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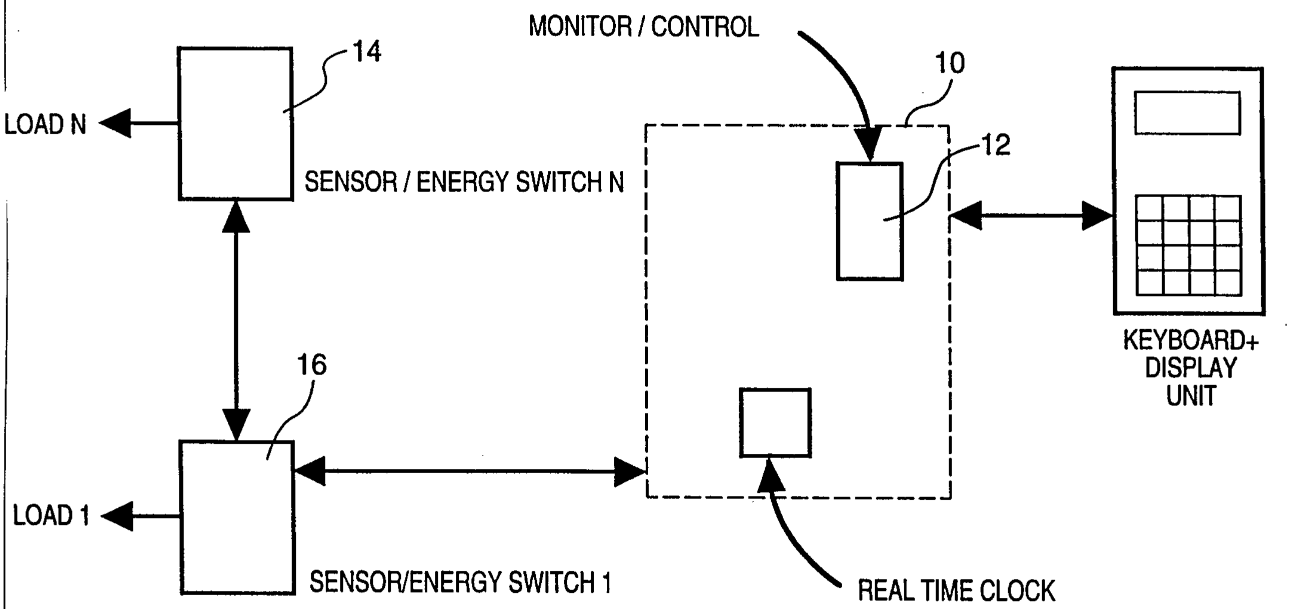
(54) Title: A HOT WATER TANK ENERGY CONTROLLER



(57) Abstract

A method and apparatus is disclosed for controlling energy supplied to water heaters, particularly electric water heaters, by load shedding and load shifting.

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A HOT WATER TANK ENERGY CONTROLLER

This invention relates to energy control and, more particularly, relates to a method and apparatus for controlling the use of electrical and hydrocarbon energy for heating water tanks.

A conventional electric or gas-fired hot water tank maintains a fixed temperature and volumetric supply of hot water 24 hours a day, regardless of demand. This practice is inefficient since energy is continually consumed to maintain this supply of hot water, even though it may not be needed for several hours.

A typical North American family is comprised of two adults and two children and has a clothes washer and a dish washer. The energy required for the hot water consumed on a daily basis for bathing and for washing clothes and dishes is substantial, particularly when maintaining a 60 gallon tank of hot water at an average temperature of about 140°F. for 24 hours.

It has been found that energy can be saved by controlling the flow of energy, either in the form of electricity or fossil fuel, supplied to a hot water heater tank during the time(s) of a no load or low demand by lowering the water temperature and by decreasing the inventory of hot water, i.e. the available gallons of hot water. An example of this could be at night time such as between 11:00 p.m. and 7:00 a.m. when a full tank of hot water normally is being maintained at a preset temperature, but little hot water is consumed.

It has also been found that energy use can be further reduced and energy costs substantially minimized for electric water heaters by essentially disconnecting the energy supply to hot water tanks during normal periods of high energy demand, utilizing the stored inventory of hot water, and subsequently replenishing the hot water consumed during periods of low demand.

