged from the compressor 11 sequentially flows to the hot water supply heat exchanger 16, the expansion valve 13, and the outdoor heat exchanger 12 as indicated by arrows R1 in FIG. 1, and returns to the compressor 11 after passing through the outdoor heat exchanger 12 to constitute a heating cycle. In this case, the hot water supply heat exchanger 16 functions as a condenser, while the outdoor heat exchanger 12 functions as an evaporator. In this boiling operation, the hot water for hot water supply is heated by heat exchange between the high-temperature refrigerant having entered from the discharge side of the compressor 11 and the hot water for hot water supply in the hot water supply heat exchanger 16.

(1-2) Configuration of hot water circuit unit 3

[0026] The hot water circuit unit 3 is connected to the hot water supply heat exchanger 16. The hot water circuit unit 3 is configured to circulate hot water by connecting the hot water storage tank 5, a pump 17, and the hot water supply heat exchanger 16 via a water pipe 45. The discharge side of the pump 17 of the hot water circuit unit 3 is connected to a hot water inlet of the hot water supply heat exchanger 16, and the suction side of the pump 17 is connected to one end of the hot water storage tank 5. A hot water outlet of the hot water supply heat exchanger 16 is connected to the other end of the hot water storage tank 5.

[0027] Hot water that exchanges heat with the refrigerant flowing through the hot water supply heat exchanger 16 circulates in the hot water circuit unit 3. Specifically, when the boiling operation is performed, hot water caused to flow from the hot water storage tank 5 by the pump 17 is supplied to the hot water supply heat exchanger 16. In addition, hot water heated by the hot water supply heat exchanger 16 is returned to the hot water storage tank 5.

[0028] A hot water delivery temperature sensor 22 is disposed in the vicinity of the hot water outlet of the hot water supply heat exchanger 16, and detects a temperature of the hot water flowing from the hot water supply heat exchanger 16. The hot water storage tank 5 includes a plurality of hot water storage temperature sensors 5a to 5d (hot water storage amount detection unit), and detects a hot water storage amount based on water temperatures detected by each of the hot water storage temperature sensors 5a to 5d. Note that the outside air temperature sensor 21, the hot water delivery temperature sensor 22, and the hot water storage temperature sensors 5a to 5d described above may be any sensors as long as the detected temperatures can be output to a control unit 30.

(1-3) Configuration of hot water supply terminal 10 and gas heater 6

[0029] Hot water in the hot water storage tank 5 of this configuration is delivered via the hot water supply terminal 10. The gas heater 6 is disposed between the hot water storage tank 5 and the hot water supply terminal 10, and has a heating unit 6a. The hot water storage tank 5, the gas heater 6, and the hot water supply terminal 10 are connected via a water pipe 47. The gas heater 6 is capable of heating the hot water supplied from the hot water storage tank 5 before the hot water is supplied to the hot water supply terminal 10. The hot water supply terminal 10 can supply the hot water in the hot water storage tank 5 for use by a user, and also supply the hot water to a bathtub 10a.

[0030] A flow rate sensor 23 (flow rate detection unit) is provided in the water pipe 46, and detects a flow rate of the hot water supplied from the hot water storage tank

5 to the hot water supply terminal 10. Alternatively, the flow rate sensor 23 may be provided in a water pipe other than the water pipe 46 as long as the amount of the hot water supplied from the hot water storage tank 5 can be detected.

[0031] As described above, the hot water supply system 1 includes the heat pump unit 2 (heat pump heating unit) capable of supplying hot water to the hot water storage tank 5, and the gas heater 6 (auxiliary heating unit) capable of heating hot water supplied from the hot water storage tank 5 to the hot water supply terminal 10. The hot water supply system 1 is capable of performing a boiling operation for storing hot water in the hot water storage tank 5 using the heat pump unit 2, and an additional heating operation for heating hot water supplied from the hot water storage tank 5 as necessary using the gas heater 6 at the time of supply of hot water from the hot water storage tank 5 to the hot water supply terminal 10. The operation performed by the hot water supply system 1 is classified into a heat pump isolated operation for performing only the boiling operation, an auxiliary heating isolated operation for performing only the additional heating operation, and an auxiliary heating combined operation for simultaneously performing both the boiling operation and the additional heating operation.

(1-4) Configuration of control unit 30 of hot water supply system 1

[0032] The control unit 30 of the hot water supply system 1 includes a CPU, a ROM, a RAM (none of them shown), and others. As shown in FIG. 2, the control unit 30 of the hot water supply system 1 includes a hot water runout determination unit 31, a COP curve storage unit 32, a COP curve calculation unit 33, an efficiency calculation unit 34a, a capability derivation unit 35, a boiling control unit 36, a hot water delivery control unit 37, a history information storage unit 38, and a hot water delivery prediction unit 39. The input side of the control unit 30 is connected to the hot water storage temperature sensors 5a to 5d attached to a side surface of the hot water storage tank 5, a remote controller 20, the outside air temperature sensor 21, the hot water delivery temperature sensor 22, and the flow rate sensor 23. The output side of the control unit 30 is connected to the compressor 11, the fan 15, the heating unit 6a, and an actuator such as the pump 17. An input received from the remote controller 20 is transmitted to each of the heat pump unit 2 and the hot water circuit unit 3.

[0033] The hot water runout determination unit 31 determines whether or not a hot water storage amount in the hot water storage tank 5 has decreased (the proportion of hot water in the hot water storage tank 5 has decreased) and the hot water has run out (whether the boiling operation needs to be performed). According to the present embodiment, the hot water runout determination unit 31 determines the need for the boiling operation to cope with runout of the hot water (a state that the hot water storage amount has become a predetermined value or smaller) caused by a decrease in the proportion of the hot water in the hot water storage tank 5 when the temperature detected by the hot water storage temperature sensor 5b attached to the side surface of the hot water storage tank 5 is lower than a hot water storage target temperature by a predetermined temperature or more. A hot water delivery target temperature is input from the user by operation of the remote controller 20.

[0034] The COP curve storage unit 32 stores a plurality of COP curves. The plurality of COP curves corresponds to various outside air temperatures and hot water delivery target temperatures. As shown in FIG. 3, each of the COP curves indicates a heating capability (compressor frequency) represented on the horizontal axis, and COP on the vertical axis to show the heating capability of the heat pump unit 2 and the COP at the corresponding heating capability. As shown in FIG. 3, the COP of the heat pump unit 2 has a maximum value b at a heating capability a1.

[0035] When the need for the boiling operation is determined, the COP curve calculation unit 33 calculates a COP curve based on the outside air temperature and the hot water delivery target temperature at that time. According to the present embodiment, the COP curve storage unit 32 stores a plurality of COP curves. Accordingly, the COP curve calculation unit 33 obtains a COP curve corresponding to the outside air temperature and the hot water delivery target temperature at that time from among the COP curves stored in the COP curve storage unit 32. The outside air temperature is a temperature detected by the outside air temperature sensor 21. The hot water delivery target temperature is a temperature input by the remote controller 20.

[0036] The efficiency calculation unit 34a calculates primary energy efficiency of the heat pump unit 2 based on the COP curve obtained by the COP curve calculation unit 33. According to the present embodiment, the efficiency calculation unit 34a uses a primary energy conversion coefficient of 0.369 for each COP curve to calculate the primary energy efficiency. Accordingly, as shown in FIG. 4, the primary energy efficiency curve calculated based on the COP curve indicates the heating capability of the heat pump unit 2, and the primary energy efficiency at the corresponding heating capability, on the horizontal axis representing the heating capability and the vertical axis representing the primary energy efficiency. As shown in FIG. 4, the curve of the primary energy efficiency calculated based on the COP curve has a maximum value c at the heating capability a1. In FIG. 4, the primary energy efficiency of the gas heater 6 is indicated as d.

[0037] The capability derivation unit 35 derives the heating capability of the heat pump unit 2 based on the COP curve in FIG. 3. The capability derivation unit 35 sets the heating capability of the boiling operation in accordance with an amount of water allowed to be boiled by a predetermined time described below and a predicted hot water delivery amount, or other operating conditions. The heating capability of the gas heater 6 during execution of the auxiliary heating combined operation is derived from a difference between the temperature of the hot water supplied from the hot water storage tank 5 and the temperature of the hot water obtained at the time of delivery of the hot water from the hot water supply terminal 10, and then based on an insufficient heating capability of the heat pump unit 2.

[0038] The boiling control unit 36 controls a frequency of the compressor 11, a number of revolutions of the pump 17, and a number of revolutions of the fan 15. Specifically, the boiling control unit 36 controls the frequency of the compressor 11 and the number of revolutions of the fan 15 during the boiling operation based on the heating capability of the heat pump unit 2 derived by the capability derivation unit 35. The boiling control unit 36 maintains a constant frequency of the compressor 11, and controls the number of revolutions of the pump 17 to obtain a hot water delivery target temperature.

[0039] The hot water delivery control unit 37 controls the heating unit 6a of the gas heater 6 during the additional heating operation performed at the time of delivery of hot water based on the heating capability of the gas heater 6 derived by the capability derivation unit 35.

[0040] The history information storage unit 38 stores a hot water delivery amount per unit time detected by the flow rate sensor 23 as history information in association with a measurement time. The history information storage unit 38 stores, as history information, a fluctuation tendency of the hot water delivery amount for each time zone in one day (or each day of the week), and a total hot water delivery amount, for example.

[0041] The hot water delivery prediction unit 39 analyzes, as a pattern, the time zone and the hot water delivery amount when a large amount of hot water is delivered for the user based on the history information stored in the history information storage unit 38 described above. The hot water delivery amount and the hot water delivery time are predicted based on this pattern of delivered hot water. The control unit 30 compares, at predetermined time intervals (e.g., at intervals of ten minutes), a hot water storage amount detected by the hot water storage temperature sensors 5a to 5d of the hot water storage tank 5 with a hot water delivery amount predicted by the hot water delivery prediction unit 38 within a predetermined time (e.g., two hours) from a current time. When the predicted hot water delivery amount is larger than the hot water storage amount herein, the control unit 30 instructs a start of the boiling operation.

(2) Description of heating operation by hot water supply system 1

[0042] As described above, the hot water supply system 1 is configured to perform the heat pump isolated operation for performing the boiling operation for the hot water storage tank 5 using only the heat pump unit 2, the auxiliary heating isolated operation for heating hot water supplied from the hot water storage tank 5 to the hot water supply terminal 10 using only the gas heater 6, and the auxiliary heating combined operation for simultaneously executing the boiling operation using the heat pump unit 2 and the additional heating operation using the gas heater 6.

[0043] The boiling operation is performed in a case where the hot water storage amount in the hot water storage tank 5 decreases, or where a large delivery amount of hot water is predicted by the hot water delivery prediction unit 39. The heat pump isolated operation of the boiling operation includes an operation in a normal boiling mode described below (one example of boiling in second mode), and an operation in a rapid boiling mode (one example of boiling in first mode). The auxiliary heating combined operation is performed in a case where the amount of heat is insufficient for supplying hot water at a desired temperature to the user even after the boiling operation, such as a case where a large amount of hot water exceeding the hot water storage amount in the hot water storage tank 5 is delivered. In this case, the additional heating operation is performed for further heating hot water supplied from the hot water storage tank 5 using the heating unit 6a in parallel with the boiling operation. In this manner, hot water at a desired temperature is supplied to the user even when the hot water storage amount in the hot water storage tank 5 decreases.

