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CONTROL SYSTEM AND METHOD FOR A HEAT PUMP WATER HEATER

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Abstract

A method of controlling the operation of a storage-type heat pump water heater, comprising: operating said storage-type heat pump water heater for a predetermined operating period; collecting data associated with the operation of the storage-type heat pump water heater during the predetermined operating period, said data including data associated with the hot water consumption over the predetermined operating period and the hours of operation of the heat pump of the storage-type heat pump water heater during the predetermined operating period; determine the trend of hot water consumption over the predetermined operating period; determine the required hours of operation of the heat pump for a predetermined future use period based on the data collected for the predetermined operating period; and controlling the operation of the heat pump for the future use period such that the operating hours of the heat pump does not exceed the required hours of operation of the heat pump during this period.

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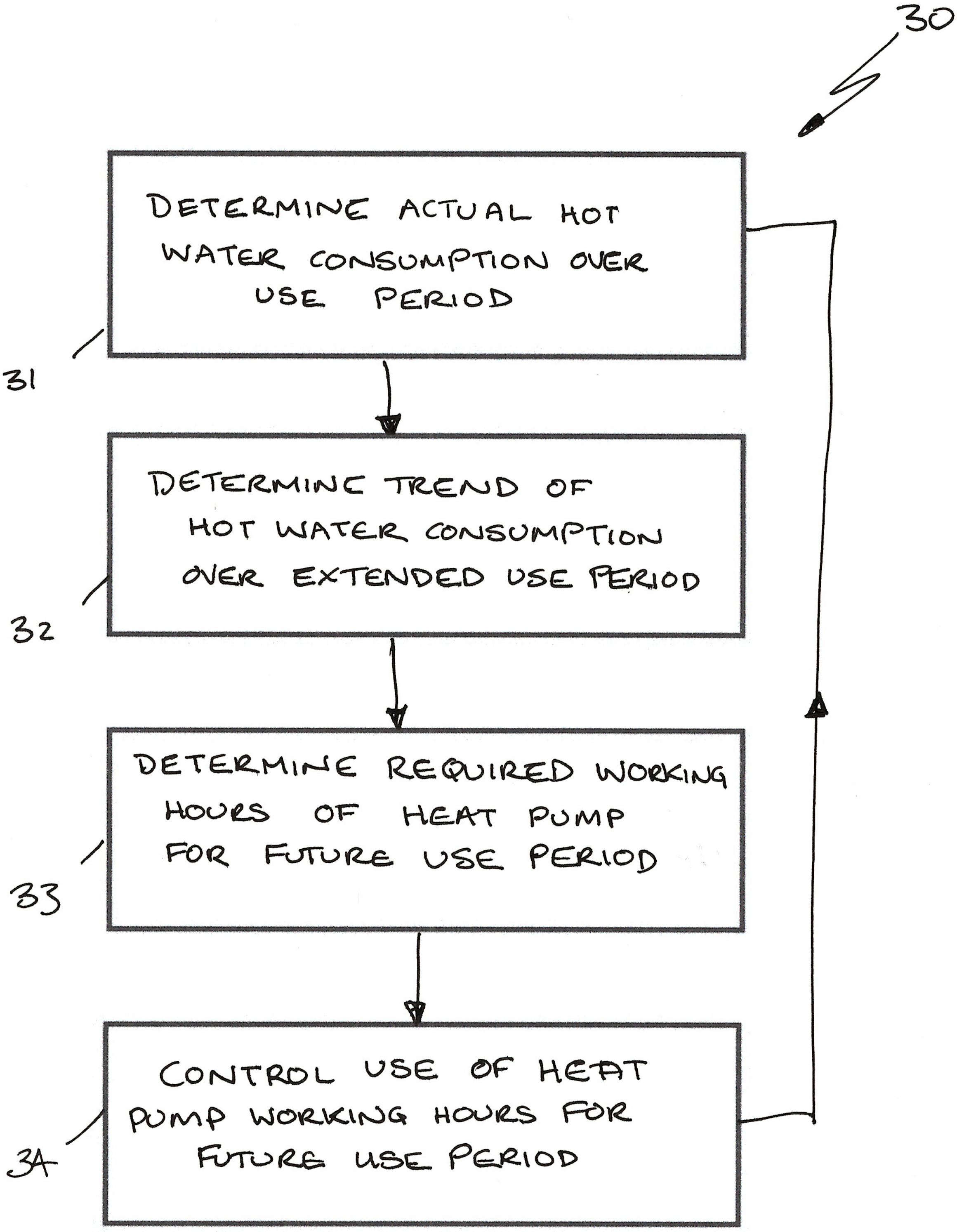

FIG. 2

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CONTROL SYSTEM AND METHOD FOR A HEAT PUMP WATER HEATER

FIELD OF INVENTION

The present invention relates generally water heaters for heating up a volume of water, and in particular, to heat pump water heaters and methods of operating such water heaters in an efficient manner.

BACKGROUND OF THE INVENTION

Water heating systems are an integral part of most domestic and commercial buildings to provide a reliable source of hot water for use by residents and occupants of the building. The hot water is typically heated in a tank and maintained at a desired temperature so that it can be delivered to an outlet in the building upon demand. As such systems require heating of water to a desired temperature and maintaining that water at the desired temperature, such systems can require considerable power to perform this task and can use considerable energy in the process.

