



(11) **EP 4 113 028 A1**

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

(43) Date of publication:
04.01.2023 Bulletin 2023/01

(51) International Patent Classification (IPC):
F24H 1/18 ^(2022.01)

(21) Application number: **21808900.1**

(52) Cooperative Patent Classification (CPC):
F24H 1/18

(22) Date of filing: **17.05.2021**

(86) International application number:
PCT/JP2021/018580

(87) International publication number:
WO 2021/235383 (25.11.2021 Gazette 2021/47)

(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:
KH MA MD TN

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(30) Priority: **19.05.2020 JP 2020087372**

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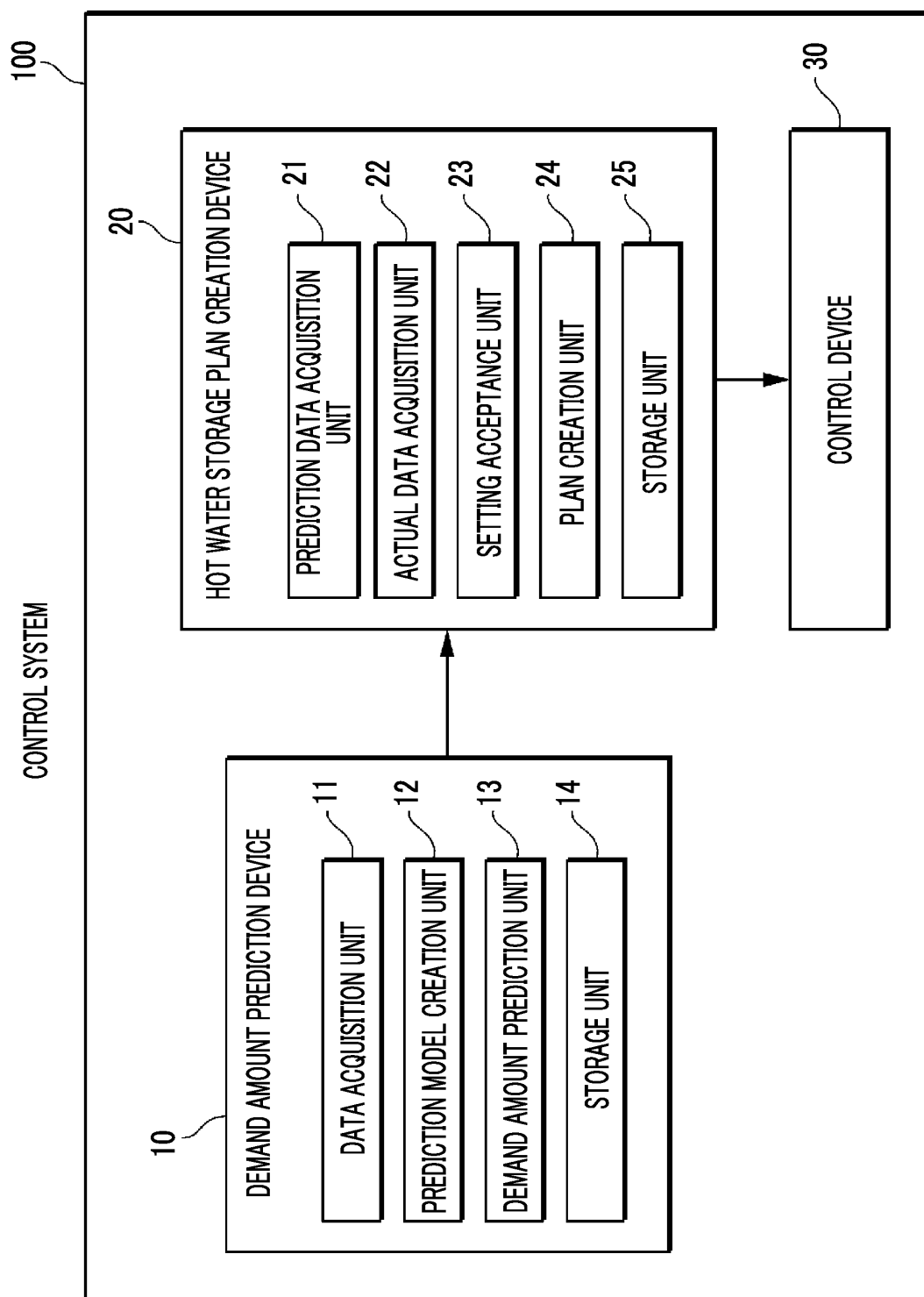
(54) **HOT WATER STORAGE PLAN CREATION SYSTEM, HOT WATER STORAGE PLAN CREATION METHOD, AND PROGRAM**

(57) This hot water storage plan creation system comprises a prediction data acquisition unit which acquires prediction data of hot water storage demand for each unit time in a prescribed future period of time, and

a plan creation unit which creates a hot water storage plan setting target hot water amount for each unit of time during the prescribed period of time on the basis of the prediction data.

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FIG. 2



Description

Technical Field

5 **[0001]** The present disclosure relates to a hot water storage plan creation system, a hot water storage plan creation method, and a program. The present application claims priority to Japanese Patent Application No. 2020-87372 filed on May 19, 2020, the content of which is incorporated herein by reference.

Background Art

10 **[0002]** In a hot water supply system used to supply hot water to a kitchen of a restaurant or a bath facility, a water heater heats tap water and stores the heated hot water in a hot water storage tank. Then, the hot water stored in the hot water storage tank is supplied to the kitchen and the bath facility. The hot water supply system often sets a water boiling amount based on a demand prediction every day, and is operated. However, since the demand prediction contains
15 an error, there is a possibility that there will be a shortage of hot water due to a sudden increase in demand, and the like. In the related art, PTL 1 discloses a control method of a water heater that stores hot water with a needed amount in a hot water storage tank by the time when the hot water supply is used, although unexpected hot water is to be discharged.

Citation List

Patent Literature

25 **[0003]** [PTL 1] Japanese Unexamined Patent Application Publication No. 2019-207058

Summary of Invention

Technical Problem

30 **[0004]** There is a need for a method of automatically setting a water boiling amount capable of avoiding running out of hot water while a daily demand prediction is satisfied.

[0005] It is an object of the present disclosure to provide a hot water storage plan creation system, a hot water storage plan creation method, and a program capable of solving the above-mentioned problems.

Solution to Problem

[0006] A hot water storage plan creation system of the present disclosure includes a prediction data acquisition unit that acquires prediction data of hot water storage demand for each unit time in a predetermined period, and a plan creation unit that creates a hot water storage plan that defines a target hot water storage amount for each unit time in
40 the predetermined period based on the prediction data.

[0007] In addition, a hot water storage plan creation method of the present disclosure is executed by a hot water storage plan creation system, and includes a step of acquiring prediction data of hot water storage demand for each unit time in a predetermined period, and a step of creating a hot water storage plan that defines a target hot water storage amount for each unit time in the predetermined period, based on the prediction data.

45 **[0008]** In addition, a program of the present disclosure causes a computer to execute a step of acquiring prediction data of hot water storage demand for each unit time in a predetermined period, and a step of creating a hot water storage plan that defines a target hot water storage amount for each unit time in the predetermined period, based on the prediction data.

Advantageous Effects of Invention

[0009] According to the hot water storage plan creation system, the hot water storage plan creation method, and the program described above, it is possible to automatically set the water boiling amount that satisfies a demand prediction amount of daily hot water supply.

Brief Description of Drawings

[0010]

Fig. 1 is a diagram illustrating an example of a hot water supply system according to one embodiment.
 Fig. 2 is a functional block diagram illustrating an example of a control system according to one embodiment.
 Fig. 3A is a first graph illustrating creation processing of a hot water storage plan according to one embodiment.
 Fig. 3B is a second graph illustrating creation processing of the hot water storage plan in one embodiment.
 Fig. 3C is a third graph illustrating creation processing of the hot water storage plan in one embodiment.
 Fig. 3D is a fourth graph illustrating creation processing of the hot water storage plan in one embodiment.
 Fig. 4A is a first graph illustrating creation processing of a long-term hot water storage plan in one embodiment.
 Fig. 4B is a second graph illustrating creation processing of the long-term hot water storage plan in one embodiment.
 Fig. 5A is a first graph illustrating how to deal with a fluctuation in hot water supply demand in one embodiment.
 Fig. 5B is a second graph illustrating how to deal with a fluctuation in the hot water supply demand in one embodiment.
 Fig. 6 is a graph illustrating switching of a plan mode in one embodiment.
 Fig. 7 is a flowchart illustrating an example of hot water storage plan creation processing in one embodiment.
 Fig. 8 is a diagram illustrating an example of a hardware configuration of a control system according to one embodiment.

Description of Embodiments

<Embodiment>

[0011] Hereinafter, a hot water supply system according to one embodiment of the present disclosure will be described with reference to Figs. 1 to 8.

(System Configuration)

[0012] Fig. 1 is a diagram illustrating an example of a hot water supply system according to one embodiment of the present disclosure.

[0013] As illustrated in the figure, a hot water supply system 1 includes a water heater 2, a hot water storage tank 3, a facility 4, and a control system 100. The water heater 2 and the hot water storage tank 3 are connected by a pipe 6B, and the hot water storage tank 3 and the facility 4 are connected by a pipe 6C. Water is supplied to the water heater 2 through the pipe 6A. The water heater 2 includes, for example, a refrigerant circuit including a compressor, a condenser, an expansion valve, and an evaporator, and heats water to generate hot water by exchanging heat with the condenser. The water heater 2 sends the generated hot water to the hot water storage tank 3 through the pipe 6B. The hot water storage tank 3 stores hot water. The hot water storage tank 3 is provided with a sensor 5 that measures a hot water storage amount. The sensor 5 is, for example, a water level sensor. The control system 100 acquires the measured value of the sensor 5 and controls the water heater 2 such that the hot water storage amount measured by the sensor 5 is a target value. The hot water of an amount corresponding to the demand of the facility 4 is supplied from the hot water storage tank 3 to the facility 4 through the pipe 6C.

[0014] The control system 100 performs demand amount prediction of hot water needed for a predetermined target period, and calculates a target value (hot water storage plan) of a hot water storage amount according to the demand amount prediction. Then, the control system 100 operates the water heater 2 based on the hot water storage plan. Next, the control system 100 will be described.