(2-1) Description of normal boiling mode (example of boiling in second mode)

[0044] According to the present embodiment, the operation in the normal boiling mode is performed when the hot water storage amount in the hot water storage tank 5 becomes a predetermined value (e.g., 40 L for a tank capacity of 100 L of the hot water storage tank 5) or smaller, or in a night time zone in which an inexpensive electricity charge is set without estimation of delivery of hot water for a long time. The operation in the normal boiling mode is also performed when the current hot water storage amount falls below the hot water delivery amount predicted by the hot water delivery prediction unit 38 within two hours from the current time.

[0045] When the operation in the normal boiling mode is performed, the capability derivation unit 35 derives a1 as the heating capability of the heat pump unit 2 to produce a heating capability maximizing COP in the COP curve in FIG. 3. Thereafter, the boiling control unit 36 controls the frequency of the compressor 11 and the number of revolutions of the pump 17 until the hot water delivery temperature detected by the hot water delivery temperature sensor 22 reaches a hot water delivery target temperature based on the heating capability a1. During the operation in the normal boiling mode, the heat pump unit operates at the capability maximizing the heat pump efficiency.

(2-2) Description of rapid boiling mode (example of boiling in first mode)

[0046] On the other hand, the operation in the rapid boiling mode is performed when the hot water storage amount needs to be rapidly increased. According to the present embodiment, the operation in the rapid boiling mode is executed when a sufficient hot water storage amount is difficult to generate by the operation in the normal boiling mode. For example, the operation in the rapid boiling mode is executed when the boiling is not completed by a predetermined time by the operation in the normal boiling mode due to delivery of hot water not predicted by the hot water delivery prediction unit 39 after a start of the operation in the normal boiling mode performed in response to a state where the current hot water storage amount falls below a scheduled hot water delivery amount within two hours from the current time.

[0047] When the operation in the rapid boiling mode is performed, the capability derivation unit 35 derives a heating capability of the heat pump unit 2 at which the primary energy efficiency of the heat pump unit 2 is equalized with the primary energy efficiency of the gas heater 6. Accordingly, as shown in FIG. 4, the capability derivation unit 35 derives a2 as the heating capability of the heat pump unit 2 at which the primary energy efficiency of the heat pump unit 2 is equalized with the primary energy efficiency d of the gas heater 6 based on a curve of the primary energy efficiency calculated based on the COP curve. Thereafter, the boiling control unit 36 controls the frequency of the compressor 11 and the number of revolutions of the pump 17 such that the hot water delivery temperature detected by the hot water delivery temperature sensor 22 becomes a hot water delivery target temperature based on the heating capability a2.

[0048] After the hot water delivery temperature detected by the hot water delivery temperature sensor 22 reaches the hot water delivery target temperature, the compressor 11 is so controlled as to operate at a frequency (frequency corresponding to the heating capability a2) higher than a frequency (frequency corresponding to the heating capability a1) during operation in the normal boiling mode. In addition, the pump 17 is so controlled as to operate at a number of revolutions larger than the number of revolutions of the pump 17 during operation in the normal boiling mode. In this manner, the pump 17 is driven at a larger number of revolutions during the operation in the rapid boiling mode. Accordingly, the flow rate of hot water circulating through the hot water circuit unit 3 increases, whereby the amount of hot water stored in the hot water storage tank 5 per unit time can increase in comparison with that amount during operation in the normal boiling mode while maintaining a constant hot water delivery temperature.

(2-3) Description of auxiliary heating combined operation

[0049] According to the present embodiment, the auxiliary heating combined operation is performed when the temperature of hot water supplied from the hot water storage tank 5 to the hot water supply terminal 10 becomes lower than the temperature desired by the user with a shortage of the hot water storage amount in the hot water storage tank 5.

[0050] When the auxiliary heating combined operation is performed, the capability derivation unit 35 initially derives a1 as the heating capability of the heat pump unit 2 to produce a heating capability maximizing COP in the COP curve in FIG. 3. Thereafter, the boiling control unit 36 controls the frequency of the compressor 11 and the number of revolutions of the pump 17 such that the hot water delivery temperature detected by the hot water delivery temperature sensor 22 becomes a hot water delivery target temperature based on the heating capability a1. The heating capability of the gas heater 6 is derived based on the insufficient heating capability of the heat pump unit 2 after the heating capability of the heat pump unit 2 is derived. Thereafter, the gas heater 6 is operated by the hot water delivery control unit 37. In the auxiliary heating combined operation, the heat pump unit 2 is also operated at a capability maximizing heat pump efficiency, similarly to the operation in the normal boiling mode.

(3) Description of heat pump isolated operation with reference to flowchart

[0051] An operation of the hot water supply system 1 according to the present embodiment will be described with reference to FIG. 5. The flowchart in FIG. 5 describes a flow of a process of the heat pump isolated operation performed by the control unit 30. In the description, S represents a step, and a number following S represents a step number.

[0052] In step S1, it is determined whether a hot water storage amount in the hot water storage tank 5 is appropriate for the additional boiling operation based on a temperature detected by the hot water storage temperature sensor 5d provided on a bottom of the side surface of the hot water storage tank 5. When the temperature of the hot water storage temperature sensor 5d is lower than x degrees (e.g., 60 degrees), it is determined that additional boiling is allowed to be performed.

[0053] In subsequent step S2, the current hot water storage amount detected by the hot water storage temperature sensors 5a to 5d of the hot water storage tank 5 is compared with a scheduled hot water delivery amount predicted by the hot water delivery prediction unit 39 within two hours from the current time. The scheduled hot water delivery amount is calculated from a water supply temperature at the current time, and a hot water supply set temperature or hot water filling set temperature set by the user using the remote controller 20. When the current hot water storage amount is smaller than the scheduled hot water delivery amount within two hours herein, the control unit 30 stores a time T as a time two hours after the current time, and the scheduled hot water delivery amount (step S3), and starts the operation in the normal boiling mode using the heat pump unit 2 (step S4). The capability derivation unit 35 derives a1 as the heating capability of the heat pump unit 2 to produce a heating capability maximizing COP in the COP curve. Thereafter, the boiling control unit 36 performs the boiling operation while controlling the frequency of the compressor 11 and the number of revolutions of the pump 17 in such a manner as to produce the heating capability a1. On the other hand, when the current hot water storage amount is larger than the scheduled hot water delivery amount within two hours in step S2, the scheduled hot water delivery amount within two hours from the current time is considered to be sufficiently covered by the current hot water storage amount. Accordingly, the process returns to step S1 and continues determination as to whether additional boiling operation is allowed to be performed.

[0054] When the operation in the normal boiling mode is started in step S4, the flow rate sensor 23 checks whether or not hot water is delivered from the hot water supply terminal 10 in step S5. When no hot water is delivered, the operation in the normal boiling mode is continued (step S6), and it is determined whether the additional boiling operation is allowed for the hot water storage amount in the hot water storage tank 5 (step S7). When the temperature detected by the hot water storage temperature sensor 5d is 60 degrees or higher with determination that the additional boiling is not allowed, the boiling operation is terminated. When the temperature detected by the hot water storage temperature sensor 5d is lower than 60 degrees with determination that the additional boiling is allowed, the process proceeds to step S8. In this step, the scheduled hot water delivery amount within two hours is compared with the current hot water storage amount. When the current hot water storage amount is larger than the scheduled hot water delivery amount within two hours in step S8, the boiling operation is terminated. When the current hot water storage amount is smaller than the scheduled hot water delivery amount within two hours, the process returns to step S5 to check whether or not hot water is delivered.

[0055] When hot water is delivered in step S5, the process further proceeds to step S9. In step S9, it is checked whether or not the predicted hot water delivery amount until the time T stored in step S3 can be generated by normal boiling. In other words, a current insufficient hot water amount is calculated and compared with a water amount allowed to be boiled by the operation in the normal boiling mode. The insufficient hot water amount (predicted hot water delivery amount until the time T) is calculated based on the water supply temperature, and the hot water supply set temperature or the hot water filling set temperature set by the user using the remote controller 20. When the current insufficient hot water amount is smaller than the water amount allowed to be boiled by the operation in the normal boiling mode, the process proceeds to step S6. In this case, the boiling operation by the operation in the normal boiling mode is continued, and determinations in foregoing steps S7 to S8 are made. On the other hand, when the current insufficient hot water amount is larger than the water amount allowed to be boiled in the normal boiling mode, it is predicted that the hot water storage amount becomes insufficient at the time T. In this case, the operation is switched to the boiling operation by the operation in the rapid boiling mode (step S10). In this case, the capability derivation unit 35 designates a2 as the heating capability of the heat pump unit 2. The boiling control unit 36 performs the boiling operation while controlling the frequency of the compressor 11 and the number of revolutions of the pump 17 in such a manner as to produce the heating capability a2.

[0056] After the operation in the rapid boiling mode is started, whether the additional boiling operation is allowed is checked based on the temperature detected by the hot water storage temperature sensor 5d (step S11). When the temperature detected by the hot water storage temperature sensor 5d is 60 degrees or higher, the boiling operation is terminated. When the temperature detected by the hot water storage temperature sensor 5d is lower than 60 degrees, the process proceeds to step S12. In this step, the scheduled hot water delivery amount within two hours is compared with the current hot water storage amount. When the scheduled hot water delivery amount within two hours is smaller than the current hot water storage amount, it is considered that a sufficient hot water storage amount has been generated. Accordingly, the boiling operation is terminated. When the scheduled hot water delivery amount within two hours is larger than the current hot water storage amount, the process returns to step S5. In this case, the current insufficient hot water amount is again compared with the water amount allowed to be boiled by the operation in the normal boiling mode.

(4) Description of heat pump isolated operation with reference to time chart

[0057] Described next will be the operation of the hot water supply system 1 described with reference to the flowchart of FIG. 5 and performed in a hot water delivery state in FIG. 6. FIG. 6 is a diagram showing an example of a hot water delivery situation and a boiling situation in a time zone from the evening to the night, as a period in which the boiling operation is generally more frequently performed due to a large amount of hot water delivery in one day. The vertical axis represents the hot water storage amount in the hot water storage tank 5 (left axis) and the hot water delivery amount (right axis), while the horizontal axis represents time. A solid line indicates a change in the actual hot water storage amount, while a broken line indicates a change in the hot water storage amount predicted at a time t0.

[0058] The hot water storage tank 5 can store 100 L of hot water in total. The heat pump unit 2 can boil 30 L/H of water by the operation in the normal boiling mode, and 45 L/H of water in the operation in the rapid boiling mode. The hot water delivery amount and the hot water storage amount are checked every ten minutes. At the time t0 (18:00), the hot water storage amount in the hot water storage tank 5 is 50 L. The hot water delivery prediction unit 39 predicts 10 L of hot water delivery from a time t4 to a time t5 (19: 10 to 19: 30), and 97.5L of hot water delivery (not shown) from a time t7 (20:00). It is assumed that hot water delivery is not predicted at a later time.

[0059] At the time t0, whether the additional boiling operation is allowed for the hot water storage tank 5 is determined as shown in step S1 shown in the flowchart in FIG. 5. At the time t0, the temperature of the hot water storage temperature sensor 5d is lower than 60 degrees, and it is determined that additional boiling is allowed to be performed. Accordingly, the process proceeds to step S2, and the current hot water storage amount (50 L) is compared with the scheduled hot water delivery amount predicted by the hot water delivery prediction unit 39 within two hours from the current time (step S2). As described above, it is predicted herein that hot delivery is executed twice, i.e., 10 L of hot water delivery and 97.5 L of hot water delivery within two hours, i.e., by 20:00 (time t7), whereby 107.5 L of hot water delivery in total is predicted. In this case, the current hot water storage amount is smaller than the scheduled hot water delivery amount until time t7. Accordingly, the time t7 and 107.5 L as the scheduled hot water delivery amount are stored (step S3), and the operation in the normal boiling mode is started (step S4).