A variety of different hot water heating systems have been proposed for this purpose, utilising electricity or gas to heat the water so as to minimise energy wastage. hot water storage units typically operate by sending cold water into a storage tank, where one or two elements are located to heat the water present therein. Once the water has been heated to a desired temperature, the hot water rises to the top of the tank and travels to the relevant outlet as it is needed. A thermostat is used to control and maintain the temperature of the heated water, which is generally above 60°C to avoid the growth of Legionella bacteria. To avoid the need to constantly maintain the tank of water at a desired temperature, instant hot water systems have also been developed, which work by heating water as needed, instead of heating and storing it. Such systems identify when a hot water outlet is opened in a building at which point cold water flows through a heat exchanger which heats the water and sends it through the piping to the outlet on demand. Such systems obviate the need to store hot water and thus the energy wastage associated therewith, but can result in inconsistent water temperatures and problems if the electricity or gas supply is interrupted.

To provide energy for heating the hot water, solar hot water systems have been utilised to utilise solar energy for this purpose. More recently, heat-pump technology has been developed for application to hot water systems that use a refrigeration cycle to extract heat from the surrounding air which is employed in

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a heat exchanger to heat water in a storage cylinder. These systems typically use around 60 to 75% less electricity than a conventional electric hot water systems as the electricity is used to operate the heat pump and doesn't heat the water directly with an element.

In storage-type heat pump water heaters, the systems start working if hot water is depleted in the tank and the water temperature remaining in the tank is detected by a thermo-sensor (conventionally half of tank) or triggered by a timer to be below a predetermined temperature. The heat cycle is then initiated to heat the water in the tank and the heat cycle stops when the entire volume of water in the tank is heated to the predetermined temperature.

However, in buildings that employ such water heating systems, should the number of users decrease, there is an unnecessary amount of residual hot water stored in the system, due to the large size of tank. Over time, the temperature of this water will drop due to tank heat losses, which can have a significantly adverse effect on the efficiency of the system from an energy consumption point of view. Whilst it may be possible to address this by replacing the storage tank with a smaller tank that may be more suited to the consumption of hot water specific to the number of users on the premises, the cost of replacement and the environmental impact of sending the original tank to landfill is undesirable. Further, if the number of users changes or if the system is has been chosen for future hot water requirements, such as a growing family, the energy consumption will not be efficient over periods where the consumption doesn't match the size of the tank.

Thus, there is a need to provide a system and method of operating such a hot water storage system that addresses these problems.

The above references to and descriptions of prior proposals or products are not intended to be, and are not to be construed as, statements or admissions of common general knowledge in the art. In particular, the above prior art discussion does not relate to what is commonly or well known by the person skilled in the art, but assists in the understanding of the inventive step of the present invention of which the identification of pertinent prior art proposals is but one part.

STATEMENT OF INVENTION

The invention according to one or more aspects is as defined in the independent claims. Some optional and/or preferred features of the invention are defined in

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the dependent claims.

Accordingly, in one aspect of the invention there is provided a method of controlling the operation of a storage-type heat pump water heater, comprising:

operating said storage-type heat pump water heater for a predetermined operating period;

collecting data associated with the operation of the storage-type heat pump water heater during the predetermined operating period, said data including data associated with the hot water consumption over the predetermined operating period and the hours of operation of the heat pump of the storage-type heat pump water heater during the predetermined operating period;

determining the trend of hot water consumption over the predetermined operating period;

determining the required hours of operation of the heat pump for a predetermined future use period based on the data collected for the predetermined operating period; and

controlling the operation of the heat pump for the future use period such that the operating hours of the heat pump does not exceed the required hours of operation of the heat pump during this period.

In one embodiment, the step of operating the storage-type heat pump water heater for a predetermined operating period requires operating the storage-type heat pump water heater in a standard mode whereby the water stored in a storage tank of the storage-type heat pump water heater is maintained at a predetermined temperature over the predetermined operating period.

The predetermined operating period may be for a period of 7 days.

The step of collecting data associated with the operation of the storage-type heat pump water heater may include collecting data associated with an inlet temperature of water received by the storage-type heat pump water heater, an outlet temperature of water released from the storage-type heat pump water heater, actual working hours of the heat pump over a past 24 hr period, and a capacity setting of the heat pump.

The hot water consumption over the predetermined operating period may be calculated by determining the volume of hot water released from the storage-type heat pump water heater over a 24-hr period.

The step of determining the trend of hot water consumption over the predetermined operating period may comprises generating an average hot water consumption figure over a preceding three-day period and then generating a difference between an actual hot water consumption in a previous 24-hour period

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against the average hot water consumption figure for said previous three-day period.

The step of determining the trend of hot water consumption over the predetermined operating period may comprise determining whether the difference between the actual hot water consumption in a previous 24-hour period against the average hot water consumption figure for said previous three-day period is increasing or decreasing.

The step of determining the required hours of operation of the heat pump for the predetermined future use period may comprise calculating the working hours of the heat pump based on the average hot water consumption in the previous three day period given the heat pump capacity, the specific heat of water, specific gravity of the water and the outlet and inlet temperature of the water.

The step of controlling the operation of the heat pump for the future use period may comprise setting a countdown timer for the heat pump to record the required hours of operation of the heat pump and preventing the heat pump from operating after the countdown timer has expired.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be better understood from the following non-limiting description of preferred embodiments, in which:

Fig. 1 is a front perspective view of storage-type heat pump water heater in accordance with a first embodiment of the present invention;

Fig. 2 is a flow chart depicting the steps of operating the storage-type heat pump water heater of Fig. 1 in accordance with a mode of operation of the present invention;

Figs. 3A – 3C depict a logic diagram depicting the mode of operation of the present invention as set out in the flow chart of Fig. 2.