(Function of Control System)

[0015] Fig. 2 is a functional block diagram illustrating an example of a control system according to one embodiment of the present disclosure. The control system 100 includes a demand amount prediction device 10 that predicts the hot water demand amount, a hot water storage plan creation device 20 that creates a hot water storage plan of hot water to be stored in the hot water storage tank 3 based on the demand amount prediction, and the control device 30 of the water heater 2. The demand amount prediction device 10, the hot water storage plan creation device 20, and the control device 30 are communicably connected to each other.

[0016] The demand amount prediction device 10 includes a data acquisition unit 11, a prediction model creation unit 12, a demand amount prediction unit 13, and a storage unit 14.

[0017] The data acquisition unit 11 acquires various data needed for the demand amount prediction.

[0018] The prediction model creation unit 12 learns the relationship between various parameters (descriptive variables) and a hot water usage amount (objective variable), and creates a prediction model that predicts the hot water demand amount. The descriptive variables of the prediction model are, for example, parameters that affect the demand for hot water such as the outside air temperature, the day of the week, the weather, the month, the season, the time, the time zone of the day (morning, noon, evening), and the like in the environment in which the hot water supply system 1 operates.

The hot water usage amount is, for example, the hot water amount supplied from the hot water storage tank 3 to the facility 4. In the present disclosure, it is assumed that the hot water amount supplied to the facility 4 is known. The data acquisition unit 11 acquires the descriptive variables exemplified above and the usage of hot water (objective variable) at that time, associates the descriptive variables with the usage of hot water, and stores the association in the storage unit 14 as learning data. The prediction model creation unit 12 reads out the stored learning data, and creates a prediction model illustrating the relationship between the descriptive variables such as the outside air temperature and the day of the week and the hot water usage amount as the objective variable by processing such as multiple regression analysis. In this way, the prediction model creation unit 12 creates a prediction model based on actual operation data (the descriptive variable and the objective variable described above) regardless of the facility configuration of the hot water supply system 1. As a result, it can be introduced into any system and a highly precise demand prediction model can be created. Since the demand of the facility 4 may change due to the convenience of the facility, the prediction model creation unit 12 may periodically recreate the prediction model.

[0019] The demand amount prediction unit 13 predicts the hot water demand amount for each unit time in a prediction target period based on the prediction model created by the prediction model creation unit 12. The demand amount prediction unit 13 outputs the demand amount prediction value for each unit time as prediction data. The prediction data includes data representing the hot water demand amount for each unit time as the hot water storage amount in the hot water storage tank 3. For example, when that the unit time is one hour, the prediction data includes information such as "7:00, 1%", "8:00, 2%", ..., and the like. Here, "7:00, 1%" indicates that the demand for hot water corresponding to 1% of the total hot water storage amount in the hot water storage tank 3 is expected from 7:00 to 8:00.

[0020] The storage unit 14 stores the data acquired by the data acquisition unit 11, the prediction model created by the prediction model creation unit 12, and the like.

[0021] The hot water storage plan creation device 20 includes a prediction data acquisition unit 21, an actual data acquisition unit 22, a setting acceptance unit 23, a plan creation unit 24, and a storage unit 25.

[0022] The prediction data acquisition unit 21 acquires the prediction data output by the demand amount prediction device 10, and writes the acquired prediction data in the storage unit 25.

[0023] The actual data acquisition unit 22 acquires actual data indicating the actual usage of hot water in the hot water storage tank 3, and writes the acquired actual data in the storage unit 25. The actual data is, for example, the hot water storage amount in the hot water storage tank 3 for each unit time. The actual data includes information such as "7:00, 80%", "8:00, 80%", ..., and the like. Here, "7:00, 80%" and "8:00, 80%" indicate that the hot water storage amount in the hot water storage tank 3 is 80% at time points of 7:00 and 8:00. Further, it is illustrated that the hot water amount supplied from the hot water storage tank 3 to the facility 4 between 7:00 and 8:00 is equal to the hot water amount supplied by the water heater 2 to the hot water storage tank 3. The actual data is used to determine whether to create a hot water storage plan that prioritizes efficiency or create a hot water storage plan that prioritizes prevention of running out of hot water when a hot water storage plan is created.

[0024] The setting acceptance unit 23 accepts the settings needed for the creation processing of the hot water storage plan.

[0025] The plan creation unit 24 creates a hot water storage plan based on the prediction data. The hot water storage plan is, for example, the hot water storage amount in the hot water storage tank 3 for each unit time. The hot water storage plan includes, for example, information such as "6:00, 80%", "7:00, 80%", "8:00, 90%", ..., and the like. Here, "7:00, 80%" indicates that the hot water storage amount that the sensor 5 measures at the time point of 7:00 is compared with 80% and an operation is performed to reach 80% when the hot water storage amount is less than 80%. That is, it is a case where the target hot water storage amount of "7:00, 80%" is given to the control device 30, and when the hot water storage amount measured by the sensor 5 does not reach 80% at the time point of 7:00, the control device 30 starts the operation of the water heater 2 such that the hot water storage amount is 80%. On the other hand, in the present disclosure, a hot water storage plan is created such that 80% can be achieved at the time point of 7:00. For example, when water boiling is needed from 1:00 to achieve 80% of the hot water storage amount at the time point of 7:00, the water heater 2 creates a hot water storage plan such that the water heater 2 can start boiling water from 1:00.

[0026] The storage unit 25 stores various information such as prediction data, actual data, and various settings.

[0027] The control device 30 acquires the hot water storage amount of the hot water storage tank 3 measured by the sensor 5, and controls the operation of the water heater 2 based on the hot water storage amount measured by the sensor 5 and the target hot water storage amount set in the hot water storage plan created by the hot water storage plan creation device 20. For example, when the hot water storage amount at 7:00 in the hot water storage plan is 80% and the hot water storage amount measured by the sensor 5 at 7:00 is 70%, the control device 30 operates the water heater 2 such that the hot water storage amount in the hot water storage tank 3 is 80%.

(Creation Processing Of Hot Water Storage Plan)

[0028] Next, the creation processing of a hot water storage plan by the plan creation unit 24 will be described. Figs.

3A to 3D are first to fourth graphs illustrating creation processing of the hot water storage plan in one embodiment, respectively.

[0029] First, the plan creation unit 24 prepares the following variables.

- 5 • Demand(i): A demand prediction amount in a frame i included in prediction data. The unit is %.
- Necessary(i): A hot water storage amount that should be secured at the start time of each frame. The unit is %.
- C1: A hot water amount that can be boiled in one frame. The unit is %/frame.
- C2: A hot water storage amount that should be secured at the end time of a plan target period. The unit is %.
- 10 • Afford(i): A flag indicating whether the demand prediction amount of the frame i is less than or equal to C1. When the demand prediction amount is less than or equal to C1 (although water boiling is started from the start time of the frame, the demand prediction amount can be supplied by the end time of the frame), the flag is "1", and when the demand prediction amount is larger than C1, the flag is "0".
- Target(i): A target hot water storage amount of the frame i. The unit is %. The hot water storage plan is configured with Target(i) for each unit time in the target period.
- 15 • Lowlim: A lower limit value of the hot water storage amount in the hot water storage tank 3. Always try not to fall below the value. The unit is %.

[0030] For example, the values of C1, C2, and Lowlim are set by the user, the setting acceptance unit 23 accepts the settings for the variables, and each value is registered in the storage unit 25.

20 **[0031]** In addition, the following assumptions are made in the creation processing of the hot water storage plan.

(a) It is assumed that the total daily demand is less than or equal to the total amount of boiling water per day. That is, it is assumed that the facility capacity of the hot water supply system 1 is sufficient for the demand.

(b) As an example, one frame is one hour. In addition, the plan period for the hot water storage amount is 24 hours.

25 (c) The hot water amount C1 to be boiled in one hour is calculated from past operation data.

(d) The lower limit value Lowlim of the hot water storage tank 3 is always secured.

[0032] The plan creation unit 24 creates a hot water storage plan by the following processing [1] to [7].

30 [1] First, the plan creation unit 24 acquires the prediction data output by the demand amount prediction device 10. The circles in Figs. 3A to 3D indicate Demand(i) in each frame i (each time).

[2] Next, the plan creation unit 24 sets Lowlim as the initial value of the Target (i) of each frame i. The asterisk in Fig. 3B indicates the initial value of Target(i) in each frame i.

35 [3] Next, the plan creation unit 24 calculates the hot water amount that should be secured at the start time of each frame i. First, the Necessary(24) of the final frame is calculated by the following equation (1).

$$\text{Necessary}(24) = \text{Demand}(24) + \text{C2} \dots (1)$$

40 Necessary (i) of the other frames (i = 0 to 23) is calculated by the following equation (2).

$$\text{Necessary}(i) = \text{Demand}(i) + \text{Necessary}(i + 1) \dots (2)$$

45 That is, all the future demand prediction amounts later than the frame i are added to the demand prediction amount of the frame i. The diamond-shaped mark in Fig. 3B indicates Necessary(i) in each frame i.

[4] Next, the plan creation unit 24 sets Afford(i) of each frame i based on the prediction data. For example, Afford(i) of 9:00 to 16:00 (frame i = 9 to 16) is set to "0", and the other Afford(i) is set to "1".

50 [5] Next, the plan creation unit 24 sets Target(i) = Necessary(i) for the frame of which Afford(i) is "0". The asterisks from 9:00 to 16:00 in Fig. 3C indicate Target(i) after the processing is performed.

[6] Next, the plan creation unit 24, for the first frame (referred to as the frame i_α) in which Afford(i) changes from "1" to "0", calculates a time (frame number) K needed to boil the hot water amount indicated by Demand(i_α) of the frame i_α , and sets the target hot water storage amount of the frame i that is traced back by the number of frames calculated from the frame i_α as Necessary(i_α). Specifically, the plan creation unit 24 calculates K by the following equation (3).

$$K = \text{ceil} \{ (\text{Necessary}(i_\alpha) - \text{Lowlim}) / \text{C1} \} + 1 \dots (3)$$

Here, ceil means rounding up an integer. In addition, 1 is added to allow time for boiling hot water. Then, the plan creation unit 24 calculates Target(i-K) by the following equation (4).

$$\text{Target}(i_{\alpha}-K) = \text{Necessary}(i_{\alpha}) \quad (K = 1, 2, \dots, K) \dots$$

(4)

The asterisks from 1:00 to 8:00 in Fig. 3C indicate Target(i) after the processing.