[0060] After the start of the operation in the normal boiling mode, the flow rate sensor 23 checks whether or not hot water is delivered from the hot water supply terminal 10 (step S5). No hot water is delivered until the time t1, whereby the boiling operation by the operation in the normal boiling mode is continued (step S6). In the period from the time t0 to the time t1, the operation in the normal boiling mode is continued, and determinations from S5 to S8 are repeated.

[0061] Subsequently, delivery of hot water is confirmed at the time t1 (18:40) (step S5). In this case, the process proceeds to step S9, where it is checked whether or not the predicted hot water delivery amount (107.5 L) can be generated by the time t7 (20:00) by the boiling operation as the operation in the normal boiling mode. The hot water storage amount at the time t1 is 62.5 L, whereby an insufficient hot water amount is 45 L. The water amount allowed to be boiled by the operation in the normal boiling mode until the time t7 is 40 L (30 L/H × one hour and 20 minutes). In other words, the current insufficient hot water amount is larger than the water amount allowed to be boiled by the operation in the normal boiling mode, whereby the operation is switched to the operation in the rapid boiling mode (step S10).

[0062] After the operation in the rapid boiling mode is started, determinations in steps S11 and S12 in the flowchart in FIG. 5 are made. However, the scheduled hot water delivery amount within two hours (107.5 L) is larger than the current hot water storage amount (62.5 L), whereby the operation in the rapid boiling mode is continued. At the times t2 to t5, steps S9 to S12 are similarly repeated, and the operation in the rapid boiling mode is continued.

[0063] At the time t6 (19:50), the insufficient hot water amount becomes 5 L in step S9, and the water amount allowed to be boiled by the operation in the normal boiling mode until the time t7 also becomes 5 L (30 L/H × ten minutes). In other words, the current insufficient hot water amount becomes equal to or smaller than the water amount allowed to be boiled by the operation in the normal boiling mode. In this case, it is predicted that a sufficient hot water storage amount can be generated by the operation in the normal boiling mode. Accordingly, the process proceeds to step S6, and the operation in the rapid boiling mode is switched to the operation in the normal boiling mode. Subsequently, the process proceeds to step S7 and step S8, but the operation in the normal boiling mode is continued.

[0064] At the time t7 (20:00), no delivery of hot water is confirmed in step S5, and the operation in the normal boiling mode continues (step S6). Subsequently, it is determined that additional boiling is allowed to be performed in step S7. However, the hot water storage amount becomes 97.5 L for the scheduled hot water delivery amount of 97.5 L within two hours (until 22:00) (hot water is delivered only once at 20:00) in step S8. In this case, the hot water storage amount is equal to or larger than the scheduled hot water delivery amount, whereby the boiling operation (operation in the normal boiling mode) is terminated.

[0065] As described above, according to the hot water supply system 1 of the present embodiment, the rapid boiling operation is performed on condition that a sufficient hot water storage amount is not generated by the boiling operation in the normal boiling operation in a state that the current hot water storage amount is smaller than the hot water delivery amount predicted by the hot water delivery prediction unit 39 within a predetermined time from the current time, as an example of a condition where a shortage of the amount of heat is likely to be produced by the operation in the normal boiling mode with an estimation of delivery of a large amount of hot water or actual delivery of a large amount of hot water. In this case, the heating ratio of the auxiliary heating combined operation can be reduced by performing rapid boiling by the operation in the rapid boiling mode. Accordingly, the total energy efficiency of the overall hot water supply system 1 improves.

(5) Modifications

[0066] Various modifications will be hereinafter described. Configurations of the following modifications are similar to the corresponding configurations of the embodiment described above except for the configurations particularly noted. Accordingly, description of the similar configurations will be omitted, and only parts different from the corresponding parts of the embodiment described above will be described below.

(5-1) Modification A

[0067] In Modification A, the operation in the rapid boiling mode is performed in a case where the hot water storage amount further decreases even after a start of boiling by the operation in the normal boiling mode based on determination of runout, i.e., determination that the hot water storage amount in the hot water storage tank 5 is smaller than a predetermined value, as an example of a condition where a shortage of the amount of heat is likely to be produced by the operation in the normal boiling mode with an estimation of delivery of a large amount of hot water or actual delivery of a large amount of hot water. The hot water storage amount is checked based on the temperatures detected by the hot water storage temperature sensors 5a to 5d attached to the side surface of the hot water storage tank 5. According to this example, the operation in the rapid boiling mode is performed in the following case. The operation in the normal boiling mode is started when the hot water storage amount becomes equal to or smaller than a first hot water storage amount (e.g., 40 L for 100 L which is the tank capacity of the hot water storage tank 5) with a decrease in the temperature detected by the hot water storage temperature sensor 5b to a temperature lower than the hot water target storage temperature by a predetermined temperature or more. Thereafter, the operation in the rapid boiling mode is performed when the hot water storage amount becomes a second hot water storage amount (e.g., 20 L) smaller than the first hot water storage amount with a decrease in the temperature of the hot water storage temperature sensor 5a provided above the hot water storage temperature sensor 5b on the hot water storage tank 5 to a temperature lower than the hot water storage target temperature by a predetermined temperature or more.

[0068] FIG. 7 is a flowchart of the present modification. In step S101, it is determined whether the temperature detected by the hot water storage temperature sensor 5b is lower than y degrees (e.g., 60 degrees). When the temperature detected by the hot water storage temperature sensor 5b is lower than y degrees, it is determined that the hot water storage amount is a predetermined value (first predetermined value, such as 40 L) or smaller, in a state of runout of hot water. In this case, the operation in the normal boiling mode is started (step S102). After the start of the operation in the normal boiling mode, whether hot water is delivered from the hot water supply terminal 10 is checked (step S103). When no hot water is delivered, the operation in the normal boiling mode is performed while repeating determinations in step S103 and step S105 until the temperature detected by the hot water storage temperature sensor 5b becomes y degrees or higher. When the temperature detected by the hot water storage temperature sensor 5b becomes equal to or higher than y degrees, it is determined that the hot water storage amount in the hot water storage tank 5 is sufficient. In this case, the boiling operation is terminated.

[0069] On the other hand, when delivery of the hot water is confirmed in step S103, the process proceeds to step S104. In this step, it is determined whether the temperature detected by the hot water storage temperature sensor 5a disposed above the hot water storage temperature sensor 5b on the hot water storage tank 5 is lower than z degrees (e.g., 60 degrees). It is determined herein whether the hot water storage amount reaches a second predetermined value (e.g., 20 L) which is smaller than the first predetermined value based on which runout of hot water has been determined. When the detected temperature is z degrees or higher, the process proceeds to step 105. In this step, the operation in the normal boiling mode is performed while repeating determinations in step S103 and step S105 until the temperature detected by the hot water storage temperature sensor 5b becomes y degrees or higher.

[0070] When the detected temperature is lower than z degrees, the hot water storage amount is the second predetermined value or smaller. In this case, it is determined that the increase in the hot water storage amount produced by the operation in the normal boiling mode is insufficient. Accordingly, the operation in the rapid boiling mode is started (step S106). After the start of the operation in the rapid boiling mode, the temperature detected by the hot water storage temperature sensor 5a is measured (step S107). The operation in the rapid boiling mode is continued until the detected temperature becomes z degrees or higher. When the detected temperature becomes equal to or higher than z degrees, the operation is switched to the operation in the normal boiling mode (step S108). Thereafter, the boiling operation is continued. Subsequently, it is checked whether or not the runout of hot water is continuing based on the temperature detected by the hot water storage temperature sensor 5b. When the runout state of hot water is cancelled with the detected temperature of y degrees or higher, the boiling operation is terminated.

[0071] According to this configuration, the frequency of execution of the auxiliary heating combined operation can be reduced even when the hot water delivery pattern cannot be analyzed using the hot water delivery prediction unit 39 in the absence of the history information accumulated in the history information storage unit 38, such as a case immediately after the power source is turned on. Accordingly, energy efficiency of the overall hot water supply system 1 improves. In addition, the auxiliary heating combined operation is predicted based on the hot water storage amount obtained by the hot water storage temperature sensors 5a to 5d provided on the hot water storage tank 5. Accordingly, energy efficiency of the overall hot water supply system 1 improves by simple control.

(5-2) Modification B

[0072] In modification B, the operation in the rapid boiling mode is performed in a case where a hot water filling instruction for supplying hot water at a target temperature to the bathtub 10a has been issued from the user using the remote controller 20, as an example of a condition where a shortage of the amount of heat is likely to be produced by boiling in the normal boiling operation with an estimation of delivery of a large amount of hot water or actual delivery of a large amount of hot water.

[0073] FIG. 8 is a flowchart of the present modification. In step S201, whether or not a hot water filling instruction has been issued is checked. When the issue of the hot water filling instruction is confirmed, the process proceeds to step S202 to start measurement of the timer T1 of the control unit 30. In this case, checking of the timer T1 continues until the timer T1 reaches α minutes (e.g., five minutes) in step S203. When the timer T1 reaches α minutes, the timer T1 is reset (step S204). Thereafter, whether filling of hot water is continuing is checked (step S205). When the hot water filling instruction is not continuing at this time, the process returns to step S201 and waits until a next hot water filling instruction is issued. When the hot water filling instruction is continuing, the boiling operation in the rapid boiling mode is started (step S206). It is estimated that water has been supplied to a lower part of the hot water storage tank 5 with an elapse of a predetermined time counted by the timer T1 from reception of the hot water filling instruction to the start of the boiling operation.

[0074] When the operation in the rapid boiling mode is started, it is checked whether filling of hot water is completed (step S207). Completion of filling of hot water is determined based on determination that the amount of hot water supplied to the bathtub 10a has reached a hot water set amount for filling, or on a termination instruction from the remote controller 20. When it is determined in step S207 that filling of hot water has been completed, measurement with the timer T2 starts (step S208). The operation in the rapid boiling mode continues while repeating determinations in steps S209 and S210 until the temperature detected by the hot water storage temperature sensor 5d provided on the bottom of the side surface of the hot water storage tank 5 becomes x degrees (e.g., 60 degrees) or higher (step S209), or until the measurement time of the timer T2 reaches β minutes (e.g., 20 minutes) (step S210). When the temperature detected by the hot water storage temperature sensor 5d becomes equal to or higher than x degrees, or in a case of an elapse of β minutes, the timer T2 is reset (step S211) with termination of the boiling operation.

[0075] According to this configuration, the frequency of execution of the auxiliary heating combined operation can be reduced even when the hot water delivery pattern cannot be analyzed using the hot water delivery prediction unit 39 in the absence of the history information accumulated in the history information storage unit 38, such as a case immediately after the power source is turned on. Accordingly, energy efficiency of the overall hot water supply system 1 improves. In particular, when the capacity of the hot water storage tank 5 is relatively small, it is highly probable that hot water in the hot water storage tank 5 runs out by filling of hot water, and that the gas heater (auxiliary heating unit) 6 needs to be operated. In this case, the rapid boiling can be started in an earliest possible stage by starting the operation in the rapid boiling mode at the time of an issue of the hot water filling instruction. Accordingly, the frequency of execution of the auxiliary heating combined operation is reduced, and energy efficiency of the overall hot water supply system 1 improves. After completion of filling of hot water, bathing is predicted. Accordingly, delivery of a large amount of hot water using a shower is predicted. By continuously performing the operation in the rapid boiling mode, the frequency of execution of the auxiliary heating combined operation can be reduced even in a case where delivery of a large amount of hot water is predicted after completion of filling of hot water. Accordingly, energy efficiency of the overall hot water supply system 1 improves.