DETAILED DESCRIPTION OF THE DRAWINGS

Preferred features of the present invention will now be described with particular reference to the accompanying drawings. However, it is to be understood that the features illustrated in and described with reference to the drawings are not to be construed as limiting on the scope of the invention.

The present invention will be described below in relation to its application for use in operating a storage-type heat pump water heater. However, it will be

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appreciated that the present invention could be used in operating a variety of different types of water and other fluid heaters as will be appreciated by those skilled in the art.

Referring to Fig. 1 a storage-type heat pump water heater unit 10 is depicted. The unit 10 has a storage tank 12 that contains and stores the heated water. The volume of the tank 12 may vary depending on the user requirements and the tank 12 may have insulation 13 to aid in minimises heat losses from the tank 12 during the storage period.

A heat pump 14 is mounted on the storage tank 12 as shown in Fig. 1. The heat pump 14 is comprises a cylindrical housing 15 that contains an evaporator 16, fan 17 and compressor 18. In an alternative embodiment, the heat pump 15 may be mounted separately to the tank 12.

Condenser coils 19 are attached to the compressor 18 and extend in a coiled manner within the centre of the tank 12, to transfer heat generated by the heat pump 14 to heat the water contained in the tank 12.

Cold water is supplied to the tank 12 by way of a cold water inlet 20 and hot water is drawn from an upper region of the tank 12 by way of a hot water outlet 21. Thermostats 22 are provided to measure the temperature of the water present in the tank, with the thermostats being typically located at a lower and an upper region of the tank, as shown.

In use, the heat pump 14 functions to draw ambient air from the surrounds through the evaporator 16 by way of the fan 17. The ambient air contains heat which is transferred to a refrigerant fluid as the ambient air passes through the evaporator 16. The refrigerant fluid is then compressed in the compressor 18 to raise the pressure of the refrigerant to a level that is sufficiently high to increase the temperature of the refrigerant fluid for passage into the condenser 19. The condenser is in the form of a coil that is present within the water present in the tank such that the condenser 19 functions as a high-temperature heat exchanger. In this regard, the high temperature refrigerant fluid passing through the condenser transfers heat to the water present in the tank 12 to heat the water to the desired temperature, which can be monitored by the thermostat sensors 22.

In a conventionally operated system, the unit 10 will function by retaining a full level of hot water within the tank 12 and as that hot water is depleted in the tank and replaced by cold water, the thermostat sensors detect this change in temperature and cause the heat pump 14 to operate to apply heat to heat the water

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to the desired temperature. This system may also be triggered by a timer to ensure that the stored water is retained at a desired temperature. The heat cycle of the heat pump 14 will stop when the entire volume of water is heated to a predetermined temperature as set by the system.

However, the storage tank 12 will lose some heat through the walls of the cylinder during storage. This will result in the system having to continually run heat cycles to retain the stored water at the desired temperature, even if no hot water is being used. As such, the heat pump 14 will use energy in the form of electricity to run the components contained therein. Thus, the storage tank 12, the more heat is lost from the system and the more energy is required to replace that heat. It has been found that for many users, heat losses can add up to a high proportion of overall hot water energy use.

Whilst the size of the storage tank 12 may be reduced to reduce the amount of energy required to heat the volume of water present in the tank, it is not practical to continually change the size of the storage tank each time the consumption requirements may change. For this reason, the control system and method of the present invention has been developed.

The present invention seeks to determine the daily heating requirements and the operation of the heat pump 14 for the unit 10 based on the user's energy consumption data, rather than the water temperature of the water present in the storage tank 12 as measured by the by the thermostat sensors 22. By doing this, the full storage tank 12 is not continually heated, therefore the amount of residual hot water in an oversized storage tank is reduced. Thus, the amount of energy required for heating for heating the water, which is then wasted due to heat loss decreases, and the efficiency of the system is improved.

It will be appreciated that the heat pump 14 will be operated to perform a legionella cycle once a week, ensuring that the entire tank of stored water is heated to 60 deg C, to avoid the risk of legionella disease.

In accordance with the present invention, the heat pump water heater unit 10 is configured to have a microcontroller that monitors the operation of the unit 10 and records ongoing data collected by the sensors of the unit 10. This includes in let water temperature from sensors 22 as well as outlet water temperature setting and working hours for the heat pump 14 and heat pump capacity setting. In this regard, the microcontroller of the unit 10 records and logs data for each 24 hr period.

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The control system of the present invention can be controlled by the user through a software application that may be downloaded on a personal computing control device, such as a smartphone, tablet or laptop. The software application is then able to communicate with the microcontroller present on the unit 10 to receive data from the microcontroller and to transmit data/instructions to the microcontroller to control operation on the unit 10. This communication can be conducted wirelessly over a network or through a wireless communication protocol such as Wi-Fi®. Alternatively, the personal computing control device may be connected by way of a wired connection.

Referring to Fig. 2, a control mode of operation 30 of the heat pump water heater unit 10 to save power usage is shown. The mode of operation 30 functions to determine the required length of a cycle operation of the heat pump 14 and is processed by the software application provided on a personal computing control device as discussed above.