[7] In addition, the plan creation unit 24 sets the value of Target(i) to 100% for Target(i) exceeding 100%, and rounds up the value of Target(i) including the decimal point to an integer. Target(i) (i = 0 to 24) obtained in this manner is a hot water storage plan. Fig. 3D illustrates the hot water storage plan. The black asterisk in Fig. 3D is the hot water storage plan.

[0033] By the processing of [1] to [7], the plan creation unit 24 automatically calculates the hot water storage plan including the target hot water storage amount for each unit time. The plan creation unit 24 outputs the created hot water storage plan to the control device 30. The above processing is one example. For example, in [2], a value (larger value) safer than Lowlim may be set as the initial value of Target(i). In addition, as described below, a value that can avoid running out of hot water can be set in C1.

(Setting of Hot Water Amount that can be Boiled in One Frame)

[0034] For example, in a time zone when hot water does not flow out from the hot water storage tank 3, the target hot water storage amount of 95% is given when the hot water storage amount measured by the sensor 5 is 45%, and it is assumed that it takes 10 hours until the hot water storage amount measured by the sensor 5 reaches 95%. That is, it is assumed that 5% of hot water can be boiled per hour. The variable C1 is calculated by dividing the 5 (%/hour) by a predetermined safety factor (referred to as "2"). In this example, $C1 = 2.5$ (%/hour). By setting C1 on the safe side (less) based on the actual measurement value in this way, it is possible to create a hot water storage plan that does not cause running out of hot water. The setting of C1 may be performed by the user, or the plan creation unit 24 may acquire the measured value of the sensor 5 and set C1 by the above calculation.

[0035] In addition, the ability of the water heater 2 to boil hot water differs depending on a system configuration and an operating condition such as a pipe diameter, a pipe length, a pipe height, a type (open type, closed type) and the number of the hot water storage tank 3, an outside air temperature, and a set temperature, and thus it is preferable to perform setting for each hot water supply system 1. Therefore, for example, the plan creation unit 24 may create a learning model that calculates the water boiling amount per unit time by machine learning and the like, calculate the water boiling amount by the learning model, and set C1 based on the calculated water boiling amount. For example, when an outside air temperature, a temperature of the supplied water, and a set temperature of the hot water are input, the learning model outputs the hot water amount of the hot water that can be boiled per unit time by inputting. The plan creation unit 24 creates a learning model based on the hot water storage amount measured by the sensor 5 during the time when the water heater 2 operates and in a time zone when hot water does not outflow from the hot water storage tank 3, and the outside air temperature and water temperature during the same time. In addition, the plan creation unit 24 may input the estimated value of the outside air temperature and the water temperature for each hour in the target period of the hot water storage plan into the created learning model, calculate the C1 for each hour, and create the hot water storage plan by using the C1 for each hour.

(Countermeasures against Risk of Running out of Hot Water)

[0036] In the above description, it is decided to create a hot water storage plan up to 24 hours later, but for example, when a large demand is planned the day after next, there is a possibility that the hot water will run out. Next, a hot water storage plan creation method for reducing such a risk of running out of hot water will be described with reference to Figs. 4A and 4B.

[0037] Figs. 4A and 4B are a first graph and a second graph illustrating creation processing of a long-term hot water storage plan according to one embodiment of the present disclosure, respectively.

[0038] The plan creation unit 24 creates a longer-term hot water storage plan to reduce the risk of running out of hot water. For example, the plan creation unit 24 creates a hot water storage plan based on the demand prediction for N days ($N > 1$) in the future. When $N = 2$, the plan creation unit 24 creates a hot water storage plan up to 48 hours ahead. The demand amount prediction device 10 creates prediction data including a demand prediction amount for each time

up to 48 hours ahead. In the hot water storage plan creation device 20, the prediction data acquisition unit 21 acquires prediction data for 48 hours, and the plan creation unit 24 creates a hot water storage plan for 48 hours. Fig. 4A illustrates a graph in which the values of Target (i) ($i = 0$ to 48) created through the above processing [1] to [6] are plotted. Fig. 4B illustrates a hot water storage plan created by the plan creation unit 24 by further performing the processing of the above [7].

[0039] As described above, the plan creation unit 24 creates a hot water storage plan by accumulating the hot water amount needed in the future while the time needed to boil the hot water amount is considered. Therefore, the risk of running out of hot water can be reduced by creating a hot water storage plan based on a long-term demand prediction. Here, creating a hot water storage plan based on a long-term (for example, $N > 1$) demand prediction is called the hot water shortage prevention mode, creating a hot water storage plan based on a shortterm (for example, $N \leq 1$) demand prediction is called the efficiency priority mode, and these modes are collectively called the plan mode. The plan creation unit 24 can create a hot water storage plan by switching to a plan mode of either the hot water shortage prevention mode or the efficiency priority mode based on the settings of the user or based on the recent tendency of the used hot water amount. For example, when efficiency is prioritized over the risk of running out of hot water (priority is given to reducing the energy consumed for water boiling as much as possible), the user sets the efficiency priority mode. The creation target period of the hot water storage plan in the efficiency priority mode is not limited to 24 hours, but may be 12 hours or 6 hours. By setting the efficiency priority mode and creating a hot water storage plan, the operating cost of the hot water supply system 1 can be suppressed. In addition, the creation target period of the hot water storage plan in the hot water shortage prevention mode is not limited to 48 hours, but may be 72 hours or one week. By setting the hot water shortage prevention mode and creating a hot water storage plan, the hot water amount needed during the target period can be secured. In the case of the hot water shortage prevention mode, for example, a hot water storage plan up to N days ahead may be created based on the demand prediction up to N days ahead every day.

(Countermeasures against Sudden Risk of Running out of Hot Water)

[0040] Although a hot water storage plan is created in the hot water shortage prevention mode, there may be a shortage of hot water due to a sudden increase in demand. In such a case, the prediction data is manually corrected, and the plan creation unit 24 is made to execute the above [1] to [7] based on the corrected prediction data, such that a hot water storage plan for avoiding running out of hot water can be created. The situation is illustrated in Figs. 5A and 5B.

[0041] Figs. 5A and 5B are a first graph and a second graph illustrating how to deal with a fluctuation in hot water supply demand in one embodiment, respectively.

[0042] For example, when a sudden increase in demand is expected from 11:00 to 13:00, the value of Demand(i) from 11:00 to 13:00 in the prediction data of Fig. 3A is corrected as illustrated in Fig. 5A (inside H1 in Fig. 5A). Fig. 5B illustrates the hot water storage plan created by the plan creation unit 24 based on the prediction data after the correction. It can be seen that the hot water storage target value before 11:00 is increased as compared with Fig. 3D. As a result, a hot water storage plan that responds to an increase in demand can be created.

[0043] In addition, although a sudden decrease in demand is expected, a hot water storage plan that responds to the decrease in demand can be created by manually correcting the prediction data. As a result, the creation of wasteful hot water can be avoided.

(Automatic Setting of Plan Mode)

[0044] Fig. 6 is a diagram illustrating switching of the plan mode in one embodiment.

[0045] The actual data of one day illustrated in Fig. 6 is illustrated. An actual data P1 is the actual data when the decrease in the hot water storage amount is small with respect to the hot water storage plan, and an actual data P2 is the actual data when the decrease in the hot water storage amount is large with respect to the hot water storage plan.

[0046] For example, the plan creation unit 24 refers to the latest actual data for one week, determines that the error of the prediction data is within the permissible range when the change of the hot water storage amount for one week tends to be as illustrated by the actual data P1, and selects the efficiency priority mode to create a hot water storage plan. In addition, when the change in the hot water storage amount in one week tends to be as illustrated by the actual data P2, the plan creation unit 24 determines that the error of the prediction data is large and selects the hot water shortage prevention mode to create a hot water storage plan. More specifically, the plan creation unit 24 acquires actual data for a predetermined period in the past (for example, the day before, one week, and the same day one week before), for example, selects the hot water shortage prevention mode when the number of frames in which the difference between the remaining hot water storage amount and Lowlim is within a predetermined range is greater than or equal to a predetermined number, and selects the efficiency priority mode when the number of such frames is less than the predetermined number. By selecting the plan mode for the next day or later according to the remaining hot water storage amount on a daily basis in this way, a hot water storage plan without waste in line with the demand prediction can be automatically created while running out of hot water is avoided.

[0047] In addition, the plan creation unit 24 may not select either the efficiency priority mode or the hot water shortage prevention mode, but may set the length of the target period in multiple stages according to the difference between the remaining hot water storage amount and Lowlim. For example, the plan creation unit 24 calculates a representative value (for example, an average value, a mode value, a minimum value, a maximum value, a median value, and the like) of the difference between the remaining hot water storage amount and Lowlim from the actual data of the past predetermined period. Then, the plan creation unit 24 sets the length of the target period to 48 hours when the representative value is less than or equal to 10%, sets the length of the target period to 36 hours when the representative value is 10% to 20%, sets the length of the target period to 30 hours when the representative value is 20% to 30%, sets 24 hours when the representative value is greater than or equal to 30%, and the like, such that the target period is set according to the difference between the remaining hot water storage amount and Lowlim. In this way, the difference between the remaining hot water storage amount and Lowlim is considered as the magnitude of the error of the prediction model, and the target period is set according to the magnitude of the error of the prediction model. As a result, a hot water storage plan that compensates for errors in the prediction model can be created.

[0048] In addition, the plan creation unit 24 may correct the hot water storage plan instead of the length of the target period. For example, the plan creation unit 24 may create a hot water storage plan in which a predetermined value (for example, +5%) is added to the target hot water storage amount, Target (i) of each frame of the hot water storage plan after creation (or each frame in the time zone when hot water consumption tends to be high) when the number of frames in which the difference between the remaining hot water storage amount and Lowlim is within a predetermined range is greater than or equal to a predetermined number based on the actual data of the past predetermined period, and may output the hot water storage plan created by the processing of [1] to [7] to the control device 30 when the number of frames in which difference between the remaining hot water storage amount and Lowlim is within a predetermined range is less than the predetermined number.