[0076] In the present modification, the operation in the rapid boiling mode is started α minutes after reception of the hot water filling instruction. Alternatively, the operation in the rapid boiling mode may be started immediately after reception of the instruction. When the operation in the rapid boiling mode is started immediately after reception of the instruction, a larger amount of water can be boiled. As a result, the frequency of execution of the auxiliary heating combined operation can be reduced.

(5-3) Modification C

[0077] According to the present embodiment, whether the predicted hot water delivery amount until the time T is allowed to be generated by the operation in the normal boiling mode is checked when hot water is delivered during the operation in the normal boiling mode. Alternatively, whether the water can be boiled by the operation in the normal boiling mode may be checked when the outside air temperature detected by the outside air temperature sensor 21 becomes a predetermined temperature or lower, or falls by a predetermined temperature or more, rather than at the time of actual delivery of hot water. In this manner, the frequency of execution of the auxiliary heating combined operation can be reduced even when the amount of water allowed to be boiled by the operation in the normal boiling mode decreases as a result of a drop of the outside air temperature during the operation in the normal boiling mode. Accordingly, energy efficiency of the overall hot water supply system 1 improves.

[0078] In addition, for example, whether boiling can be performed by the operation in the normal boiling mode may be checked when the temperature of water to be mixed (water supply temperature) at the time of supply of hot water from the hot water storage tank 5 to the hot water supply terminal 10 becomes a predetermined temperature or lower, or drops by a predetermined temperature or more, rather than actual delivery of hot water. Alternatively, whether the water can be boiled by the operation in the normal boiling mode may be checked when the hot water supply set temperature or the hot water filling set temperature set by the user becomes a predetermined temperature or higher, or increases by a predetermined temperature or more. In this manner, the frequency of execution of the auxiliary heating combined operation can be reduced even when the predicted hot water delivery amount required by a predetermined time T increases during the operation in the normal boiling mode. Accordingly, energy efficiency of the overall hot water supply system 1 improves.

(5-4) Modification D

[0079] According to the embodiment described above, the efficiency calculation unit 34a derives the primary energy efficiency of the heat pump unit 2 based on the COP curve obtained by the COP curve calculation unit 33, and calculates the heating capability of the operation in the rapid boiling mode based on a comparison between the primary energy efficiency of the heat pump unit 2 and the primary energy efficiency of the gas heater 6. Alternatively, a usage charge of the heat pump unit 2 may be calculated based on the COP curve obtained by the COP curve calculation unit 33, and compared with a usage charge of the gas heater 6 to derive the heating capability of the operation in the rapid boiling mode.

[0080] FIG. 9 shows a relationship between the heating capability (horizontal axis) and the usage charge per unit heating capability (vertical axis) for the heat pump unit 2 and the gas heater 6. In Modification E, the control unit 30 includes a usage charge calculation unit 34b. The usage charge calculation unit 34b calculates a usage charge per unit heating capability based on the COP curve obtained by the COP curve calculation unit 33. Each usage charge is calculated by multiplying a consumption per unit time by a unit price of the usage charge. The power consumption of the heat pump unit 2 is calculated by dividing the heating capability by COP. Accordingly, as shown in FIG. 9, the usage charge per unit capability varies in accordance with the heating capability, and becomes a minimum value e at the heating capability a1. On the other hand, the usage charge per unit capability of the gas heater 6 is a constant usage charge f regardless of the heating capability.

[0081] When the operation in the normal boiling mode is performed, the capability derivation unit 35 derives a1 as the heating capability of the heat pump unit 2 to produce a heating capability maximizing COP in the COP curve in FIG. 3. Thereafter, the boiling control unit 36 controls the frequency of the compressor 11 and the number of revolutions of the pump 17 until the hot water delivery temperature detected by the hot water delivery temperature sensor 22 reaches a hot water delivery target temperature based on the heating capability a1. In other words, during the operation in the normal boiling mode, the heat pump unit 2 operates at the capability maximizing heat pump efficiency.

[0082] On the other hand, when the operation in the rapid boiling mode is performed, the capability derivation unit 35 derives a heating capability of the heat pump unit 2 at which the usage charge of the heat pump unit 2 is equalized with the usage charge of the gas heater 6. Accordingly, as shown in FIG. 9, the capability derivation unit 35 derives, based on a usage charge curve calculated based on the COP curve, a heating capability a3 of the heat pump unit 2 at which the usage charge of the heat pump unit 2 is equalized with the usage charge f of the gas heater 6. Thereafter, the boiling control unit 36 controls the frequency of the compressor 11 and the number of revolutions of the pump 17 based on the heating capability a3 until the hot water delivery temperature detected by the hot water delivery temperature sensor 22 reaches a hot water delivery target temperature.

[0083] This configuration can reduce a rise of the usage charge of the heat pump unit 2 from the usage charge of the gas heater 6, thereby reducing a rise of the usage charge of the overall hot water supply system 1.

(5-5) Modification E

[0084] In addition, for example, a carbon emission amount of the heat pump unit 2 may be calculated based on the COP curve obtained by the COP curve calculation unit 33, and compared with a carbon emission amount of the gas heater 6 to derive the heating capability of the operation in the rapid boiling mode.

[0085] FIG. 10 shows a relationship between the heating capability (horizontal axis) and the carbon emission amount per unit heating capability (vertical axis) for the heat pump unit 2 and the gas heater 6. According to Modification F, the control unit 30 includes a carbon emission amount calculation unit 34c. The carbon emission amount calculation unit 34c calculates a carbon emission amount per unit heating capability based on the COP curve obtained by the COP curve calculation unit 33. Each carbon emission amount is obtained by dividing a carbon dioxide emission coefficient per unit capability by device efficiency. The heat pump unit 2 is driven by electric power. Accordingly, a carbon emission amount per unit capability of the heat pump unit 2 is calculated by dividing a carbon dioxide emission amount per unit capability during power generation by COP. As shown in FIG. 10, the carbon emission amount per unit capability varies in accordance with the heating capability, and becomes a minimum value g at the heating capability a1. On the other hand, the carbon emission amount per unit capability of the gas heater 6 is a constant carbon emission amount h regardless of the heating capability.

[0086] When the operation in the normal boiling mode is performed, the capability derivation unit 35 derives a1 as the heating capability of the heat pump unit 2 to produce a heating capability maximizing COP in the COP curve in FIG. 3. Thereafter, the boiling control unit 36 controls the frequency of the compressor 11 and the number of revolutions of the pump 17 until the hot water delivery temperature detected by the hot water delivery temperature sensor 22 reaches a hot water delivery target temperature based on the heating capability a1. In other words, during the operation in the normal boiling mode, the heat pump unit 2 operates at the capability maximizing heat pump efficiency.

[0087] On the other hand, when the operation in the rapid boiling mode is performed, the capability derivation unit 35 derives a heating capability of the heat pump unit 2 at which the carbon emission amount of the heat pump unit 2 is equalized with the carbon emission amount of the gas heater 6. Accordingly, as shown in FIG. 10, the capability derivation unit 35 derives, based on a carbon emission amount curve calculated based on the COP curve, a heating capability a4 of the heat pump unit 2 at which the carbon emission amount of the heat pump unit 2 is equalized with the carbon emission amount h of the gas heater 6. Thereafter, the boiling control unit 36 controls the frequency of the compressor 11 and the number of revolutions of the pump 17 based on the heating capability a4 until the hot water delivery temperature detected by the hot water delivery temperature sensor 22 reaches a hot water delivery target temperature.

[0088] This configuration can reduce a rise of the carbon emission amount of the heat pump unit 2 from the carbon emission amount of the gas heater 6, thereby reducing a rise of the carbon emission amount of the overall hot water supply system 1.

(5-6) Modification F

[0089] According to the embodiment described above, the heating capability of the heat pump unit 2 is derived such that the primary energy efficiency at the heating capability (a2) in the operation in the rapid boiling mode is equalized with the primary energy efficiency d of the gas heater 6. However, the setting of the heating capability is not limited to this manner of setting. Various settings may be adopted as long as such conditions that the heating capability of the heat pump unit 2 during the operation in the rapid boiling mode is higher than the heating capability (a1) during the operation in the normal boiling mode, and that the heat pump efficiency of the heat pump unit 2 during the operation in the rapid boiling mode is lower than the heat pump efficiency of the heat pump unit 2 during the operation in the normal boiling mode are met in a state that the outside air temperature is equalized.

[0090] Similarly, according to Modification D and Modification F described above, the heating capability of the heat pump unit 2 is derived such that the usage charge per unit capability or the carbon emission amount per unit capability at the heating capability (a3 or a4) of the heat pump unit 2 during the operation in the rapid boiling mode is equalized with those of the gas heater 6. However, the setting of the heating capability is not limited to this manner of setting. Various settings may be adopted as long as such conditions that the heating capability of the heat pump unit 2 during the operation in the rapid boiling mode is higher than the heating capability (a1) during the operation in the normal boiling mode, and that the heat pump efficiency of the heat pump unit 2 during the operation in the rapid boiling mode is higher than the heat pump efficiency of the heat pump unit 2 during the operation in the normal boiling mode are met in a state that the outside air temperature is equalized.

[0091] Concerning Modification D, it is sufficient if the heating capability in the rapid boiling mode is higher than the heating capability at which COP is maximized at the outside air temperature at that time, and if the usage charge per unit capability in the rapid boiling mode is equal to or lower than the usage charge per unit capability of the gas heater 6. In addition, concerning Modification E, it is sufficient if the heating capability in the rapid boiling mode is higher than the heating capability at which COP is maximized at the outside air temperature at that time, and if the carbon emission amount per unit capability in the rapid boiling mode is equal to or lower than the carbon emission amount per unit capability of the gas heater 6.

[0092] In addition, concerning the heating capability during the operation in the normal boiling mode, a1 is derived as the heating capability of the heat pump unit 2 to produce the heating capability maximizing COP in the COP curve. However, various settings may be established within a range where the heating capability during the operation in the normal boiling mode produces relatively high COP.

(5-7) Modification G

[0093] According to the embodiment described above, the boiling control unit 36 controls the frequency of the compressor 11 based on the heating capability a2 until the hot water delivery temperature detected by the hot water delivery temperature sensor 22 reaches the hot water delivery target temperature in the operation in the rapid boiling mode. However, for setting the heating capability, instead of or in addition to this method, the boiling control unit 36 may control the number of revolutions of the fan 15 disposed at a position facing the outdoor heat exchanger 12 such that the hot water delivery temperature detected by the hot water delivery temperature sensor 22 becomes the hot water delivery target temperature based on the heating capability a2.

[0094] In this case, after the hot water delivery temperature detected by the hot water delivery temperature sensor 22 reaches the hot water delivery target temperature, the fan 15 is controlled at the number of revolutions (number of revolutions based on the heating capability a2) larger than the number of revolutions (number of revolutions based on the heating capability a1) during the operation in the normal boiling mode. In addition, the pump 17 is controlled at the number of revolutions larger than the number of revolutions of the pump 17 during the operation in the normal boiling mode. In this manner, the pump 17 is driven at a larger number of revolutions during the operation in the rapid boiling mode. Accordingly, the flow rate of hot water circulating through the hot water circuit unit 3 increases, whereby the amount of hot water stored in the hot water storage tank 5 per unit time can increase in comparison with that amount during operation in the normal boiling mode while maintaining a constant hot water delivery temperature.

[0095] The embodiment of the present invention has been described above with reference to the drawings. However, it should be understood that specific configurations are not limited to those described in the embodiment. The scope of the present invention is defined not by the embodiment described above, but by the scope of the claims, and further includes meanings equivalent to the claims and all modifications within the scope of the claims.