The software application is able to interrogate the unit 10 microcontroller to obtain the following data from the unit:

- inlet water temperature
- outlet water temperature setting
- actual working hours per past predetermined period (24 hours)
- heat pump capacity setting

In step 31 the software application is able to determine/calculate the actual hot water consumption of the unit over a predefined use period. In the present embodiment the period is the previous 24 hours of operation of the unit 10, although the time period may vary according to the application. The consumption of hot water is determined by the following equation:

> Amount of hot water = heat pump capacity setting / specific heat of water / (outlet - inlet water temperature) / specific gravity of water x working hours

In step 32, the software application then determines the trend of hot water consumption over an extended use period. The extended use period in the present embodiment is over the preceding 3 days of operation of the unit 10. The system generates an average hot water consumption figure over this three day period (A) and then generates a difference between the actual hot water consumption in the past 24 hour period against the average consumption figure for the previous 3 days (B). Based on this difference the system is able to

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determine the trend of usage, namely whether the consumption is increasing over the three-day period or decreasing(C).

In step 33, the system is then able to determine the required working hours required from the heat pump 14 for the next three-day working period, based on the estimated hot water consumption required. The Estimated hot water consumption for the next three-day period is calculated by:

Estimated hot water consumption = (A) x y(B) x z(C)

Where y, z are coefficients that are variable based on the application of the system specific for the end user.

By having an estimation of the hot water consumption over the following three-day period the system is able to calculate the working hours for the heat pump as it also has data on the heat pump capacity setting, the specific heat of water, the outlet and inlet water temperature and the specific gravity of water.

In step 34 the controller controls the operation of the heat pump to ensure that it works only for the intended working hours calculated in step 33, for the next three-day period.

The system then completes the process for the next three-day period as set out above in steps 31, 32, 33 and 34.

In this regard, the heat pump 14 initialises a heat cycle when it receives the start signal from the software application provided on the user's personal computer controller. The heat pump will terminate a heat cycle when it receives the stop signal from the software application, and the end user can select on/off of this system at any time from their personal computing device.

Referring to Figs. 3A – 3C, a control flow diagram 40 is provided depicting how the system of the present invention functions to control the unit 10.

In step 41, after installation of the unit, the unit is allowed to function in an installation mode whereby for the first 7 days, the heat pump commences operation at 10.00 am each day to heat the water present in the storage tank to the desired temperature, and over the day the system functions to maintain the water in the storage tank at the desired temperature. At 5.00 am each morning the system collects the working hour figures for the heat pump for the preceding day and after the end of the first 7 days the system calculates the average working hours for the heat pump (WTn).

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In step 42, after the installation mode has been completed the energy saving mode of the present invention is initiated. For each day of a predetermined use period (three-day period) the system counts or measures the normal operating hours of the heat pump for a 24-hr period.

IN step 43 the system records the operating hours for the previous 24 hr period (WTn). And in step 44 the trend relating to whether there is an increase or decrease in working hours of the heat pump is determined by comparing the previous figure WTn against a newly determined figure WTn-1 and if:

WTn>= WTn-1 then AHWDWn=1 (increase in working hours), else AHWDW=-1.

The trend result is then saved for this period.

Referring to Fig. 3A, if at step 45 it is determined that the end of the three-day period has been achieved (n=3), at step 46 the difference between actual and average hot water consumption is calculated for this period as AHWI in accordance with the calculation:

$$AHWI = \sum_{n=1}^{3}(WTn - AHWA)$$

In step 47, the trend of usage over the three-day period is calculated to determine whether the overall trend is increasing or decreasing as AHWD in accordance with the calculation:

$$AHWD = \sum_{n=1}^{3}(AHWDWn)$$

In step 48, the number of working hours of the heat pump over the three working days is calculated as OH, in accordance with the following equation

$$OH = AHWA + y*AHWI + z*AHWD$$

Where y and z are predetermined coefficients.

Referring to Fig. 3C, the determined working hours of the heat pump calculated in step 48 is transmitted to the microcontroller present on the unit 10 with the value input into a countdown timer present on the unit 10 in step 49.

In step 50 the heat pump 14 is then initiated by the software application sending a

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start signal to the microcontroller of the unit. The heat pump then commences operation to heat the water present in the storage tank 12 in a usual manner.

In step 51, during normal operation of the heat pump 14 the countdown timer counts down the working hours of the heat pump from the calculated working hours OH.

In step 52 an assessment is made by the system to determine whether the countdown timer has reached zero. If the count down timer has reached zero the software application sends a signal to the unit microcontroller to terminarte the heat cycle of the heat pump 14 by sending an “off signal” to the microcontroller indicating that the heat pump has reached its calculated working hours for that time period. If the countdown timer has not reached zero, the heat pump continues to operate normally and the system continues to monitor the working parameters of the system for the determined run period (three-day period) after which adjustments will be made to the run time parameters to further adjust the operation of the heat pump to increase the efficiency of the overall system.

It will be appreciated that the present invention provides a system and method of operating the system that determines the daily heating requirements of the system based on the user's energy consumption data rather than a detected temperature of the water present in the tank. By doing this, the entire storage tank of water is not heated, thereby reducing the amount of residual hot water in the storage tank. The amount of energy required for heating the water and the amount of heat wasted due to heat loss from the tank decreases and the efficiency of the overall system is improved.

Throughout the specification and claims the word “comprise” and its derivatives are intended to have an inclusive rather than exclusive meaning unless the contrary is expressly stated or the context requires otherwise. That is, the word “comprise” and its derivatives will be taken to indicate the inclusion of not only the listed components, steps or features that it directly references, but also other components, steps or features not specifically listed, unless the contrary is expressly stated or the context requires otherwise.

It will be appreciated by those skilled in the art that many modifications and variations may be made to the methods of the invention described herein without departing from the spirit and scope of the invention.