[0049] In addition, in order to create a more efficient hot water storage plan, the plan creation unit 24, for example, with respect to the hot water storage plan created in the efficiency priority mode and based on the actual data of the past predetermined period, may add an optional correction amount (for example, +5%) to Target(i) of a frame in which the difference between the remaining hot water storage amount and the Lowlim is within a predetermined range, subtract an optional correction amount (for example, -3%) from Target (i) of a frame in which the difference between the remaining hot water storage amount and Lowlim is greater than the predetermined value, learn the correction amount added or subtracted for each frame, and calculate a hot water storage plan that has no excess or deficiency for the demand. In addition, in the learning, the difference between the remaining hot water amount and Lowlim and the size of the appropriate correction amount may be learned together with the parameter such as the outside air temperature, the time, and the weather. In this way, by adjusting the target hot water storage amount from the next day or later according to the remaining hot water storage amount on a daily basis, it is possible to create a hot water storage plan optimized for the minimum hot water storage amount such that the hot water does not run out. In addition, by correcting the target hot water storage amount based on the daily actual result, for example, a hot water storage plan close to the actual demand can be created even while the prediction model cannot cope with the change in the demand in the facility 4.

(Operation of Hot Water Storage Plan Creation Processing)

[0050] Next, the flow of the hot water storage plan creation processing will be described.

[0051] Fig. 7 is a flowchart illustrating an example of hot water storage plan creation processing in one embodiment.

[0052] First, the user performs various settings in the hot water storage plan creation device 20. For example, the user sets the variables C1, C2, and Lowlim used to create the hot water storage plan, automatically sets or fixes the plan mode, or sets whether the setting of the target period is set according to the difference between the remaining hot water storage amount and Lowlim. When fixing the plan mode, the user sets either the efficiency priority mode or the hot water shortage prevention mode. In addition, the user sets the target period in each of the efficiency priority mode and the hot water shortage prevention mode. When setting the target period according to the difference between the remaining hot water storage amount and Lowlim, the user sets the target period according to the difference. The setting acceptance unit 23 accepts the settings (step S1) and writes the settings in the storage unit 25.

[0053] Next, the plan creation unit 24 determines whether the target period is variable (step S2). The plan creation unit 24 determines that the target period is variable when the plan mode is set to be automatic or when it is selected to set the target period according to the difference between the remaining hot water storage amount and Lowlim, and determines that the target period is not variable when the efficiency priority mode or the hot water shortage prevention mode is set in the plan mode. When it is determined that the target period is variable (step S2; Yes), the actual data acquisition unit 22 acquires the actual data (step S3). The plan creation unit 24 determines the causing risk of running out of hot water based on the actual data, selects the hot water shortage prevention mode when the risk of running out of hot water is greater than or equal to a predetermined standard, and selects the efficiency priority mode when the risk of running out of hot water is less than the standard. The plan creation unit 24 sets the target period corresponding to

the selected plan mode (step S4). Alternatively, the plan creation unit 24 sets a target period according to the difference between the remaining hot water storage amount and Lowlim based on the actual data (step S4).

[0054] Next, the hot water storage plan creation device 20 designates the target period to the demand amount prediction device 10 and instructs the demand amount prediction device 10 to create prediction data. In the demand amount prediction device 10, the demand amount prediction unit 13 inputs the value (prediction value) of the descriptive variable in the designated target period into the prediction model, and creates the prediction data including the demand prediction amount of hot water for each unit time in the target period (step S5). The demand amount prediction unit 13 outputs the prediction data to the hot water storage plan creation device 20. In the hot water storage plan creation device 20, the prediction data acquisition unit 21 acquires the prediction data (step S6).

[0055] Next, the user determines whether the demand in the target period is expected to change, and inputs the frame and the correction amount to be changed into the hot water storage plan creation device 20 when the change is expected (step S7; Yes). The setting acceptance unit 23 acquires the correction amount for changing the demand, and corrects the prediction data as described with reference to Fig. 5A (step S8).

[0056] When the correction of the prediction data is completed or when there is no change in the demand (step S7; No), the plan creation unit 24 performs the above processing [1] to [7] and creates a hot water storage plan of the target period set by the above processing (step S9).

[0057] As described above, according to the present embodiment, the target hot water storage amount (a command value to the water heater 2) for each unit time in the target period can be automatically calculated based on the demand prediction of hot water. In addition, since the target hot water storage amount is calculated based on the prediction data calculated based on the operation data of the hot water supply system 1, the target hot water storage amount can be applied to any system without depending on the facility configuration (the type and number of hot water storage tanks 3, the capacity and number of water heaters 2, and a pipe diameter and a pipe length) and the operating condition of the hot water supply system 1.

[0058] In addition, since it is a plan without waste based on demand prediction data and it is possible to create a hot water storage plan that takes into account the time needed to boil water, running out of hot water can be prevented in advance when the actual demand is less than or equal to the prediction data.

[0059] In addition, by optionally setting the target period of plan creation, a hot water storage plan (hot water shortage prevention mode) that avoids running out of hot water more reliably, or a hot water storage plan that prioritizes efficiency with less waste (efficiency priority mode) can be created. Alternatively, a hot water storage plan that achieves both efficiency and prevention of running out of hot water may be created by designating an intermediate length between the hot water shortage prevention mode and the efficiency priority mode in the target period. In addition, since the efficiency priority mode and the hot water shortage prevention mode can be automatically selected based on the actual data, the user does not need to think about which plan mode to adopt. Furthermore, by flexibly changing the target period according to the remaining hot water storage amount indicated by the actual data, a hot water storage plan that compensates for the error of the prediction model can be created.

[0060] In addition, when the actual demand is expected to deviate from the prediction data due to a sudden event that is difficult to predict, a hot water storage plan that responds to a fluctuation in demand can be created by manually correcting the prediction data.

[0061] Fig. 8 is a diagram illustrating an example of a hardware configuration of a control system according to one embodiment.

[0062] The computer 900 includes a CPU 901, a main storage device 902, an auxiliary storage device 903, an input and output interface 904, and a communication interface 905.

[0063] The demand amount prediction device 10, the hot water storage plan creation device 20, and the control device 30 described above are mounted on the computer 900. Each of the above-mentioned functions is stored in the auxiliary storage device 903 in the form of a program. The CPU 901 reads a program from the auxiliary storage device 903, expands the program to the main storage device 902, and executes the above processing according to the program. In addition, the CPU 901 secures a storage area in the main storage device 902 according to the program. In addition, the CPU 901 secures a storage area that stores the data being processed in the auxiliary storage device 903 according to the program.

[0064] A program that realizes all or a portion of the functions of the demand amount prediction device 10, the hot water storage plan creation device 20, and the control device 30 may be recorded on a computer-readable recording medium, and the program recorded on the recording medium may be read and executed by the computer system, such that the processing by each functional unit may be performed. The term "computer system" as used herein includes an OS and hardware such as a peripheral device. In addition, the "computer system" includes the homepage providing environment (or display environment) when the WWW system is used. In addition, the "computer-readable recording medium" refers to a portable medium such as CD, DVD, and USB, or a storage device such as a hard disk built in a computer system. In addition, when the program is distributed to the computer 900 by a communication line, the computer 900 that receives the distribution may expand the program to the main storage device 902 and execute the above

processing. In addition, the above program may be one for realizing a portion of the above-mentioned functions, and further may be one capable of realizing the above-mentioned functions in combination with a program already recorded in the computer system.

[0065] As described above, some embodiments according to the present disclosure have been described, but all of these embodiments are presented as examples and are not intended to limit the scope of the disclosure. These embodiments can be implemented in various other embodiments, and various omissions, replacements, and changes can be made without departing from the gist of the disclosure. These embodiments and variations thereof are included in the scope of the disclosure described in the claims and the equivalent scope thereof, as are included in the scope and gist of the disclosure.

<Additional Notes>

[0066] The hot water storage plan creation system, the hot water storage plan creation method, and the program described in each embodiment are grasped as follows, for example.

(1) A hot water storage plan creation system (the control system 100 and the hot water storage plan creation device 20) according to a first aspect includes a prediction data acquisition unit 21 that acquires prediction data of hot water storage demand for each unit time in a predetermined period, and a plan creation unit 24 that creates a hot water storage plan that defines a target hot water storage amount for each unit time in the predetermined period based on the prediction data.

As a result, it is possible to automatically set a water boiling amount without waste that satisfies the demand prediction amount of daily hot water supply.

(2) The hot water storage plan creation system (the control system 100 and the hot water storage plan creation device 20) according to a second aspect is the hot water storage plan creation system of (1), and further includes the setting acceptance unit 23 that accepts a setting of the predetermined period.

As a result, a hot water storage plan of an optional target period can be created. For example, when efficiency is prioritized, a short period is set for a predetermined period, and when it is desirable to create a more conservative hot water storage plan that expects a fluctuation of a future demand amount, a long period is set for the predetermined period, such that the desired hot water storage plan can be created.

(3) The hot water storage plan creation system (the control system 100 and the hot water storage plan creation device 20) according to a third aspect is the hot water storage plan creation system of (2), and the setting acceptance unit 23 accepts a change in the prediction data.

As a result, a hot water storage plan that responds to a sudden change in demand can be created.

(4) The hot water storage plan creation system (the control system 100 and the hot water storage plan creation device 20) according to a fourth aspect is the hot water storage plan creation system of (1) to (3), and further includes the actual data acquisition unit 22 that acquires actual data of a remaining hot water storage amount in the hot water storage tank 3, and the plan creation unit 24 sets the predetermined period based on the actual data.

(5) The hot water storage plan creation system (the control system 100 and the hot water storage plan creation device 20) according to a fifth aspect is the hot water storage plan creation system of (4), and the plan creation unit 24 sets a first period (for example, 48 hours) set for a hot water shortage prevention mode to the predetermined period when the remaining hot water storage amount indicated by the actual data is less than a predetermined threshold value, and sets a second period (for example, 24 hours) shorter than the first period set for an efficiency priority mode to the predetermined period when the remaining hot water storage amount is greater than or equal to the threshold value.

(6) The hot water storage plan creation system (the control system 100 and the hot water storage plan creation device 20) according to a sixth aspect is the hot water storage plan creation system of (4), and based on a difference between the remaining hot water storage amount indicated by the actual data and a predetermined threshold value, the plan creation unit 24 sets a shorter period to the predetermined period as the difference is larger, and sets a longer period to the predetermined period as the difference is smaller.

[0067] (For example, the plan creation unit 24 sets 48 hours to the target period when the representative value of the difference is less than or equal to 10%, 36 hours when the representative value is 10% to 20%, 30 hours when the representative value is 20% to 30%, and 24 hours when the representative value is greater than or equal to 30%)

[0068] According to the fourth to sixth aspects, it is possible to automatically set a hot water storage plan without waste according to the demand prediction while running out of hot water is avoided based on the actual result of the remaining hot water storage amount.