[0096] For example, in the embodiment and modifications described above, the hot water supply system 1 includes the gas heater 6 as the auxiliary heating unit. However, the auxiliary heating unit is not limited to the gas heater 6. Accordingly, as the auxiliary heating unit, the hot water supply system 1 may have another heating unit such as an electric heater. The present invention is applicable as long as the auxiliary heating unit constituted by a heating means other than the heat pump unit 2 has primary energy efficiency lower than that of the heat pump unit 2. More specifically, the primary energy efficiency of the auxiliary heating unit is lower than the primary energy efficiency of the heat pump unit 2 when compared at the heating capability maximizing COP of the heat pump unit 2. Examples of these heating means include an electric heater and gas or other combustion-type heating means.

INDUSTRIAL APPLICABILITY

[0097] When the present invention is applied, improvement of total energy efficiency of an overall hot water supply system is achievable by reducing a proportion of a heating amount generated by an auxiliary heating unit in a heating amount of the entire system.

REFERENCE SIGNS LIST

[0098]

2	Heat pump unit (heat pump heating unit)
5	Hot water storage tank
5a to 5d	Hot water storage temperature sensor (hot water storage amount detection unit)
6	Gas heater (auxiliary heating unit)
10	Hot water supply terminal (hot water delivery unit)
10a	Bathtub
11	Compressor
12	Outdoor heat exchanger (heat source side heat exchanger)
13	Expansion valve (expansion mechanism)
15	Fan
16	Hot water supply heat exchanger (usage-side heat exchanger)
23	Flow rate sensor (hot water delivery amount detection unit)
30	Control unit
38	History information storage unit
39	Hot water delivery prediction unit
41	Refrigerant circuit

CITATION LIST

PATENT LITERATURE

[0099] [Patent Literature 1] JP 2013-113495 A

Claims

1. A hot water supply system comprising:

a hot water storage tank (5) that stores hot water;
a hot water delivery unit (10) that supplies the hot water from the hot water storage tank (5) to a usage side;
a heat pump heating unit (2) that boils the hot water in the hot water storage tank (5); and
an auxiliary heating unit (6) capable of heating the hot water supplied from the hot water storage tank (5) to the hot water delivery unit (10),
wherein the hot water supply system is capable of performing:

a heat pump isolated operation that boils the hot water in the hot water storage tank (5) using the heat pump heating unit (2); and
an auxiliary heating combined operation that simultaneously performs boiling of the hot water in the hot water storage tank (5) and heating of the hot water using the auxiliary heating unit (6) when an amount of heat is insufficient only by the boiling of the hot water in the hot water storage tank (5) using the heat pump heating unit (2),
the heat pump isolated operation includes boiling in a first mode and boiling in a second mode having heating capabilities different from each other,
the heating capability of the boiling in the first mode is higher than the heating capability of the boiling in the second mode, and
heat pump efficiency of the boiling in the first mode is lower than heat pump efficiency of the boiling in the second mode, and
the boiling in the first mode is performed in

a predetermined condition where a shortage of the amount of heat is likely to be caused by the boiling in the second mode in a state where a large amount of delivery of the hot water is estimated or a large amount of the hot water is actually delivered.

2. The hot water supply system according to claim 1, wherein the heating capability of the boiling in the first mode is higher than a heating capability at which COP is maximized at an outside air temperature at that time, and primary energy efficiency of the boiling in the first mode is equal to or higher than primary energy efficiency during isolated operation of the auxiliary heating unit (6).

3. The hot water supply system according to claim 1 or 2, further comprising a hot water storage amount detection unit (5a to 5d) that detects a hot water storage amount in the hot water storage tank (5),
wherein the boiling in the second mode is started when the hot water storage amount detected by the hot water storage amount detection unit (5a to 5d) becomes smaller than a first hot water storage amount, and
the boiling in the second mode is switched to the boiling in the first mode when the hot water storage amount becomes a second hot water storage amount smaller than the first hot water storage amount.

4. The hot water supply system according to claim 1 or 2, further comprising a bathtub (10a) to which the hot water is supplied from the hot water delivery unit (10),
wherein the boiling in the first mode is performed when a hot water filling instruction for supplying the hot water at a target temperature to the bathtub (10a) is issued.

5. The hot water supply system according to claim 1 or 2, further comprising:

a hot water delivery amount detection unit (23) that detects a hot water delivery amount supplied from the hot water storage tank (5) to the hot water delivery unit;
a history information storage unit (38) that stores history information indicating a hot water delivery amount detected by the hot water delivery amount detection unit, and a hot water delivery time; and
a hot water delivery prediction unit (39) that predicts a scheduled hot water delivery amount and a scheduled hot water delivery time based on the history information stored in the history information storage unit (38),
wherein the boiling in the first mode is performed when delivery of the hot water not predicted by the hot water delivery prediction unit (39) is executed at a time of operation of the heat pump heating unit (2) for storing the scheduled hot water delivery amount predicted by the hot water delivery prediction unit (39) in the hot water storage tank (5) by the scheduled hot water delivery time.

6. The hot water supply system according to claim 1 or 2, further comprising:

a hot water storage amount detection unit (5a to 5d) that detects a hot water storage amount in the hot water storage tank (5);
a hot water delivery amount detection unit (23) that detects a hot water delivery amount supplied from the hot water storage tank (5) to the hot water delivery unit (10);
a history information storage unit (38) that stores history information indicating a hot water delivery amount detected by the hot water delivery amount detection unit (23), and a hot water delivery time; and
a hot water delivery prediction unit (39) that predicts a scheduled hot water delivery amount and a scheduled hot water delivery time based on the history information stored in the history information storage unit (38),
wherein the boiling in the first mode is performed when the scheduled hot water delivery amount is larger than a total value of the hot water storage amount detected by the hot water storage amount detection unit (5a to 5d) and a scheduled hot water storage amount at the scheduled hot water delivery time of an operation by the boiling in the second mode.

7. The hot water supply system according to any one of claims 1 to 6,

wherein the heat pump heating unit (2) includes a refrigerant circuit (41) through which a refrigerant circulates, the refrigerant circuit (41) including a compressor (11), a heat source side heat exchanger (12), an expansion mechanism (13), and a usage-side heat exchanger (16) each connected to the refrigerant circuit (41),
the hot water is supplied to the hot water storage tank (5) using the usage-side heat exchanger (16), and
a frequency of the compressor (11) in the boiling in the first mode is higher than a frequency of the compressor (11) in the boiling in the second mode at a same outside air temperature.

8. The hot water supply system according to any one of claims 1 to 6,

wherein the heat pump heating unit (2) includes a refrigerant circuit (41) through which a refrigerant circulates, the refrigerant circuit (41) including a compressor (11), a heat source side heat exchanger (12), an expansion mechanism (13), and a usage-side heat exchanger (16) each connected to the refrigerant circuit (41), the heat pump heating unit (2) further including a fan (15) that feeds air to the heat source side heat exchanger (12) to cause heat exchange,
the hot water is supplied to the hot water storage tank (5) using the usage-side heat exchanger (16), and
a number of revolutions of the fan (15) in the boiling in the first mode is larger than a number of revolutions of the fan (15) in the boiling in the second mode at a same outside air temperature.

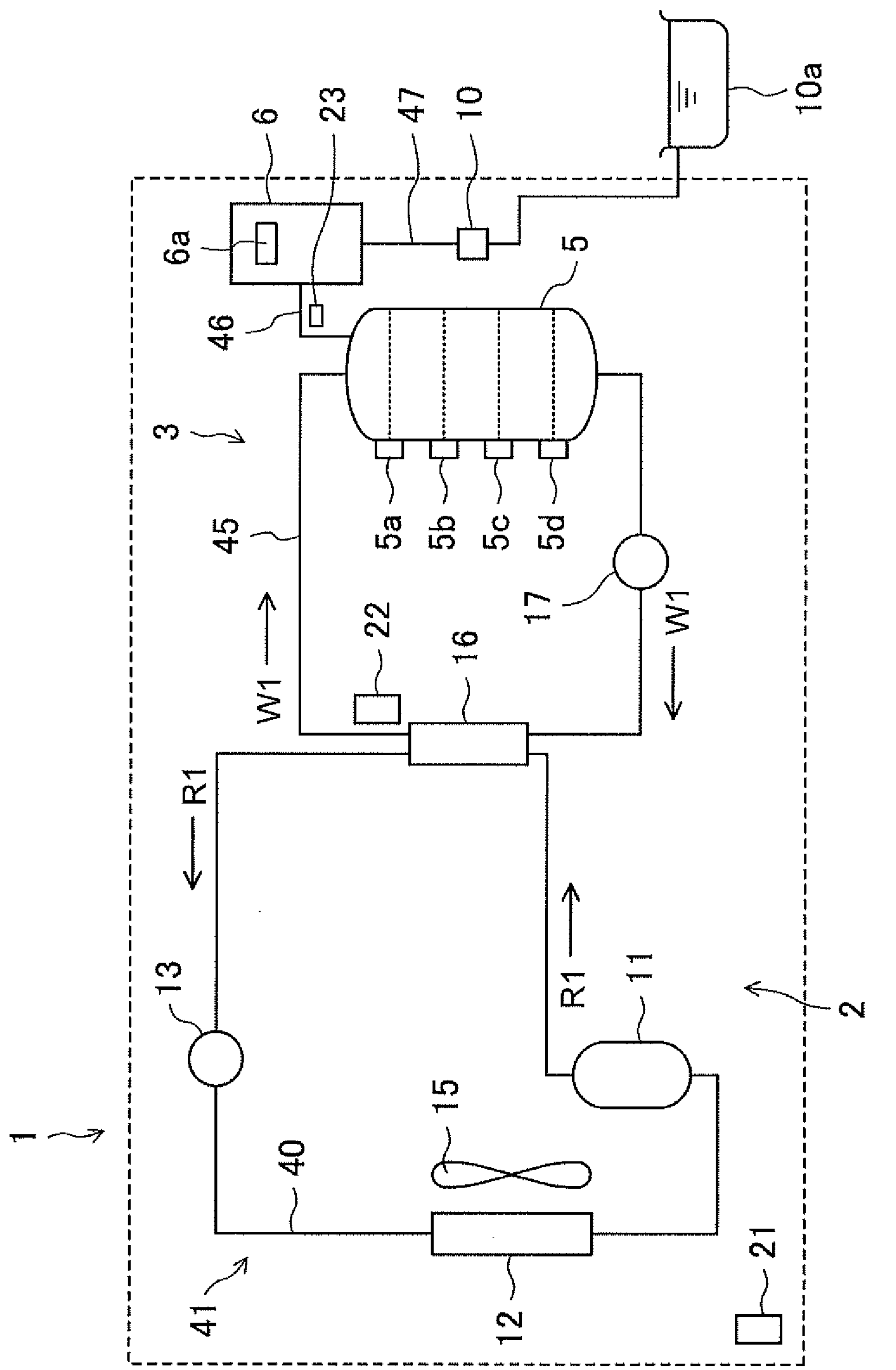
1
2
3
5
5a
5b
5c
5d
6
6a
10
10a
11
12
13
15
16
17
21
22
23
40
41
45
46
47
R1
W1