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The claims defining the invention are as follows:

1. A method of controlling the operation of a storage-type heat pump water heater, comprising:

   operating said storage-type heat pump water heater for a predetermined operating period;

   collecting data associated with the operation of the storage-type heat pump water heater during the predetermined operating period, said data including data associated with the hot water consumption over the predetermined operating period and the hours of operation of the heat pump of the storage-type heat pump water heater during the predetermined operating period;

   determine the trend of hot water consumption over the predetermined operating period;

   determine the required hours of operation of the heat pump for a predetermined future use period based on the data collected for the predetermined operating period; and

   controlling the operation of the heat pump for the future use period such that the operating hours of the heat pump does not exceed the required hours of operation of the heat pump during this period.

2. The method according to claim 2, wherein the step of operating the storage-type heat pump water heater for a predetermined operating period requires operating the storage-type heat pump water heater in a standard mode whereby the water stored in a storage tank of the storage-type heat pump water heater is maintained at a predetermined temperature over the predetermined operating period.

3. The method according to claim 2, wherein the predetermined operating period is for a period of 7 days.

4. The method according to claim 2, wherein the step of collecting data associated with the operation of the storage-type heat pump water heater includes collecting data associated with an inlet temperature of water received by the storage-type heat pump water heater, an outlet temperature of water released from the storage-type heat pump water heater, actual working hours of the heat pump over a past 24 hr period, and a capacity setting of the heat pump.

5. The method according to claim 4, wherein the hot water consumption over the predetermined operating period is calculated by determining the volume of hot water released from the storage-type heat pump water

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heater over a 24-hr period.

6. The method according to claim 5 wherein the step of determining the trend of hot water consumption over the predetermined operating period comprises generating an average hot water consumption figure over a preceding three-day period and then generating a difference between an actual hot water consumption in a previous 24-hour period against the average hot water consumption figure for said previous three-day period.

7. The method according to claim 6, wherein the step of determining the trend of hot water consumption over the predetermined operating period comprises determining whether the difference between the actual hot water consumption in a previous 24-hour period against the average hot water consumption figure for said previous three-day period is increasing or decreasing.

8. The method according to claim 7, wherein the step of determining the required hours of operation of the heat pump for the predetermined future use period comprises calculating the working hours of the heat pump based on the average hot water consumption in the previous three day period given the heat pump capacity, the specific heat of water, specific gravity of the water and the outlet and inlet temperature of the water.

9. The method according to claim 9, wherein the step of controlling the operation of the heat pump for the future use period comprises setting a countdown timer for the heat pump to record the required hours of operation of the heat pump and preventing the heat pump from operating after the countdown timer has expired.

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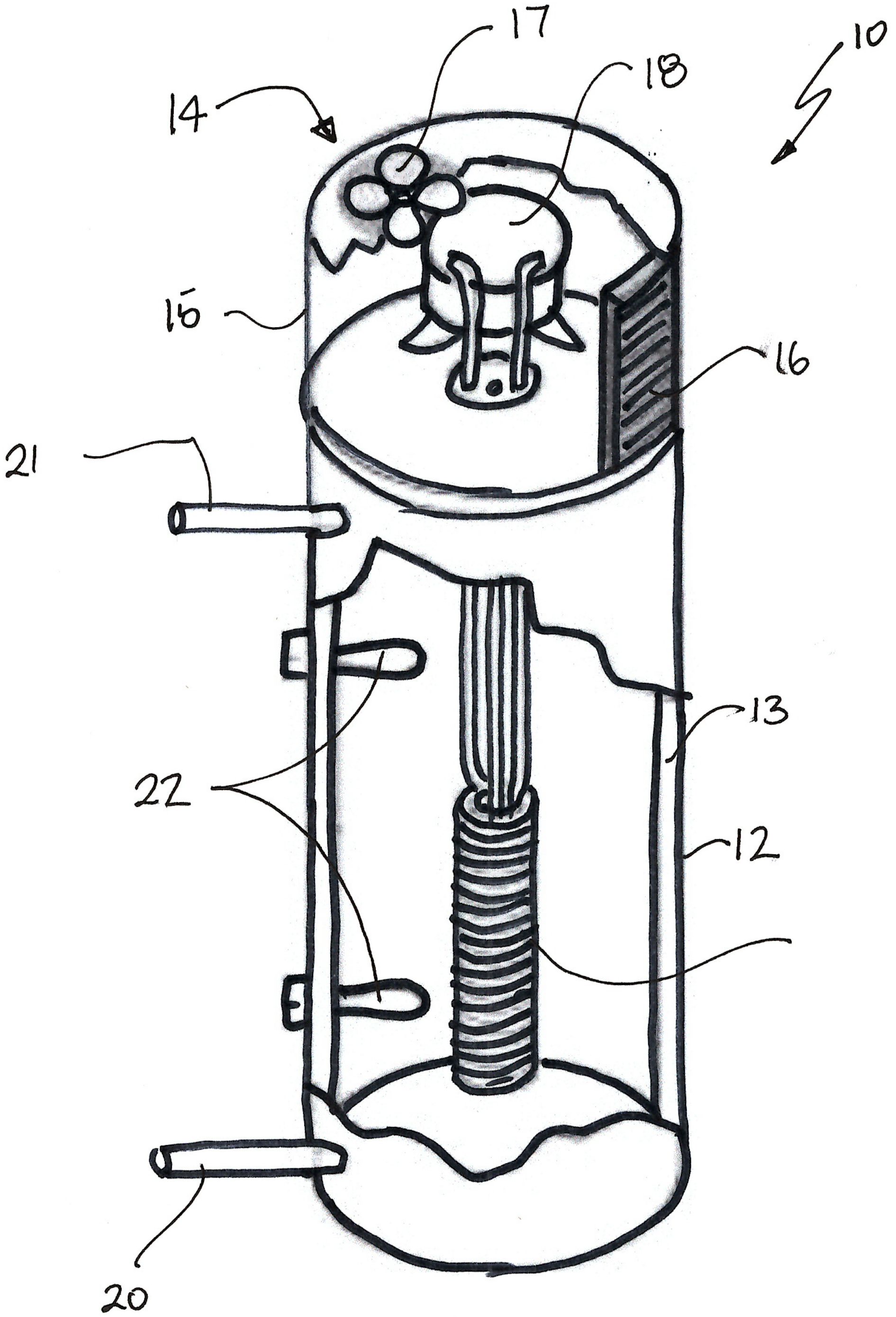