[0069] (7) The hot water storage plan creation system (the control system 100 and the hot water storage plan creation device 20) according to a seventh aspect is the hot water storage plan creation system of (1) to (6), and when the hot

water storage demand (Demand(i)) in a first unit time exceeds a hot water amount C1 capable of being created per unit time, the plan creation unit 24 sets a total of the hot water storage demand in the first unit time and the hot water storage demand for each unit time in the future as compared with the first unit time in the predetermined period, to the target hot water storage amount (Target(i)) in the first unit time (processing of the above [5]).

[0070] (8) The hot water storage plan creation system (the control system 100 and the hot water storage plan creation device 20) according to an eighth aspect is the hot water storage plan creation system of (7), and when the hot water storage demand in the first unit time exceeds the hot water amount C1 capable of being created per unit time, the plan creation unit 24 calculates the number of the unit times corresponding to a time needed to create hot water for the hot water storage demand, and sets the target hot water storage amount of the first unit time, to the target hot water storage amount of each of the calculated number of the unit times before the first unit time (processing of the above [6]).

[0071] According to the seventh to eighth aspects, although the demand amount exceeds the hot water creation capacity per unit time, it is possible to create a hot water storage plan that can create the hot water amount that satisfies the demand by the needed time.

[0072] (9) The hot water storage plan creation system (the control system 100 and the hot water storage plan creation device 20) according to a ninth aspect is the hot water storage plan creation system of (8), and the plan creation unit 24 calculates the hot water amount C1 capable of being created per unit time by machine learning based on a hot water amount actually created per unit time.

[0073] As a result, the precision of the hot water storage plan can be improved.

[0074] (10) The hot water storage plan creation system (the control system 100, the hot water storage plan creation device 20, and the demand amount prediction device 10) according to a tenth aspect is the hot water storage plan creation system (the control system 100, the hot water storage plan creation device 20, and the demand amount prediction device 10) of (1) to (9), and further includes a prediction model creation unit 12 that creates a prediction model that outputs, when a condition that affects demand of hot water is input, a hot water demand amount under the condition and a demand amount prediction unit 13 that creates the prediction data based on the condition in the predetermined period and the prediction model.

[0075] (11) A hot water storage plan creation method according to an eleventh aspect is a hot water storage plan creation method executed by the hot water storage plan creation system (the control system 100 and the hot water storage plan creation device 20), and includes a step of acquiring prediction data of hot water storage demand for each unit time in a predetermined period, and a step of creating a hot water storage plan that defines a target hot water storage amount for each unit time in the predetermined period based on the prediction data.

[0076] (12) A program according to a twelfth aspect causes a computer 900 to execute a step of acquiring prediction data of hot water storage demand for each unit time in a predetermined period, and a step of creating a hot water storage plan that defines a target hot water storage amount for each unit time in the predetermined period based on the prediction data.

Reference Signs List

[0077]

1	Hot water supply system
2	Water heater
3	Hot water storage tank
4	Facility
5	Sensor
6A, 6B, 6C	Pipe
100	Control system
10	Demand amount prediction device
11	Data acquisition unit
12	Prediction model creation unit
13	Demand amount prediction unit
14	Storage unit
20	Hot water storage plan creation device
21	Prediction data acquisition unit
22	Actual data acquisition unit
23	Setting acceptance unit
24	Plan creation unit
25	Storage unit
30	Control device

900	Computer
901	CPU
902	Main storage device
903	Auxiliary storage device
5 904	Input and output interface
905	Communication interface

Claims

1. A hot water storage plan creation system comprising:

a prediction data acquisition unit that acquires prediction data of hot water storage demand for each unit time in a predetermined period; and

a plan creation unit that creates a hot water storage plan that defines a target hot water storage amount for each unit time in the predetermined period based on the prediction data.

2. The hot water storage plan creation system according to claim 1, further comprising a setting acceptance unit that accepts a setting of the predetermined period.

3. The hot water storage plan creation system according to claim 2, wherein the setting acceptance unit accepts a change in the prediction data.

4. The hot water storage plan creation system according to any one of claims 1 to 3, further comprising

an actual data acquisition unit that acquires actual data of a remaining hot water storage amount in a hot water storage tank, wherein

the plan creation unit sets the predetermined period based on the actual data.

5. The hot water storage plan creation system according to claim 4, wherein the plan creation unit sets a first period set for a hot water shortage prevention mode to the predetermined period when the remaining hot water storage amount indicated by the actual data is less than a predetermined threshold value, and sets a second period shorter than the first period set for an efficiency priority mode to the predetermined period when the remaining hot water storage amount is greater than or equal to the threshold value.

6. The hot water storage plan creation system according to claim 4, wherein based on a difference between the remaining hot water storage amount indicated by the actual data and a predetermined threshold value, the plan creation unit sets a shorter period to the predetermined period as the difference is larger, and sets a longer period to the predetermined period as the difference is smaller.

7. The hot water storage plan creation system according to any one of claims 1 to 6, wherein when the hot water storage demand in a first unit time exceeds a hot water amount capable of being created per unit time, the plan creation unit sets a total of the hot water storage demand in the first unit time and the hot water storage demand for each unit time in the future as compared with the first unit time in the predetermined period, to the target hot water storage amount in the first unit time.

8. The hot water storage plan creation system according to claim 7, wherein when the hot water storage demand in the first unit time exceeds the hot water amount capable of being created per unit time, the plan creation unit calculates the number of the unit times corresponding to a time needed to create hot water for the hot water storage demand, and sets the target hot water storage amount of the first unit time, to the target hot water storage amount of each of the calculated number of the unit times before the first unit time.

9. The hot water storage plan creation system according to claim 8, wherein the plan creation unit calculates the hot water amount capable of being created per unit time by machine learning based on a hot water amount actually created per unit time.

10. The hot water storage plan creation system according to any one of claims 1 to 8, further comprising:

a prediction model creation unit that creates a predication model that outputs, when a condition that affects demand of hot water is input, a hot water demand amount under the condition; and
a demand amount prediction unit that creates the prediction data based on the condition in the predetermined period and the prediction model.

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11. A hot water storage plan creation method executed by a hot water storage plan creation system, the method comprising:

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a step of acquiring prediction data of hot water storage demand for each unit time in a predetermined period; and
a step of creating a hot water storage plan that defines a target hot water storage amount for each unit time in the predetermined period based on the prediction data.

12. A program that causes a computer to execute
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a step of acquiring prediction data of hot water storage demand for each unit time in a predetermined period, and
a step of creating a hot water storage plan that defines a target hot water storage amount for each unit time in the predetermined period based on the prediction data.