FIG. 1

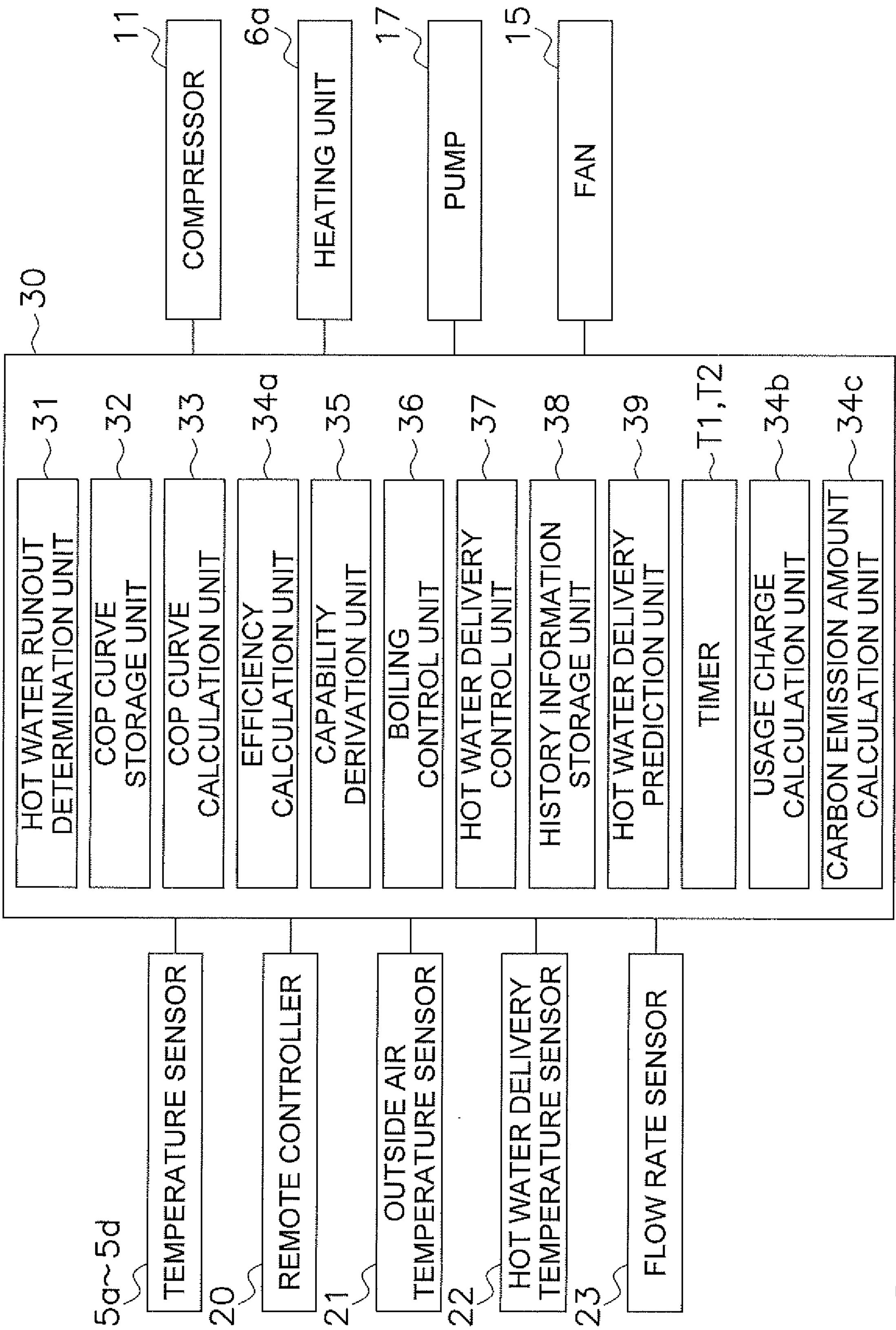
11
COMPRESSOR
6a
HEATING UNIT
17
PUMP
15
FAN
30
31
HOT WATER RUNOUT DETERMINATION UNIT
32
COP CURVE STORAGE UNIT
33
COP CURVE CALCULATION UNIT
34a
EFFICIENCY CALCULATION UNIT
35
CAPABILITY DERIVATION UNIT
36
BOILING CONTROL UNIT
37
HOT WATER DELIVERY CONTROL UNIT
38
HISTORY INFORMATION STORAGE UNIT
39
HOT WATER DELIVERY PREDICTION UNIT
T1,T2
TIMER
34b
USAGE CHARGE CALCULATION UNIT
34c
CARBON EMISSION AMOUNT CALCULATION UNIT
5a~5d
TEMPERATURE SENSOR
20
REMOTE CONTROLLER
21
OUTSIDE AIR TEMPERATURE SENSOR
22
HOT WATER DELIVERY TEMPERATURE SENSOR
23
FLOW RATE SENSOR

FIG. 2

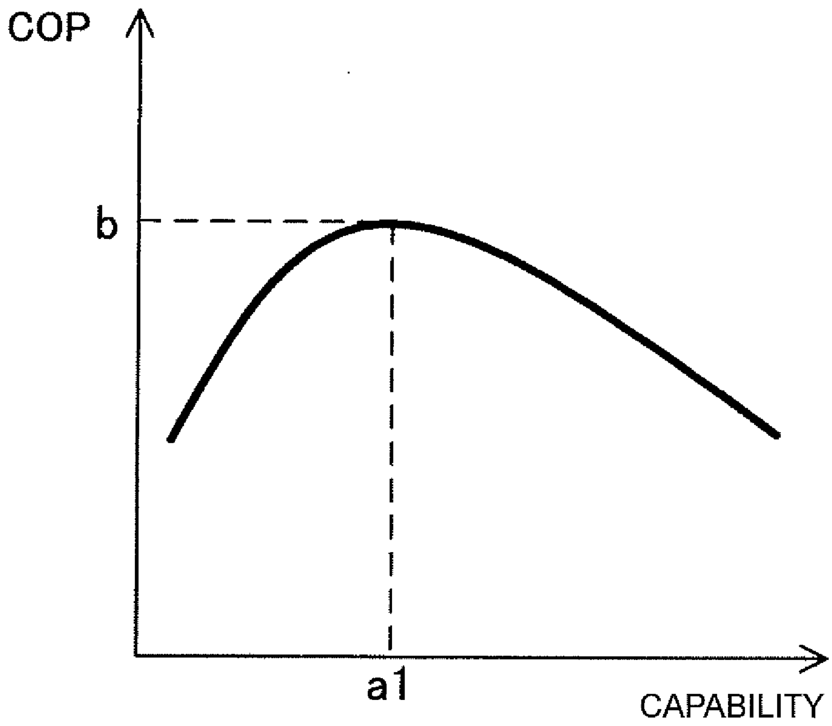
COP
b
a1
CAPABILITY

FIG. 3

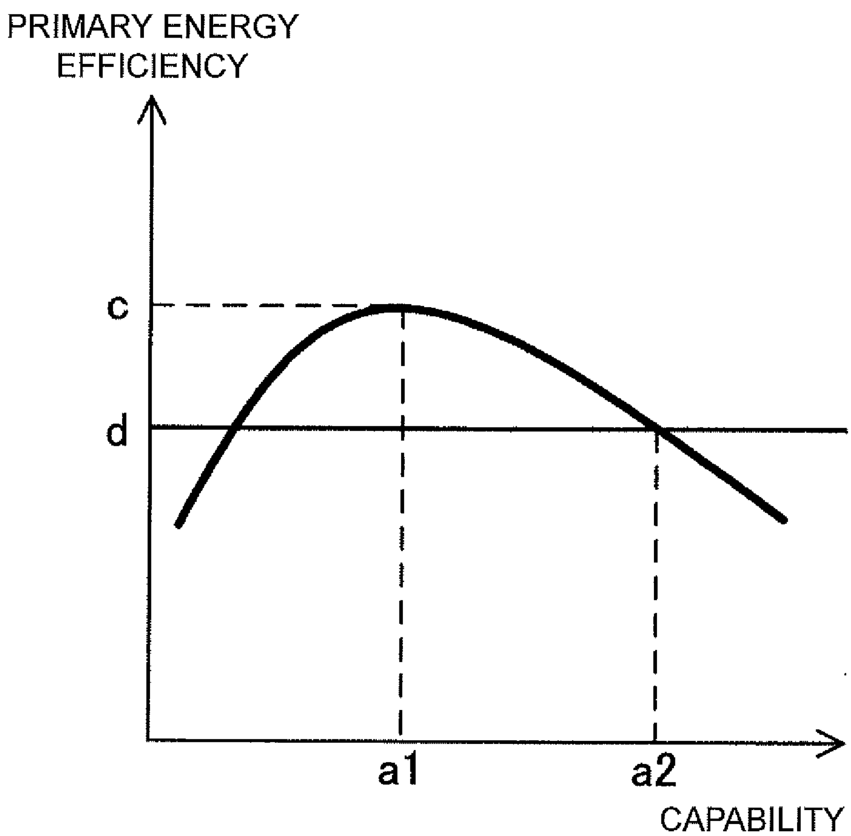
PRIMARY ENERGY
EFFICIENCY
c
d
a1
a2
CAPABILITY

FIG. 4

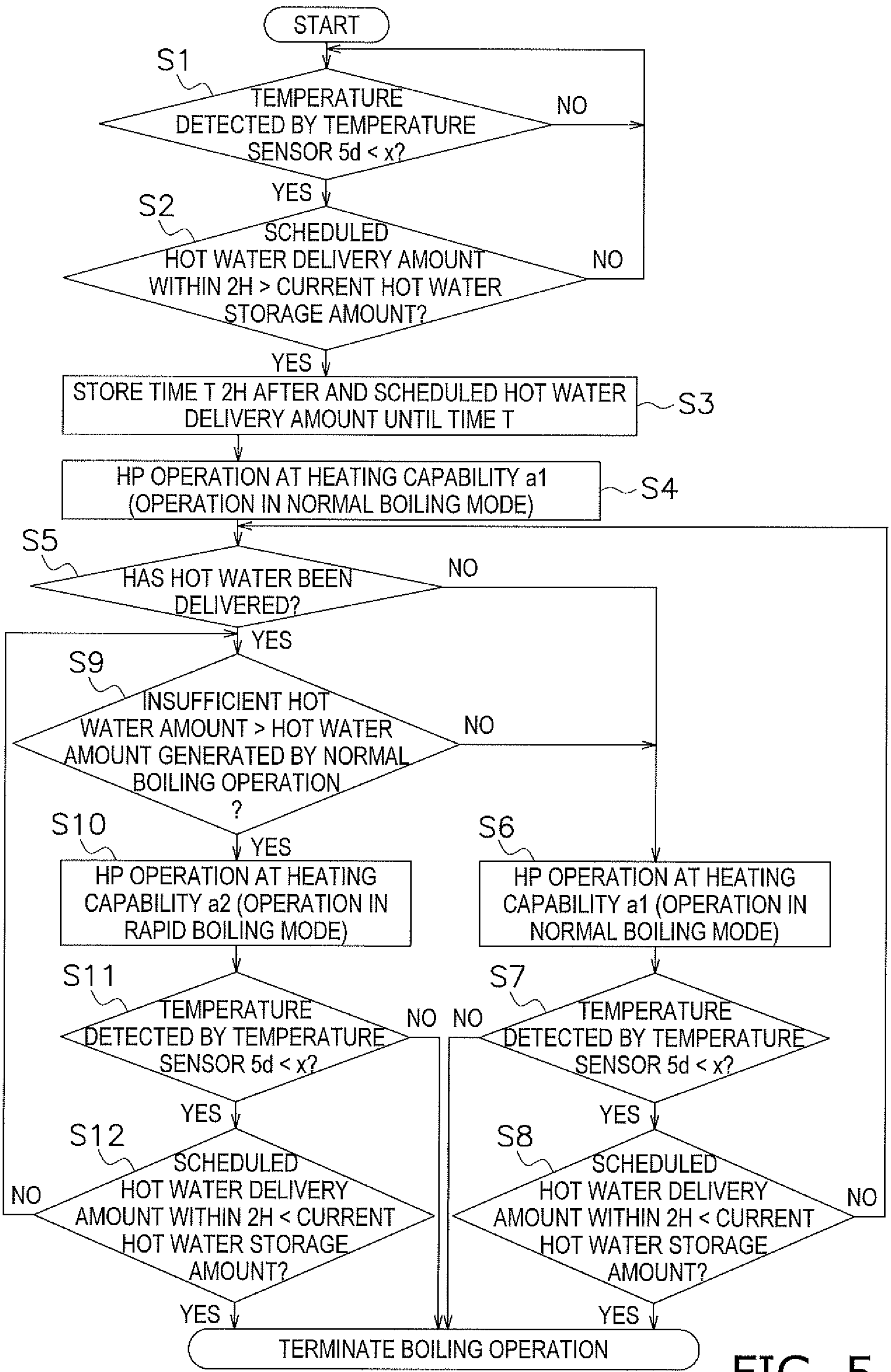
START
S1
TEMPERATURE DETECTED BY TEMPERATURE SENSOR 5d < x?
NO
YES
S2
SCHEDULED HOT WATER DELIVERY AMOUNT WITHIN 2H > CURRENT HOT WATER STORAGE AMOUNT?
NO
YES
STORE TIME T 2H AFTER AND SCHEDULED HOT WATER DELIVERY AMOUNT UNTIL TIME T
S3
HP OPERATION AT HEATING CAPABILITY a1 (OPERATION IN NORMAL BOILING MODE)
S4
S5
HAS HOT WATER BEEN DELIVERED?
NO
YES
S9
INSUFFICIENT HOT WATER AMOUNT > HOT WATER AMOUNT GENERATED BY NORMAL BOILING OPERATION ?
NO
S10
YES
HP OPERATION AT HEATING CAPABILITY a2 (OPERATION IN RAPID BOILING MODE)
S6
HP OPERATION AT HEATING CAPABILITY a1 (OPERATION IN NORMAL BOILING MODE)
S11
TEMPERATURE DETECTED BY TEMPERATURE SENSOR 5d < x?
NO
NO
S7
TEMPERATURE DETECTED BY TEMPERATURE SENSOR 5d < x?
YES
YES
S12
SCHEDULED HOT WATER DELIVERY AMOUNT WITHIN 2H < CURRENT HOT WATER STORAGE AMOUNT?
NO
S8
SCHEDULED HOT WATER DELIVERY AMOUNT WITHIN 2H < CURRENT HOT WATER STORAGE AMOUNT?
NO
YES
YES
TERMINATE BOILING OPERATION