Fig. 1

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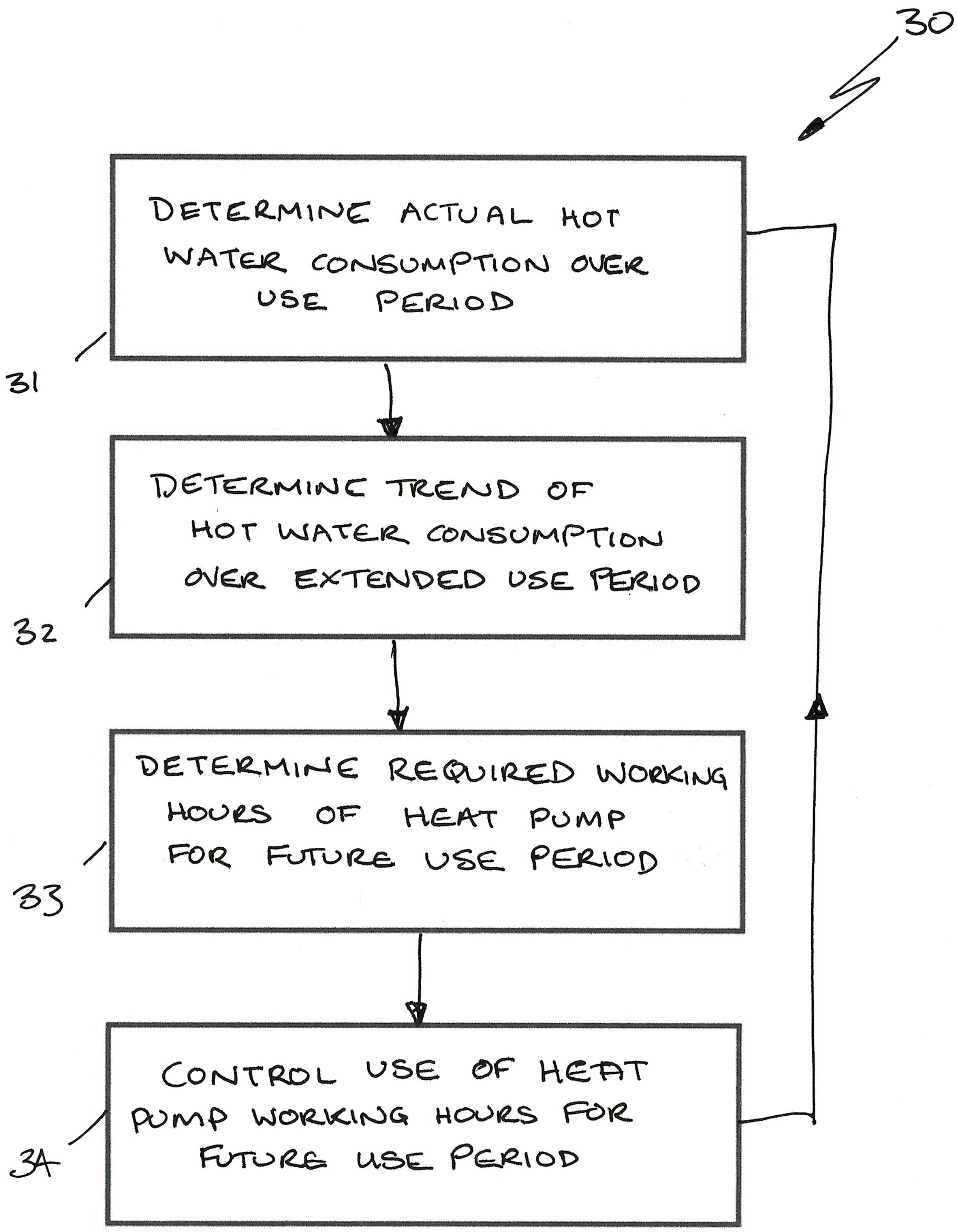