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FIG. 1

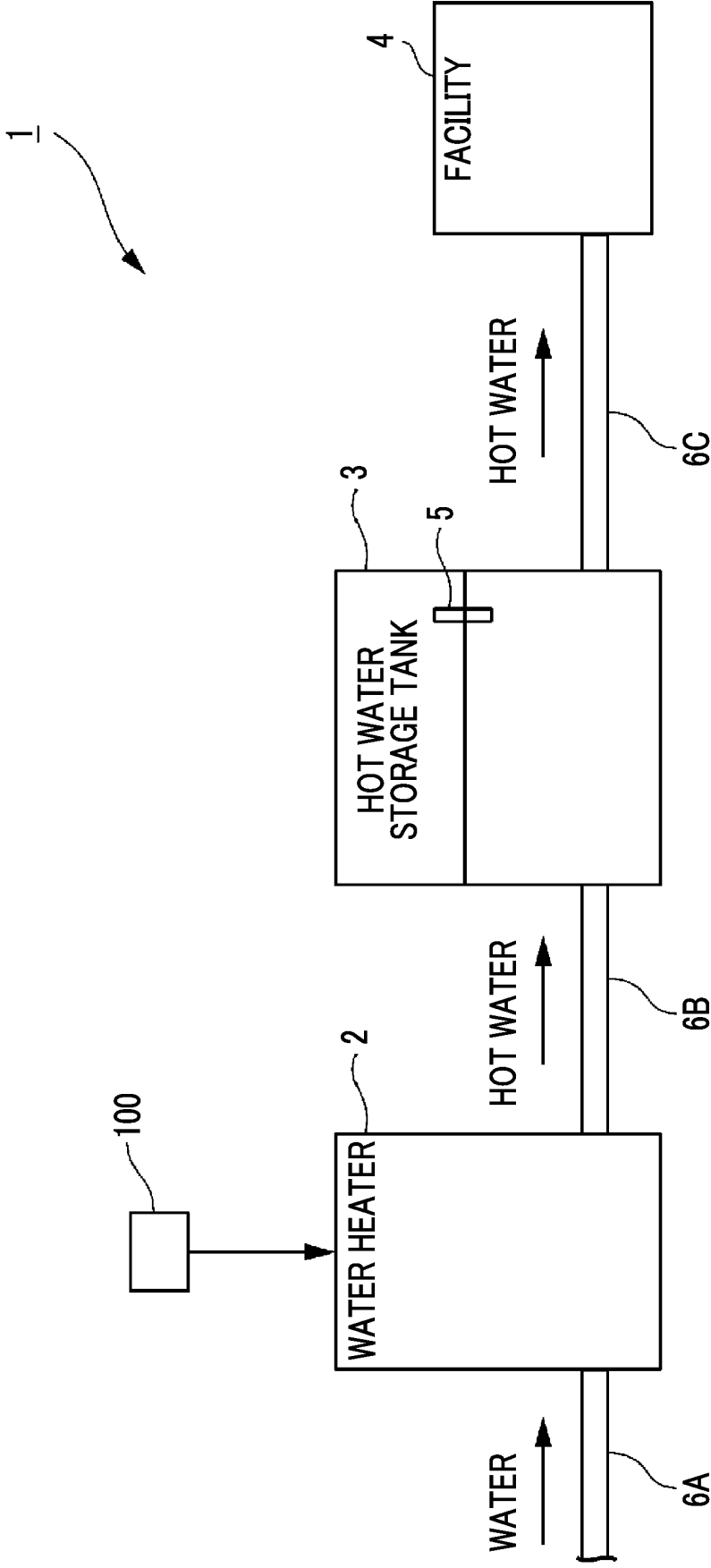


FIG. 2

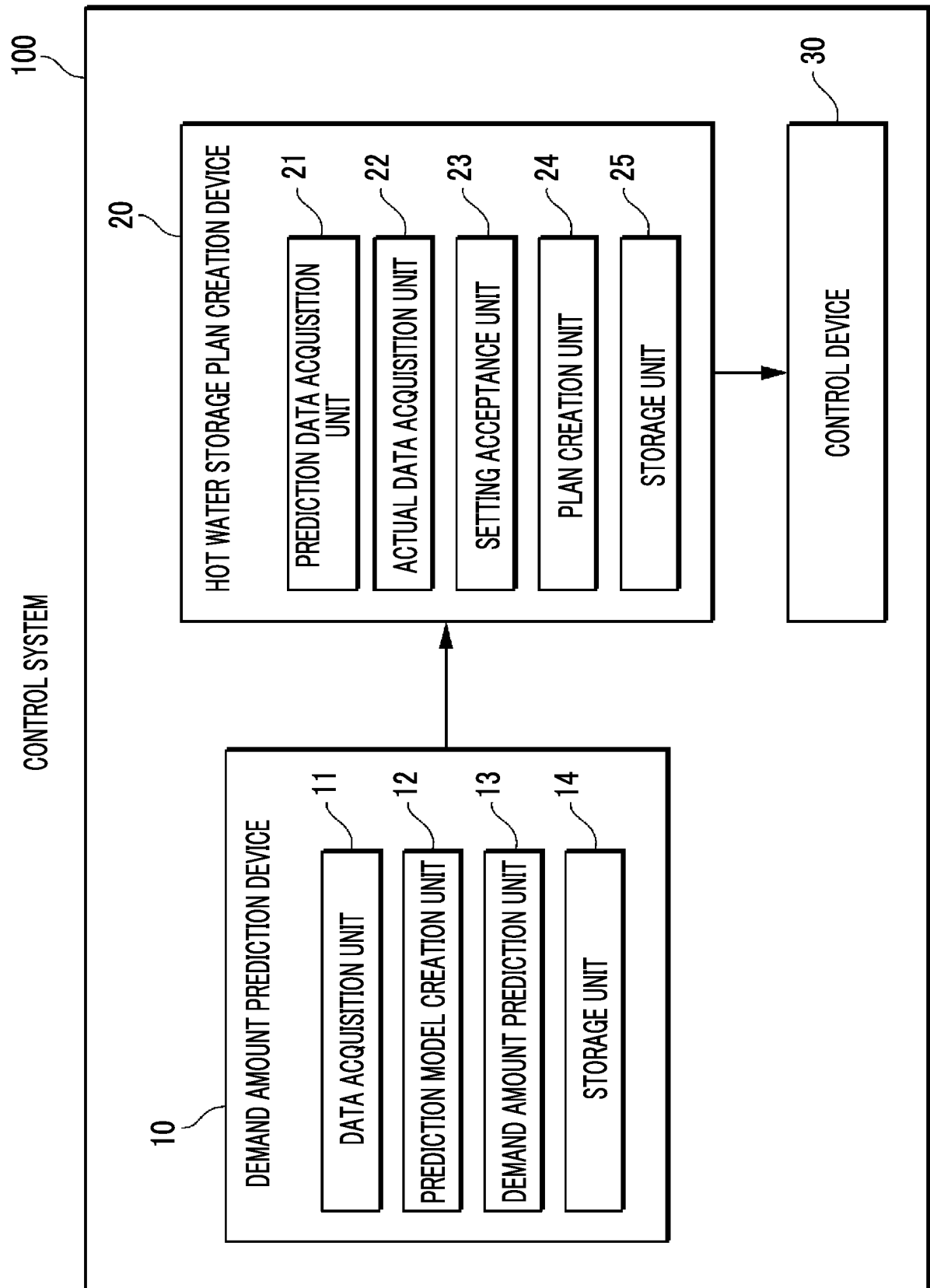


FIG. 3A

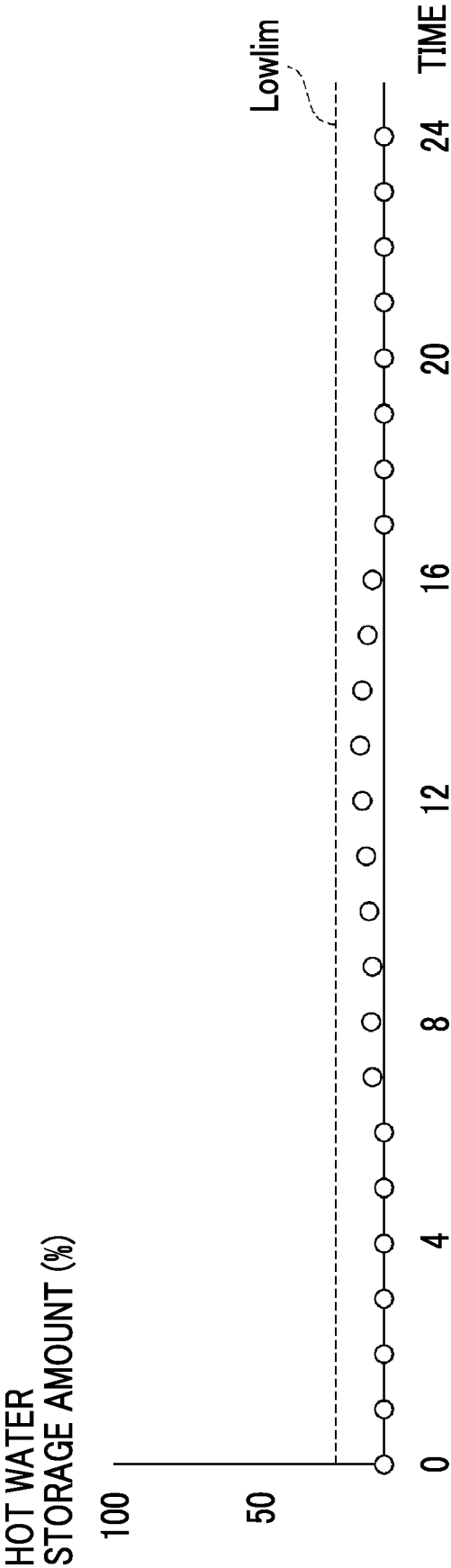


FIG. 3B

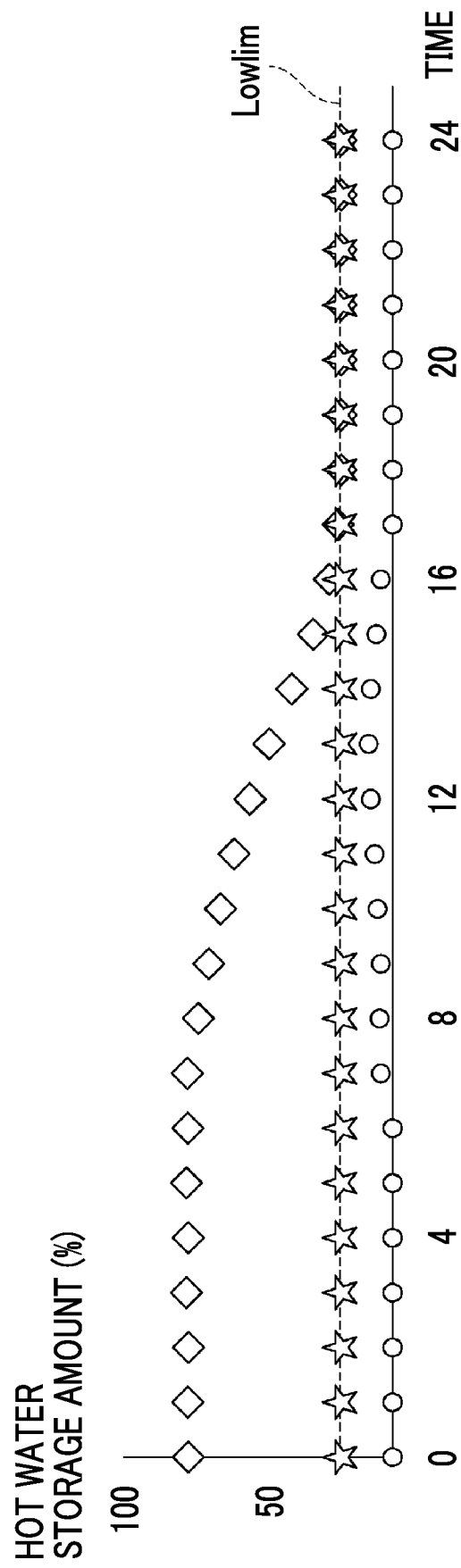


FIG. 3C