FIG. 5

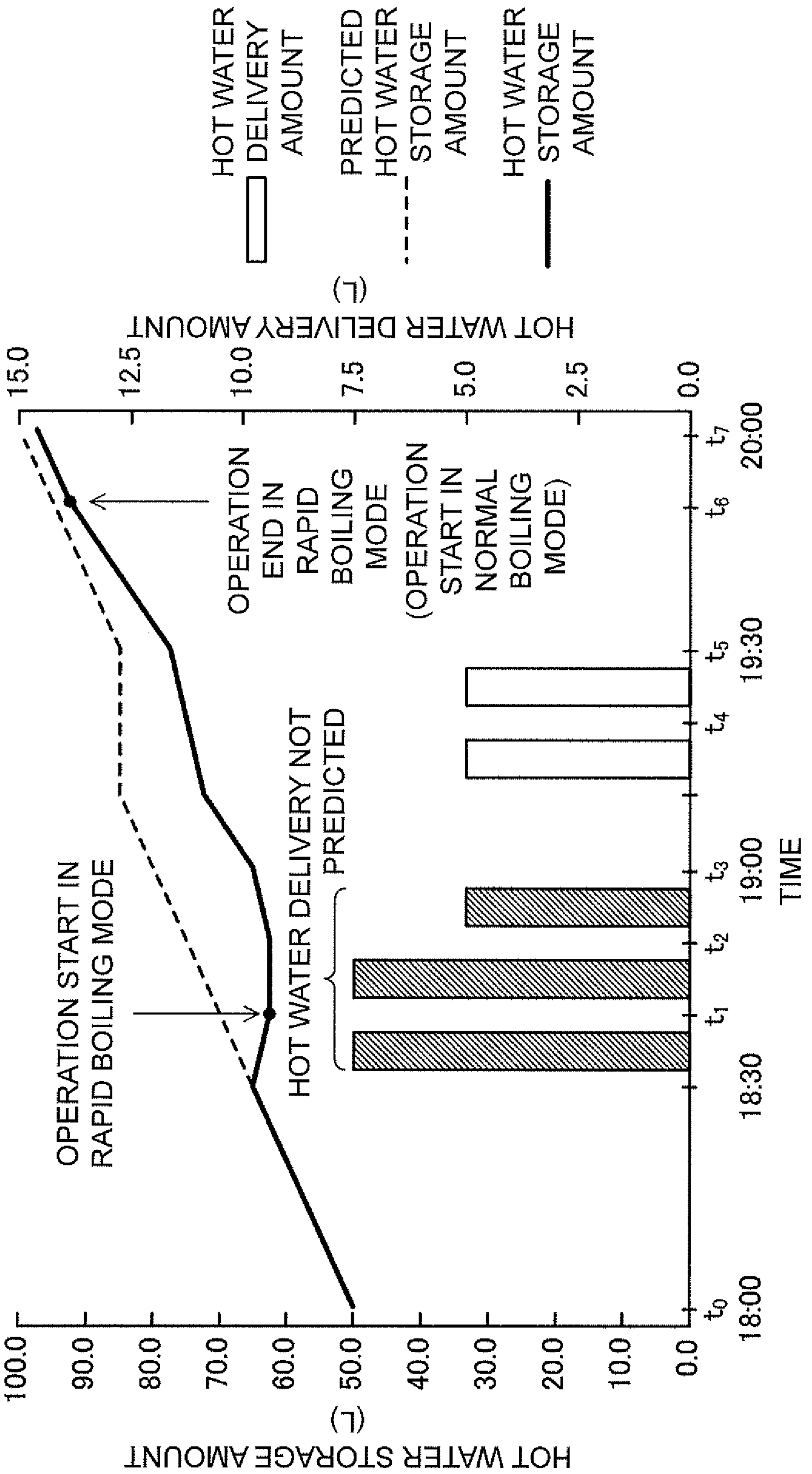
HOT WATER DELIVERY AMOUNT
PREDICTED HOT WATER STORAGE AMOUNT
HOT WATER STORAGE AMOUNT
HOT WATER STORAGE AMOUNT (L)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
HOT WATER DELIVERY AMOUNT (L)
15.0
12.5
10.0
7.5
5.0
2.5
0.0
OPERATION START IN RAPID BOILING MODE
HOT WATER DELIVERY NOT PREDICTED
OPERATION END IN RAPID BOILING MODE (OPERATION START IN NORMAL BOILING MODE)
t_0
t_1
t_2
t_3
t_4
t_5
t_6
t_7
18:00
18:30
19:00
19:30
20:00
TIME

FIG. 6

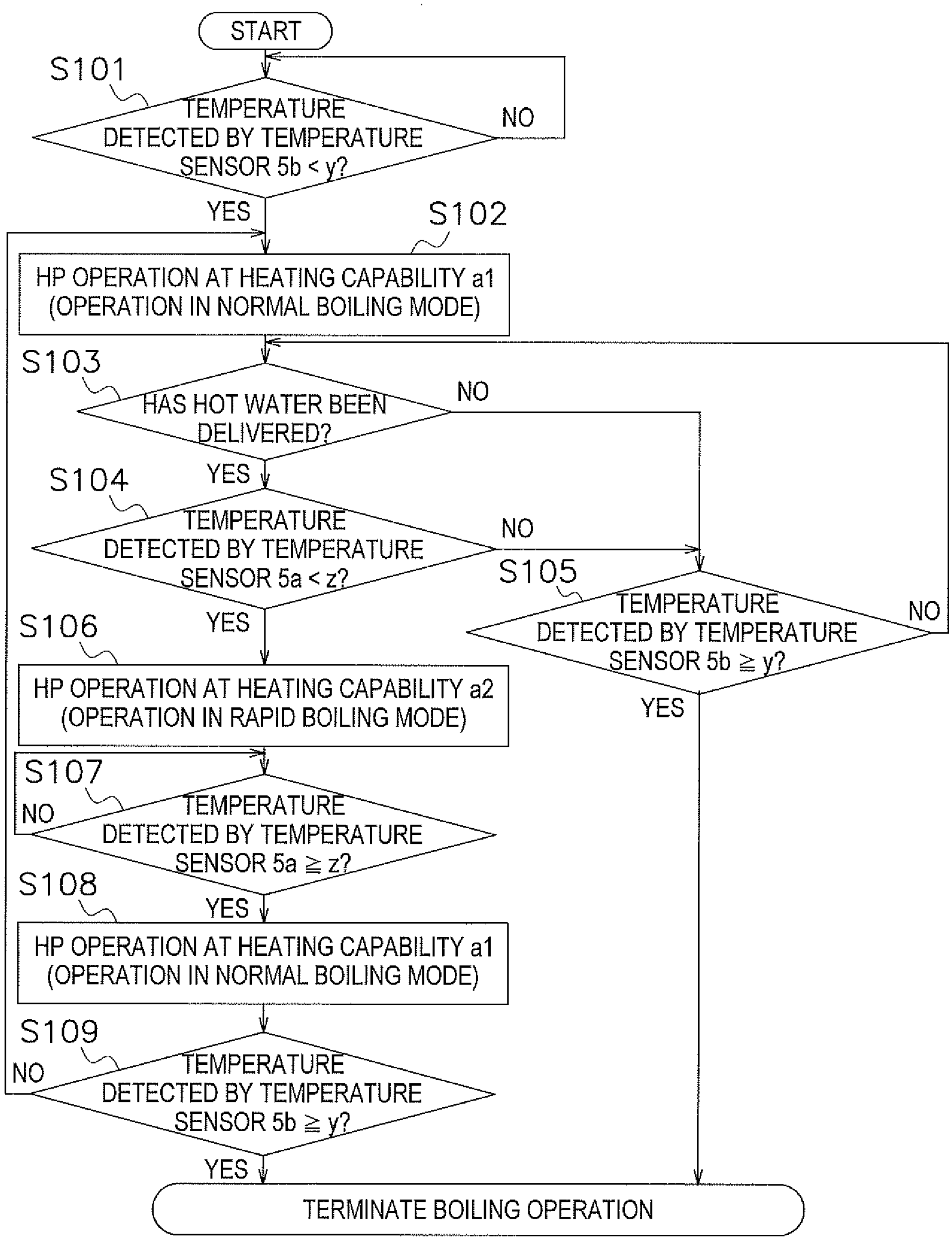
START
S101
TEMPERATURE DETECTED BY TEMPERATURE SENSOR 5b < y?
NO
YES
S102
HP OPERATION AT HEATING CAPABILITY a1 (OPERATION IN NORMAL BOILING MODE)
S103
HAS HOT WATER BEEN DELIVERED?
NO
YES
S104
TEMPERATURE DETECTED BY TEMPERATURE SENSOR 5a < z?
NO
YES
S105
TEMPERATURE DETECTED BY TEMPERATURE SENSOR 5b ≧ y?
NO
YES
S106
HP OPERATION AT HEATING CAPABILITY a2 (OPERATION IN RAPID BOILING MODE)
S107
TEMPERATURE DETECTED BY TEMPERATURE SENSOR 5a ≧ z?
NO
YES
S108
HP OPERATION AT HEATING CAPABILITY a1 (OPERATION IN NORMAL BOILING MODE)
S109
TEMPERATURE DETECTED BY TEMPERATURE SENSOR 5b ≧ y?
NO
YES
TERMINATE BOILING OPERATION