FIG. 2

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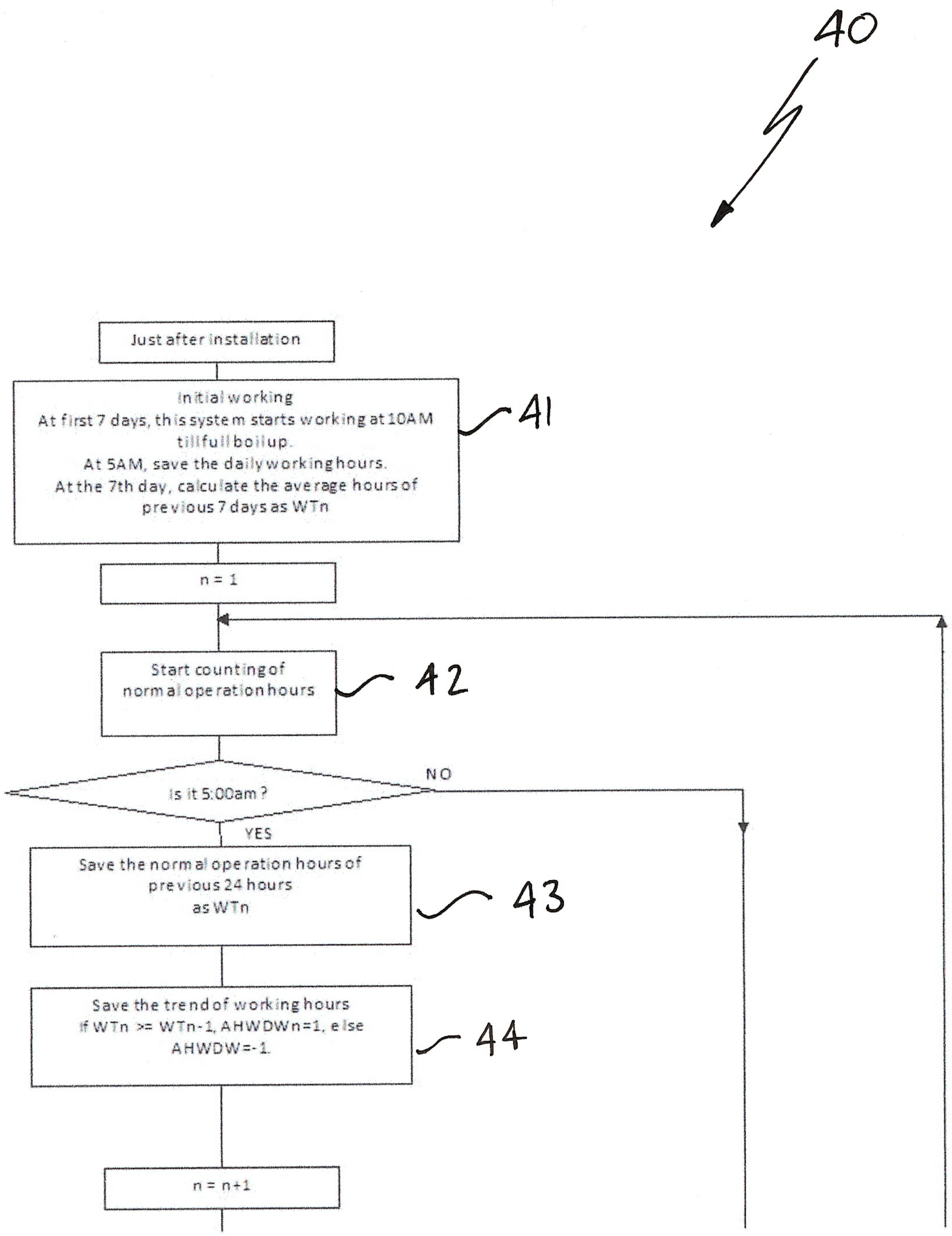

FIG. 3A

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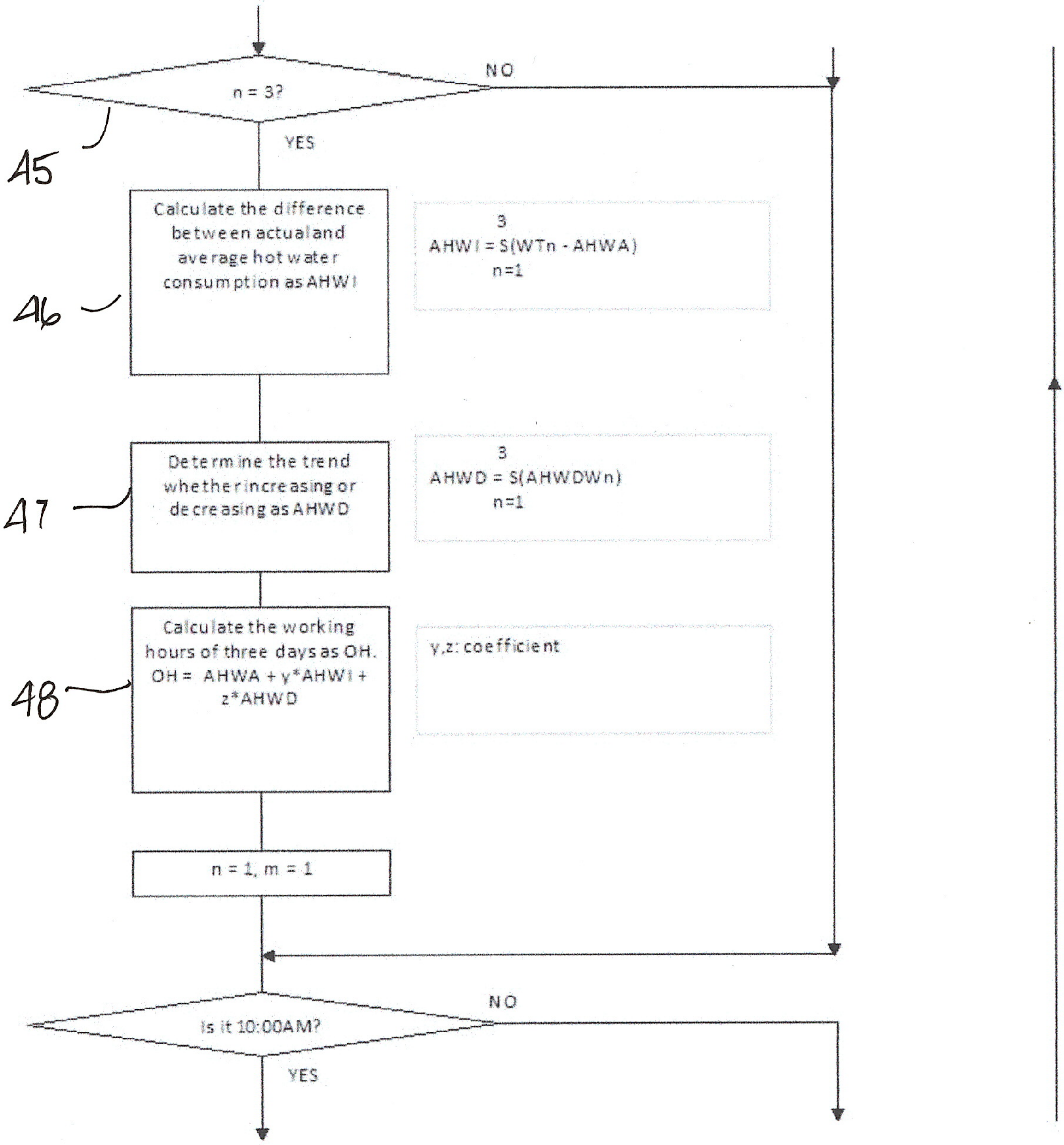