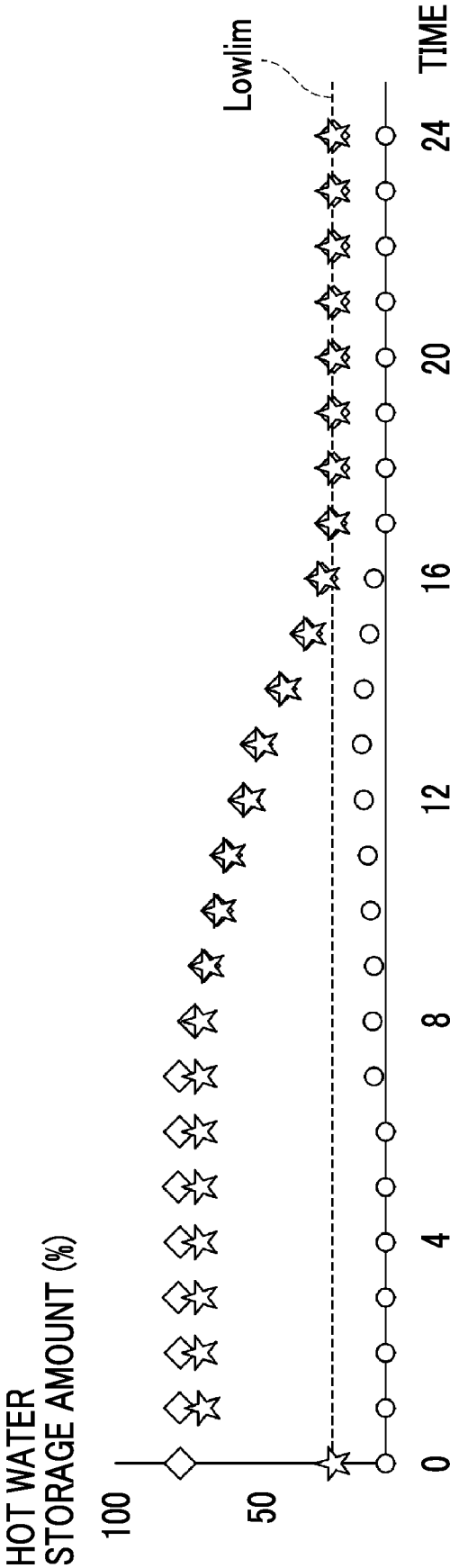


FIG. 3D

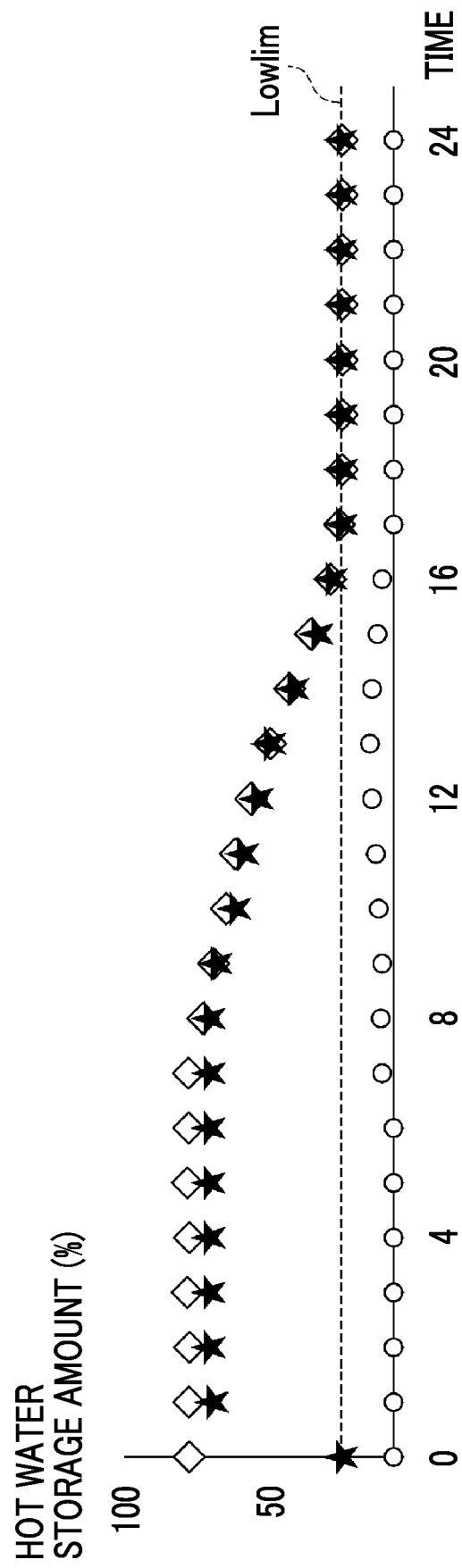


FIG. 4A

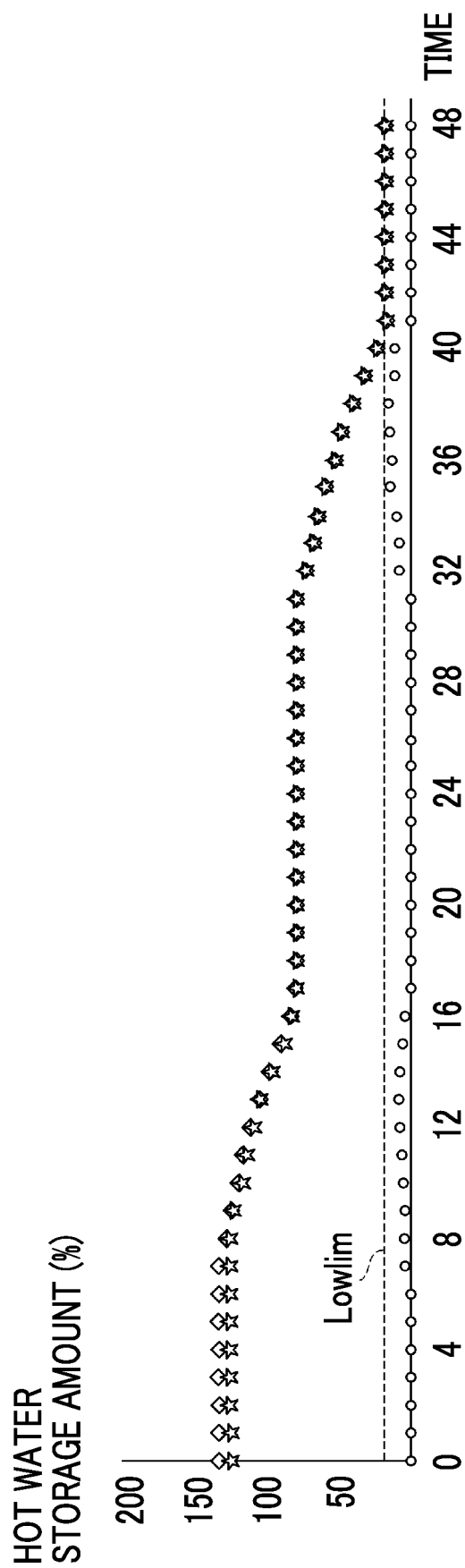


FIG. 4B

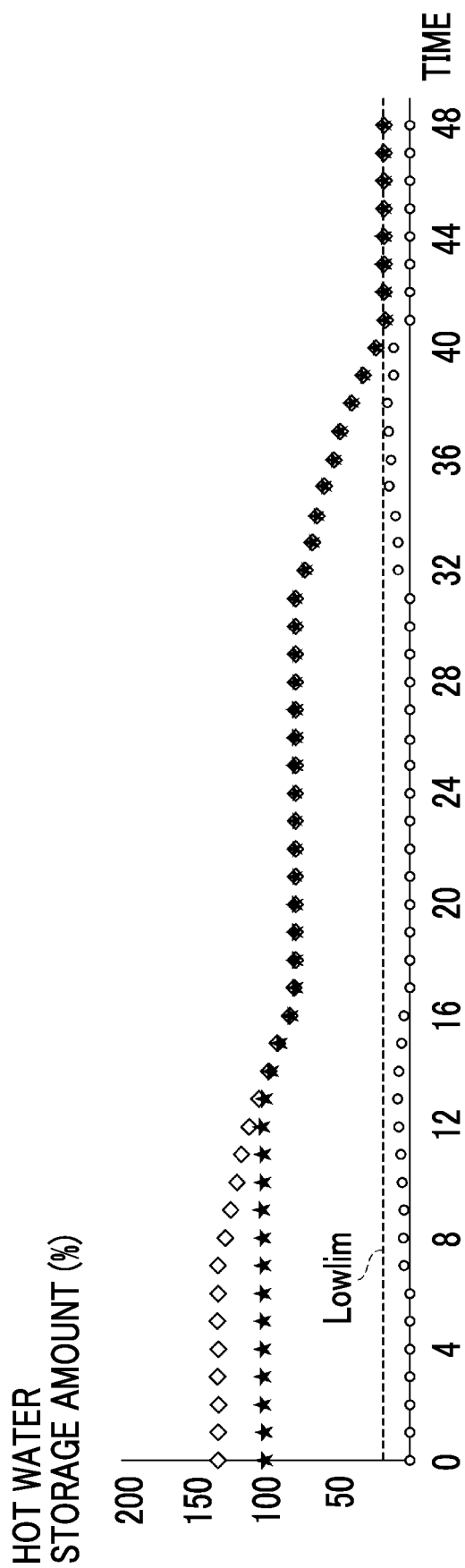


FIG. 5A

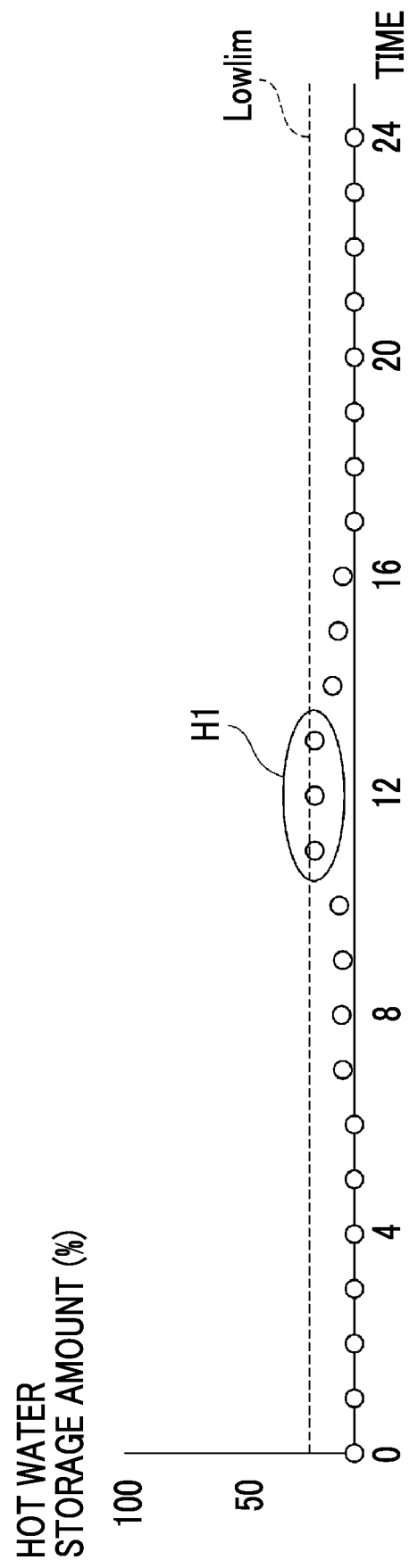
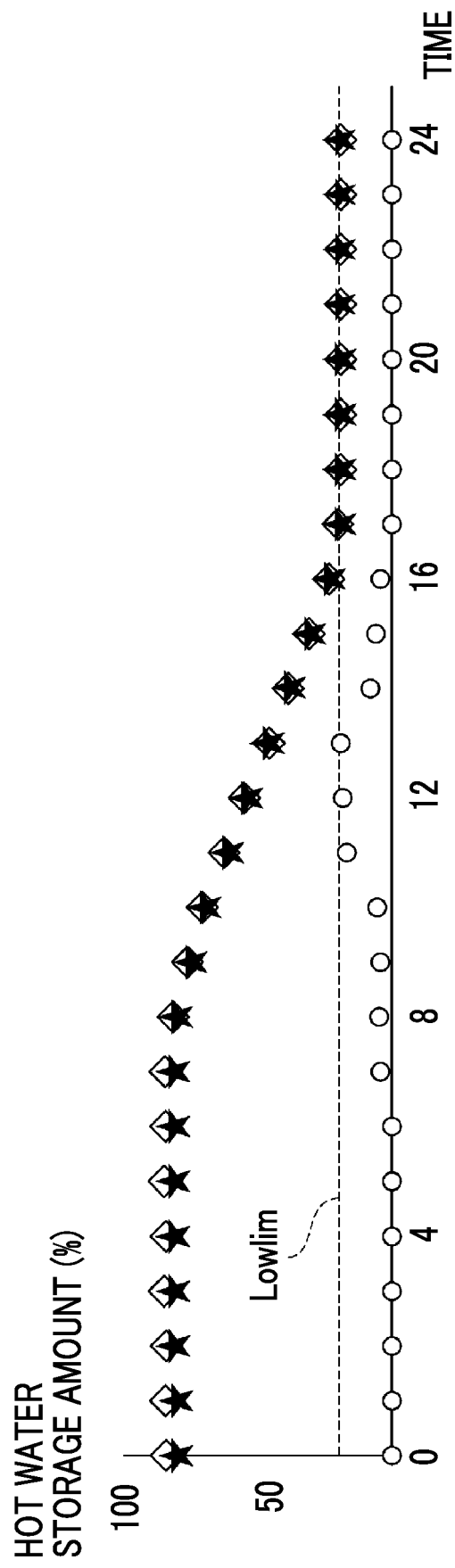