The majority of energy consumed to heat hot water occurs between the hours of 7 and 11, with peaks of energy consumption occurring between 8 - 12 AM and 6 - 10 PM. The power utilities that supply this electrical energy must meet substantially increased demand during these peak hours resulting in temporary high load demands on generating equipment and high energy costs, particularly if energy must be imported from other jurisdictions to meet peak demands.

It is known to provide programmable switches for space heating requirement which will lower room temperature during sleeping hours and possibly during day hours when a residence may be vacated. Hot water heater tanks, on the other hand, normally have a fixed thermostat setting at, for example, 140°F. Set back thermostat devices are available which will turn off the energy supply to water heaters during peak demand periods.

It is known that the hot water in an insulated hot water tank, stratified in layers according to density which is determined by the water temperature, can be maintained as a constant source of hot water for long periods of time even though the source of electrical energy has been turned "off". However, it is not known to combine the reduction of inventory or gallonage of hot water during low demand periods with an interruption of energy supply during peak demand periods.

In accordance with the method of the invention, it has been found that the energy source can be reduced and distributed during non-peak hours such as during early morning hours to reduce the inventory and temperature of the hot water and the energy source then intermittently, randomly increased in increments in advance of the peak demand in the morning with a lead-time sufficient to heat a desired quantity of water from the existing temperature to the required temperature immediately before the peak demand. The energy source preferably then is turned off during the peak demand. In order thus to reduce the peak energy demand in the morning hours, the load shift system of the invention distributes the energy requirements of the heating cycle over a prolonged period of time immediately prior to the demand peak. This is achieved by cycling the heating elements on and off several times in the morning hours in advance of the peak, thus allowing the volume of water to increase and the water temperature to slowly rise over an extended period of time. To avoid the possibility of a large percentage of electrical heaters in hot water tanks on a grid system turning on and off at the same time, a random number generator is used to control the heating elements duty cycle.

In drawings which illustrate embodiments of the invention.

Figure 1 is a block diagram of the control system of the invention;

Figure 2 is a graph showing hot water use in an average household;

Figure 3 is a graph showing load shifting according to the present inventions; and,

Figure 4 is a graph showing hot water inventory and temperature control in accordance with the present invention.

With reference to Figure 1, the monitor controller 10 comprises a microprocessor 12 which is electrically connected to heating loads 14, 16 such as a gas burner or upper and lower electrical heating elements in a water heater by means of energy switches 1, N in a heating circuit. The switches can be solenoids for actuating a gas burner or relays for immersion of electric heaters.

The microprocessor 12 is also electrically connected to upper and lower temperature sensors in a temperature circuit for monitoring tank water temperature levels in a tank.

The method and apparatus of the invention permits load shedding and load shifting.

Load shedding consists of removing hot water heater's energy consumption during the high demand periods. The controller is programmed with utility designated lock-out times during which the water heater will remain off. The controller moves the water heater's heating cycle to immediately before or after the lock-out time, depending on the user's programming. The lock-out times will be of limited duration, so the user will experience no shortage of hot water.

It may be deduced that implementing load shedding alone may result in lower, but wider demand peaks. To counter this spreading of the peaks, the controller is designed to use load shifting. Load shifting consists of the spreading of energy demand over a pre-determined period of time (see Figure 3). The controller accomplishes this by taking tank temperature information and, by using a heating rate learned from each specific tank, calculates the time required to heat the water to the user's next programmed temperature. The controller then looks at how long a time period exists until the water is required, subtracts lock-out periods, and calculates a heating schedule which will effectively spread the water heater's energy consumption outside of peak demand periods.

The power for the device is supplied by an electrical utility, and is applied only to the main controller unit. The first step is to read in the temperatures from the tank. Based on the incoming temperatures, the current calendar time, the scheduled demand times programmed within the unit, and the actual demand of hot water, as seen from sudden temperature decreases within the tank, the device will calculate an economical schedule to when to heat the tank, as well as an appropriate temperature to ensure hot water demand is still met. A switching device 14, 16, controlled by the computing device, will apply power to the appropriate stratifications of the tank, based on the concepts of load-shifting and load-shedding described herein. The computing device, programmable memory and calendar time may be changed/updated with the use of an external device.