FIG. 7

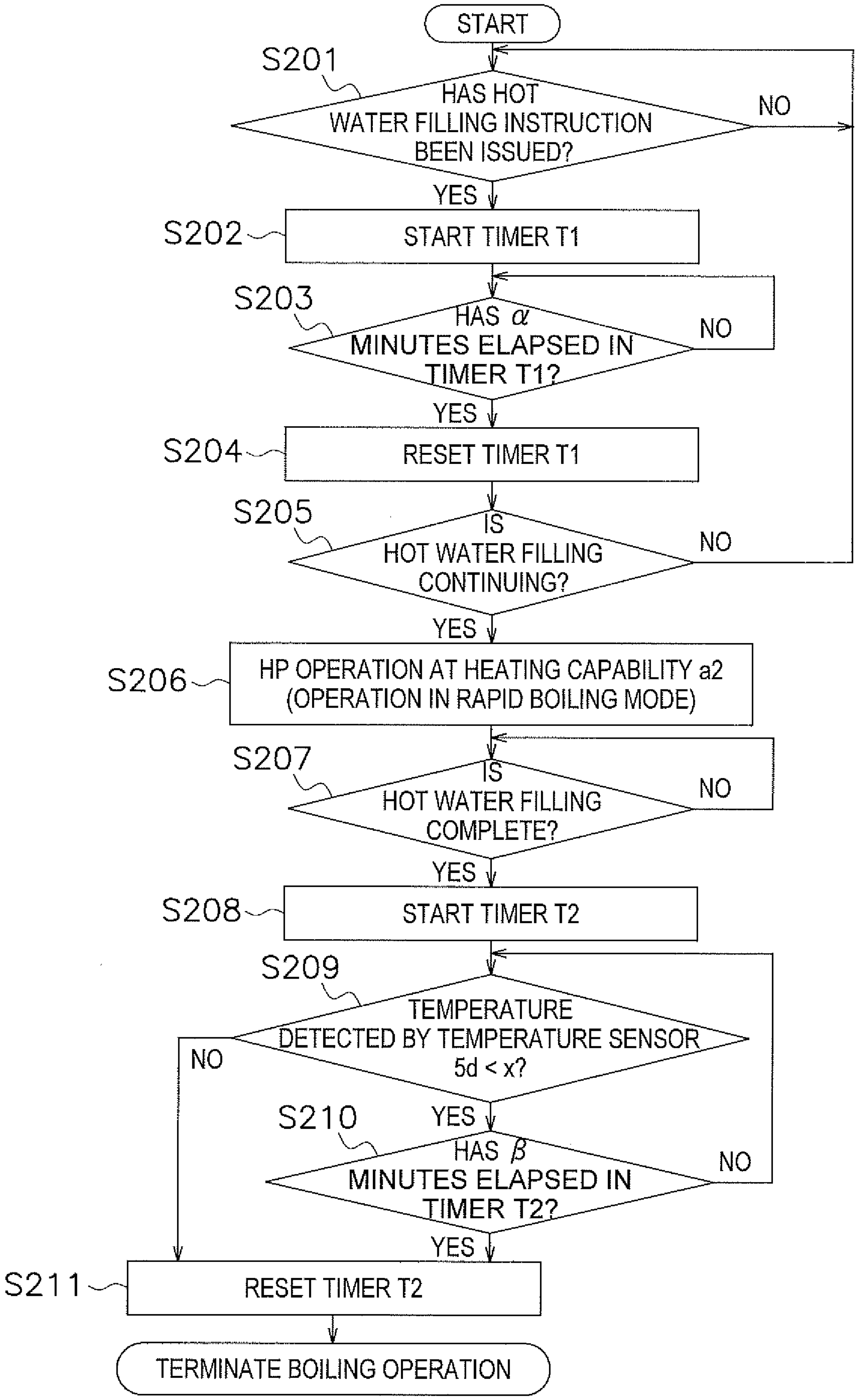
START
S201
HAS HOT WATER FILLING INSTRUCTION BEEN ISSUED?
NO
YES
S202
START TIMER T1
S203
HAS α MINUTES ELAPSED IN TIMER T1?
NO
YES
S204
RESET TIMER T1
S205
IS HOT WATER FILLING CONTINUING?
NO
YES
S206
HP OPERATION AT HEATING CAPABILITY a2 (OPERATION IN RAPID BOILING MODE)
S207
IS HOT WATER FILLING COMPLETE?
NO
YES
S208
START TIMER T2
S209
TEMPERATURE DETECTED BY TEMPERATURE SENSOR 5d < x?
NO
YES
S210
HAS β MINUTES ELAPSED IN TIMER T2?
NO
YES
S211
RESET TIMER T2
TERMINATE BOILING OPERATION

FIG. 8

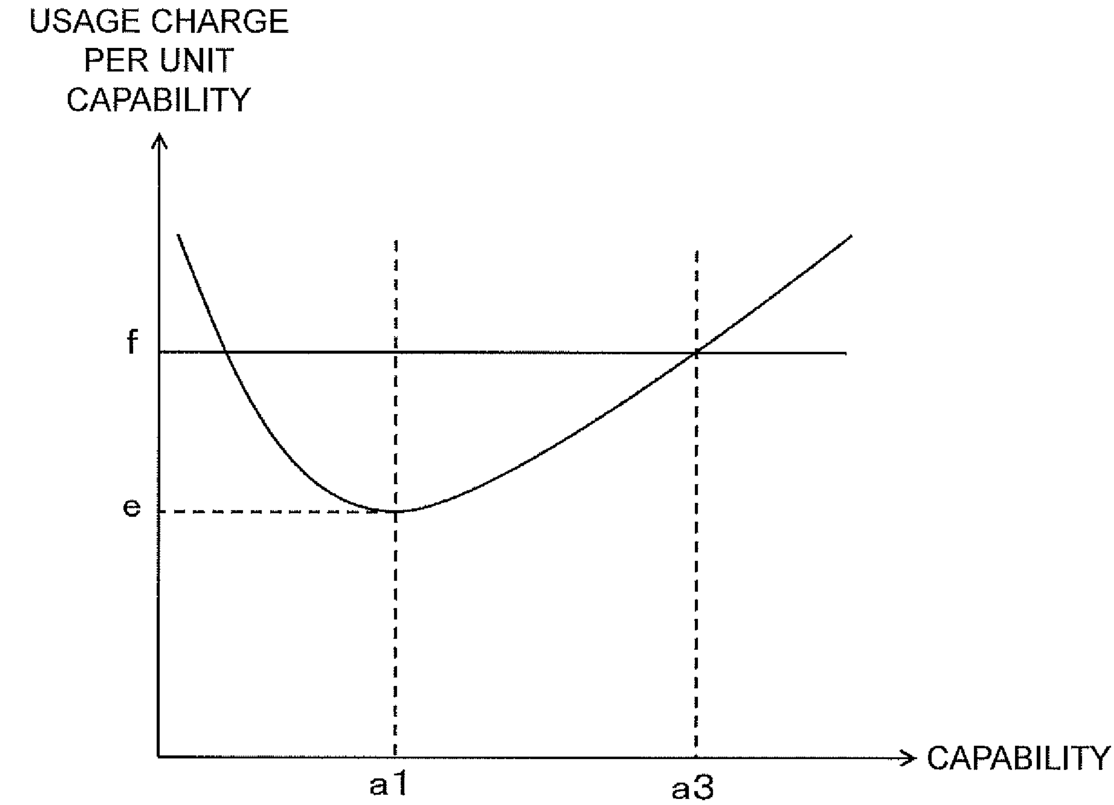
USAGE CHARGE
PER UNIT
CAPABILITY
f
e
a1
a3
CAPABILITY

FIG. 9

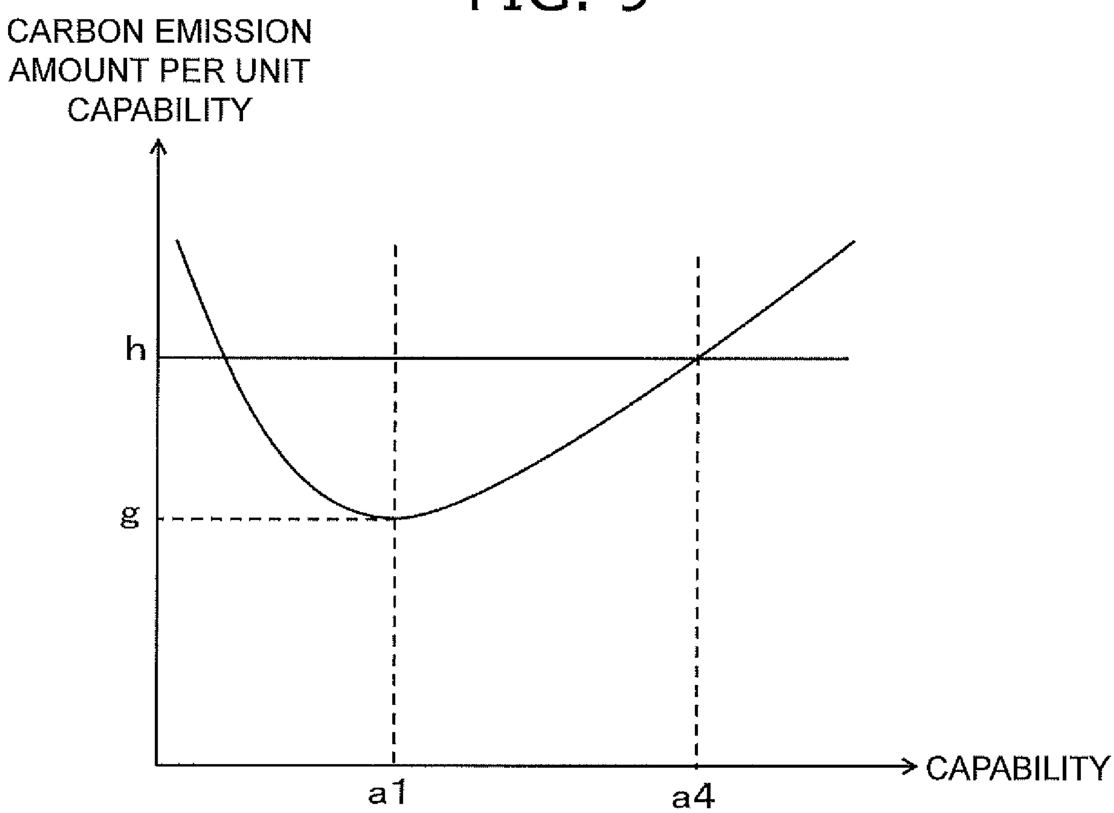
CARBON EMISSION
AMOUNT PER UNIT
CAPABILITY
h
g
a1
a4
CAPABILITY

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2018/028302

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. F24H4/02(2006.01)i, F24H1/18(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)
Int.Cl. F24H1/00-4/06

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2018
Registered utility model specifications of Japan	1996-2018
Published registered utility model applications of Japan	1994-2018

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2012-225587 A (DENSO CORP.) 15 November 2012, entire text, all drawings (Family: none)	1-8
Y	JP 2010-169272 A (DAIKIN INDUSTRIES, LTD.) 05 August 2010, entire text, all drawings (Family: none)	1-8
Y	JP 2009-275958 A (DENSO CORP.) 26 November 2009, paragraphs [0020]-[0062], fig. 1-4 (Family: none)	2-8
Y	JP 2017-83045 A (PANASONIC IP MANAGEMENT CO., LTD.) 18 May 2017, entire text, all drawings (Family: none)	5-8
Y	JP 2017-53526 A (DENSO CORP.) 16 March 2017, claim 14 (Family: none)	8

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

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 October 2018 (11.10.2018)	23 October 2018 (23.10.2018)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

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Patent documents cited in the description

- JP 2013113495 A **[0002] [0099]**