FIG. 5B



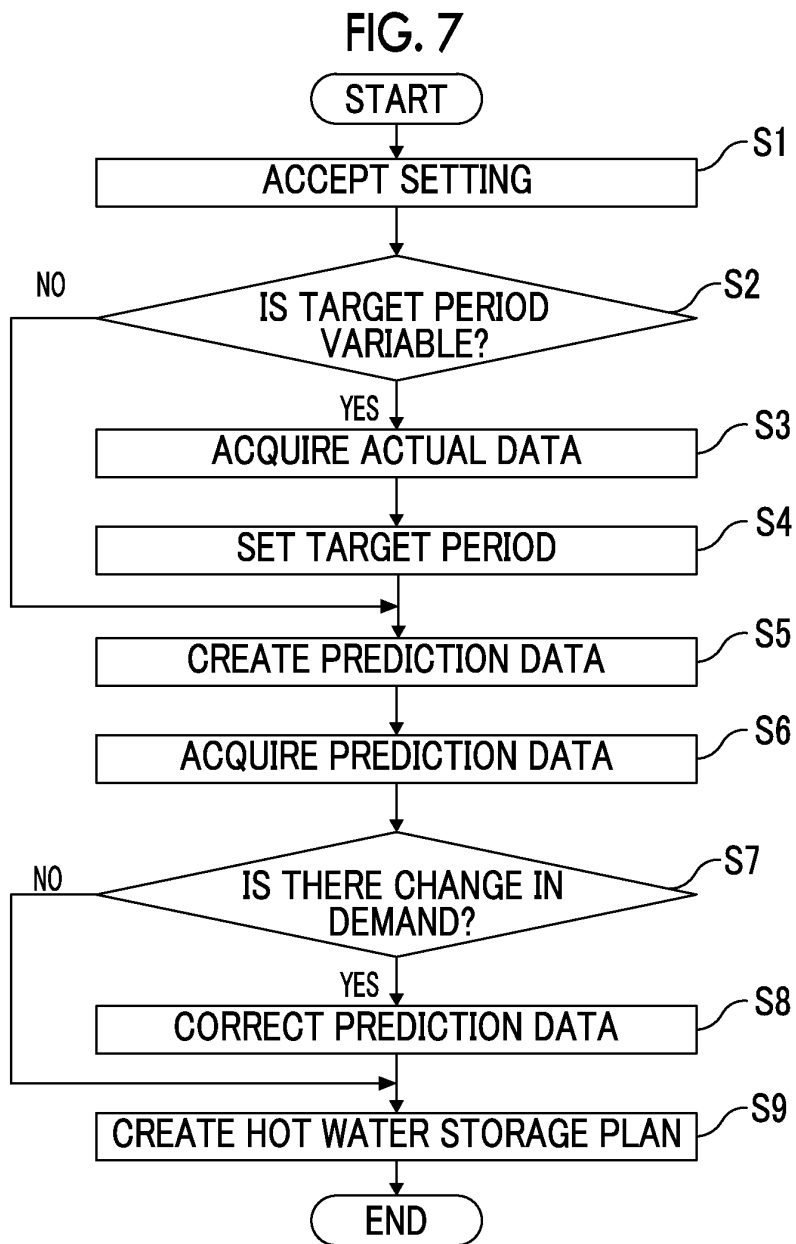
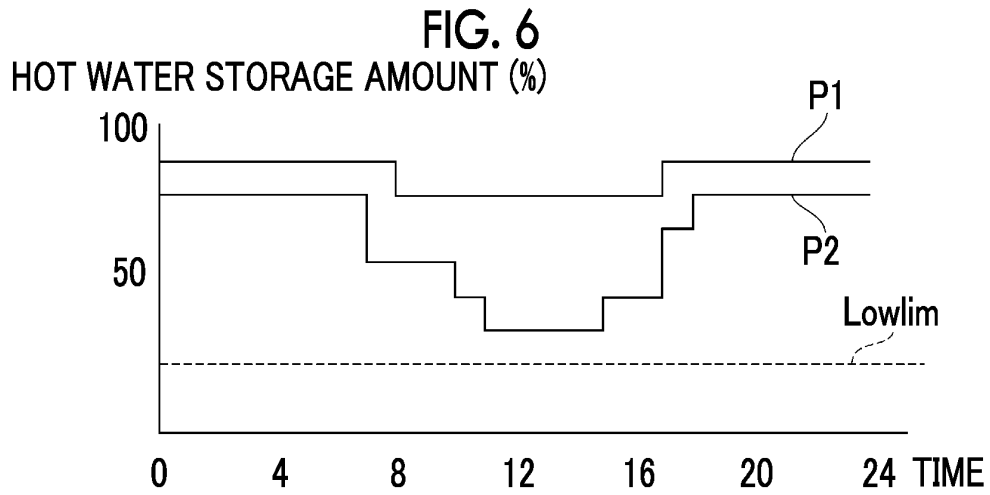
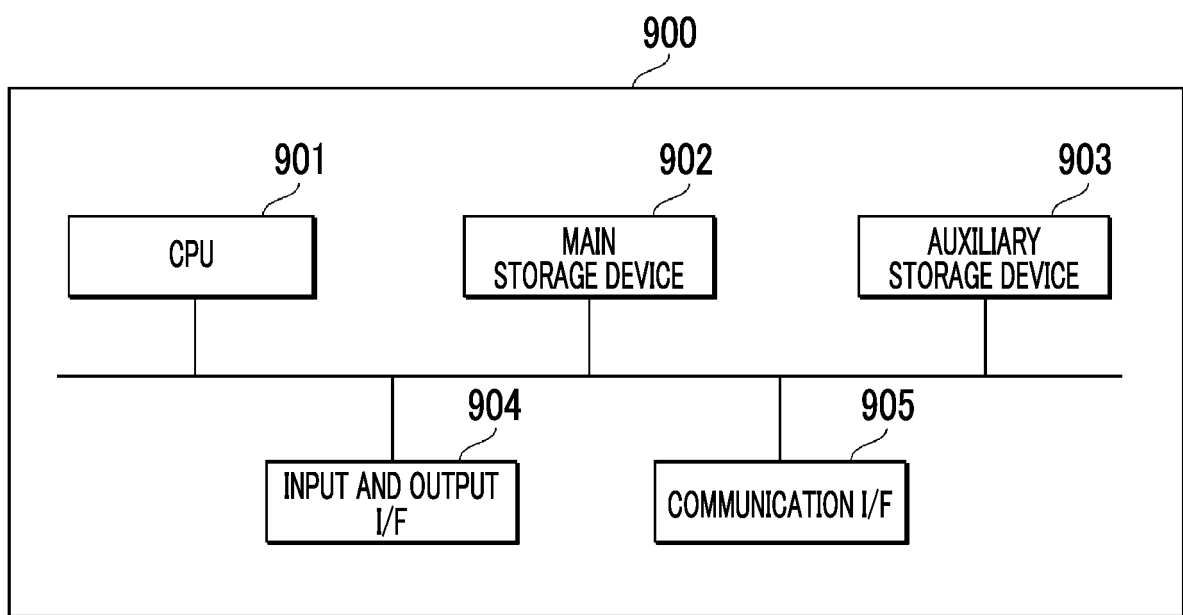


FIG. 8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2021/018580

A. CLASSIFICATION OF SUBJECT MATTER

F24H 1/18 (2006.01) i

FI: F24H1/18 301Z; F24H1/18 301H; F24H1/18 Z

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)

F24H1/18

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 1971-2021

Registered utility model specifications of Japan 1996-2021

Published registered utility model applications of Japan 1994-2021

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.
X	JP 2011-89702 A (RINNAI CORP.) 06 May 2011 (2011-05-06) paragraphs [0013]-[0062], fig. 1-5	1, 11-12
Y		2-3, 10
A		4-9
Y	JP 2011-27408 A (OSAKA GAS CO., LTD.) 10 February 2011 (2011-02-10) paragraphs [0065]-[0066], [0216]	2-3, 10
Y	JP 2014-149094 A (NORITZ CORPORATION) 21 August 2014 (2014-08-21) paragraph [0025]	3, 10
Y	JP 2011-247513 A (MITSUBISHI ELECTRIC CORP.) 08 December 2011 (2011-12-08) paragraphs [0034]-[0035], [0050], [0069]-[0087], fig. 3-4, 7	10



Further documents are listed in the continuation of Box C.



See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T"

later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X"

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y"

document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"

document member of the same patent family

Date of the actual completion of the international search

03 June 2021 (03.06.2021)

Date of mailing of the international search report

22 June 2021 (22.06.2021)

Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/JP2021/018580

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
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JP 2011-89702 A	06 May 2011	(Family: none)	
JP 2011-27408 A	10 Feb. 2011	JP 2006-29771 A	
JP 2014-149094 A	21 Aug. 2014	(Family: none)	
JP 2011-247513 A	08 Dec. 2011	(Family: none)	

REFERENCES CITED IN THE DESCRIPTION

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