Since heat rises, hot water will always be extracted from the top of the tank, and cold water will always enter at the bottom of the tank, to replace the water extracted. The priority of any ordinary hot water tank is to heat the top portion of the tank first, then work downward until the whole tank is heated. From there on, if there is a loss of temperature, the tank will be

serviced with more heat to compensate for the loss, until at such time that hot water is removed from the tank, then the cycle repeats itself. The device will "control" this cycle, and totally eliminate the need to service the tank due to heat loss. If the desired temperature of the tank is lowered, the tank itself will have a greater chance of maintaining this temperature. Not only does the device "control" the temperature, it will also maintain the cycle only when programmed to have hot water provided. This also takes into consideration, times requested NOT to heat the tank, at the local utilities' option. This
time, for example can be peak utility demand times, in which electricity is more expensive to produce. This concept alone greatly increases savings to the utility.

There thus are two ways in which the heating cycle can be manipulated in order to save energy.

Load shedding involves heating the tank prior to the times requested by the user or utility. Along with the times requested NOT to use energy, actual volume and temperature to be provided can also be specified. The unit will then disallow energy to be applied to the heating system at this time, unless the supply of water is extremely low. The reason for heating prior to the demand time is to allow heating the tank at a more economical time, before energy costs to the utility increase rapidly, due to the need to import electricity from other sources to meet the demand. The unit will not allow the tank to be heated during the peak times, unless requested by the utility and/or hot water demand exceeds supply, thus allowing the unit to update hot water requirements for that time of day, for the next occurring period. In addition to moving the load, load-shedding provides the benefit of removing the brief "servicing" periods during the non-demand periods.

Load shifting involves heating the tank to a specified temperature and volume over a longer period of time by splitting the heating cycle into separate, incremental stages. The incremental stages will be equal to each other, in order to disallow any loss of energy. Load-shedding works in conjunction with load-shifting. During the heating process under load-shedding, the water will have virtually no chance to lose heat, because as the hot water rises to the top, this leaves the water that is closest to the element a chance to heat up during the next incremental cycle.

The controller measures the water temperature with temperature sensors by a means which will translate an analog voltage potential from the sensors to a digital equivalent value which is understood by the computing device. The controller then calculates the length of time, termed calibration-time, that is required to heat water within the tank from a pre-defined temperature up to a higher pre-defined temperature. This action is performed on a pre-defined on-going basis when the water is heated to continually update the calibration-time. This calibration-time is therefore a dynamic value which will be used to compensate for possible changes in the environment of the water, that may affect the heating time. The environment changes would include, but not limited to, temperature variances of the water within the tank, the ambient temperature outside of the hot water tank and internal tank physical changes, such as density changes of the water, impurities in the water and sediment carried into the tank by the water, of which any or all of these may affect the time required to heat the water. This calibration-time will be used as a constant to calculate when to start to supply energy to the heating system, such that the water will be heated from a present temperature up to a pre-defined temperature. This calibration-time is a unit of time, in minutes, that requires energy from the heating system to

heat the water to raise the temperature by 5 degrees Fahrenheit, but may also be any other pre-defined temperature or temperature unit and time measurement unit.

The present invention provides the important advantage of meeting the demand for hot water during peak hours while substantially obviating peak hour energy demands with substantial savings in energy costs.

SUBSTITUTE SHEET

CLAIMS:

1. A method of controlling the heating of an inventory of hot water during periods of low energy demand and high energy demand in a heater tank from a source of heating energy comprising: reducing the heating energy during a portion of a period of low energy demand to decrease the inventory of hot water, intermittently, randomly providing heating energy for heating said water immediately prior to a period of high energy demand to increase the inventory of hot water to a predetermined level, and disconnecting said source of heating energy during the period of high energy demand whereby hot water consumed is provided solely from the inventory of hot water, and replenishing hot water consumed during a subsequent period of low energy demand.