FIG. 3B

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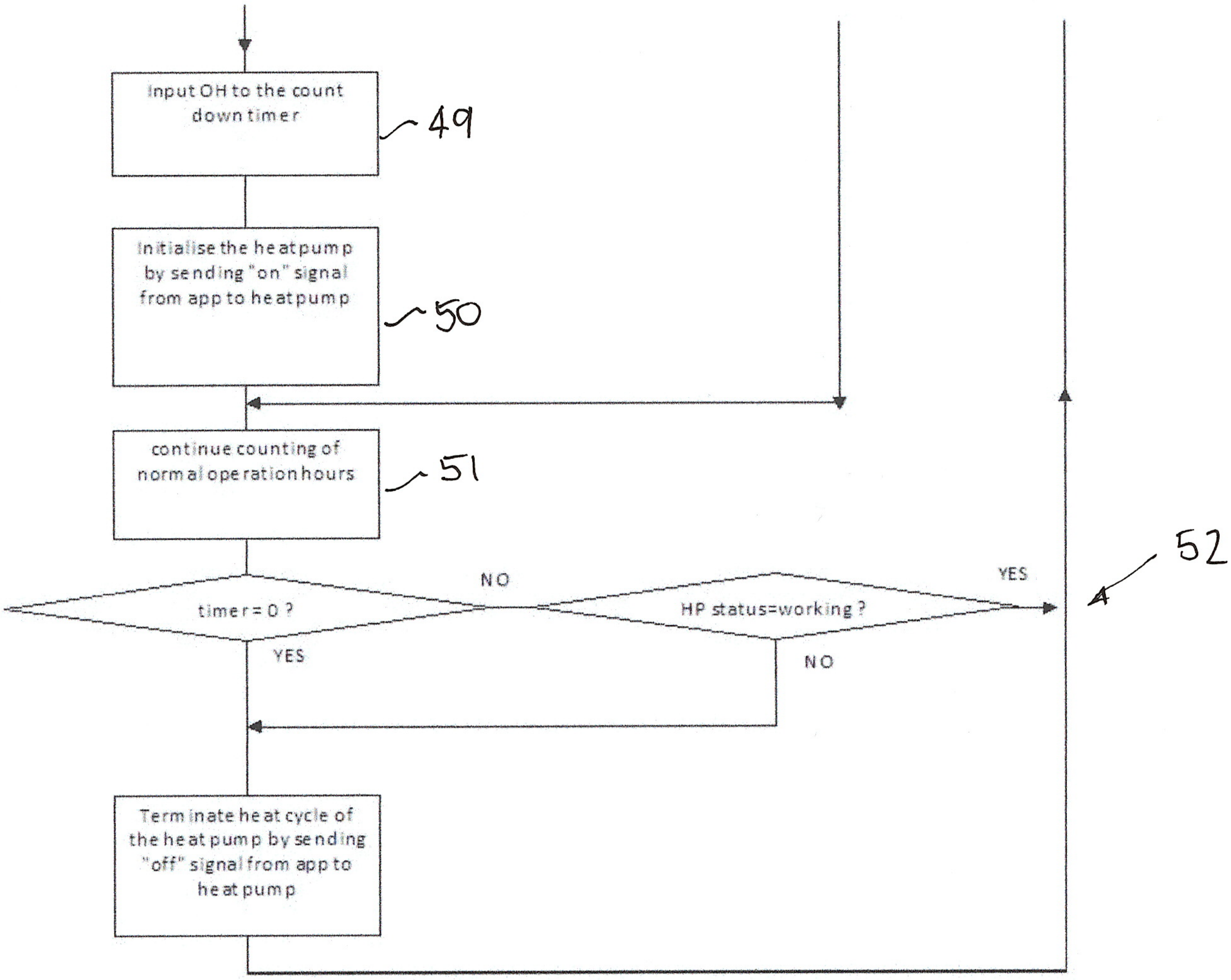

FIG. 3C