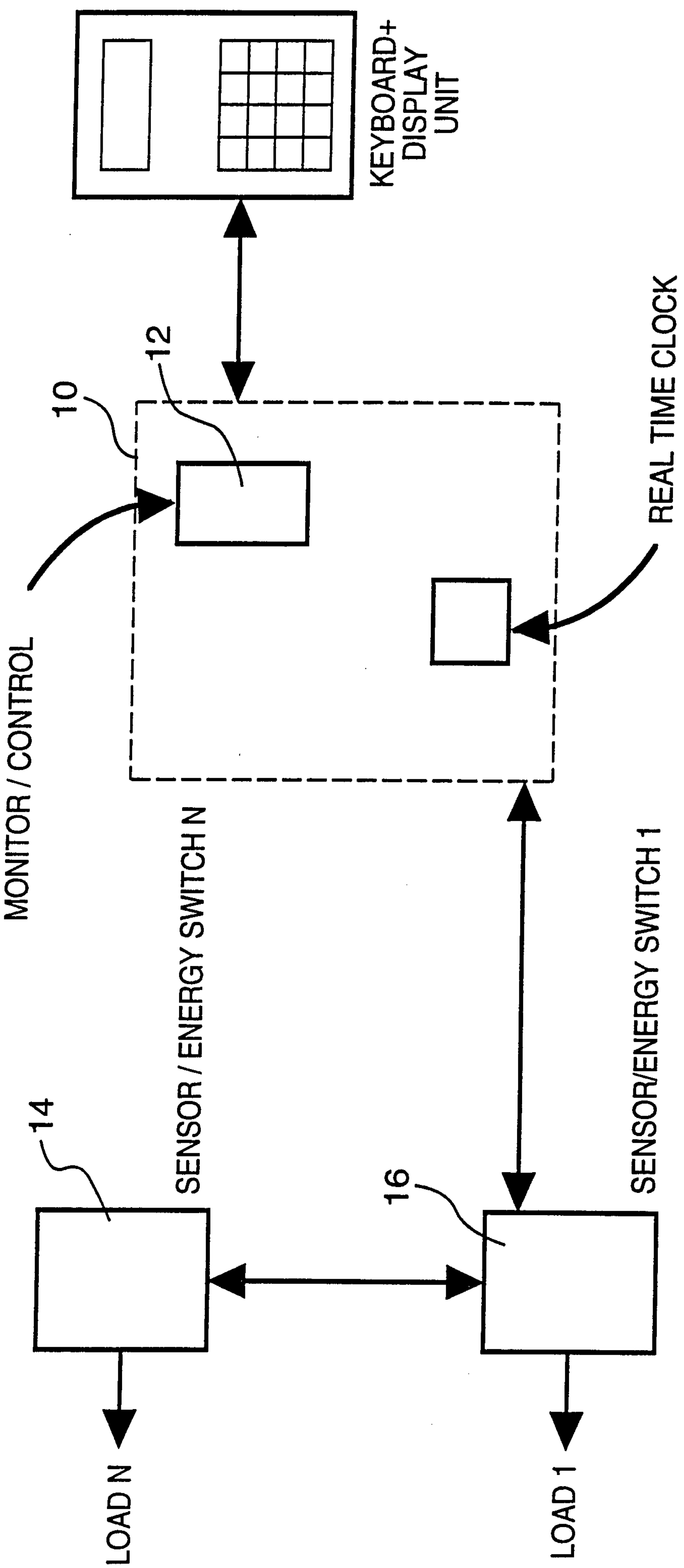
2. A method as claimed in claim 1, applying a random number generator for heating said water intermittently, randomly providing heating energy for heating said water.

3. A method as claimed in claim 2, in which said heating energy is electricity and the heater tank is an electric hot water tank.

4. A method as claimed in claim 3, in which the period of low energy demand is during early morning hours and in which the water temperature in the hot water tank is permitted to decrease during the early morning hours concurrently with the decrease of inventory of hot water

and the water temperature is increased intermittently concurrently with the increase of inventory of hot water immediately prior to the period of high energy demand.

5. A method as claimed in claim 3 or 4, in which the electric hot water tank has upper and lower electric heating elements electrically connected to a heater circuit and upper and lower temperature sensors for measuring upper and lower tank temperatures electrically connected to a temperature circuit, and computer means operatively communicating with the heater circuit and the temperature circuit, the method additionally comprising measuring upper and lower tank temperatures and energy consumption for the upper and lower electric heating elements to determine a heating rate for the tank, calculating the time required to heat the tank water to the next desired tank temperature, calculating a heating schedule to spread the energy consumption over the low energy demand, and selectively energizing the upper and lower heating elements.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DISPLAY
UNIT
10
12
MONITOR / CONTROL
REAL TIME CLOCK
SENSOR / ENERGY SWITCH N
SENSOR/ENERGY SWITCH 1
14
16
LOAD N
LOAD 1

FIG.1.

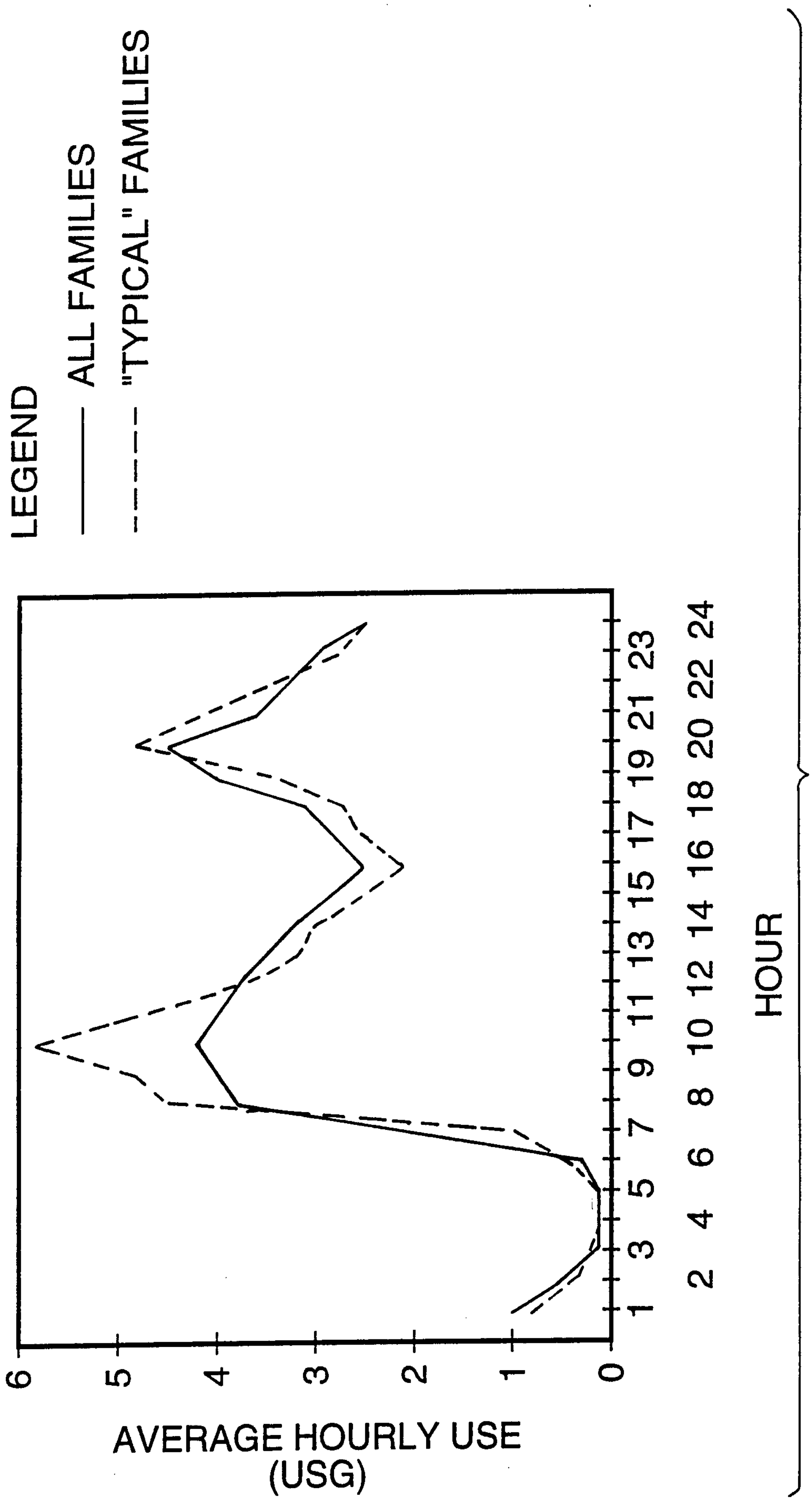
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FIG.2.

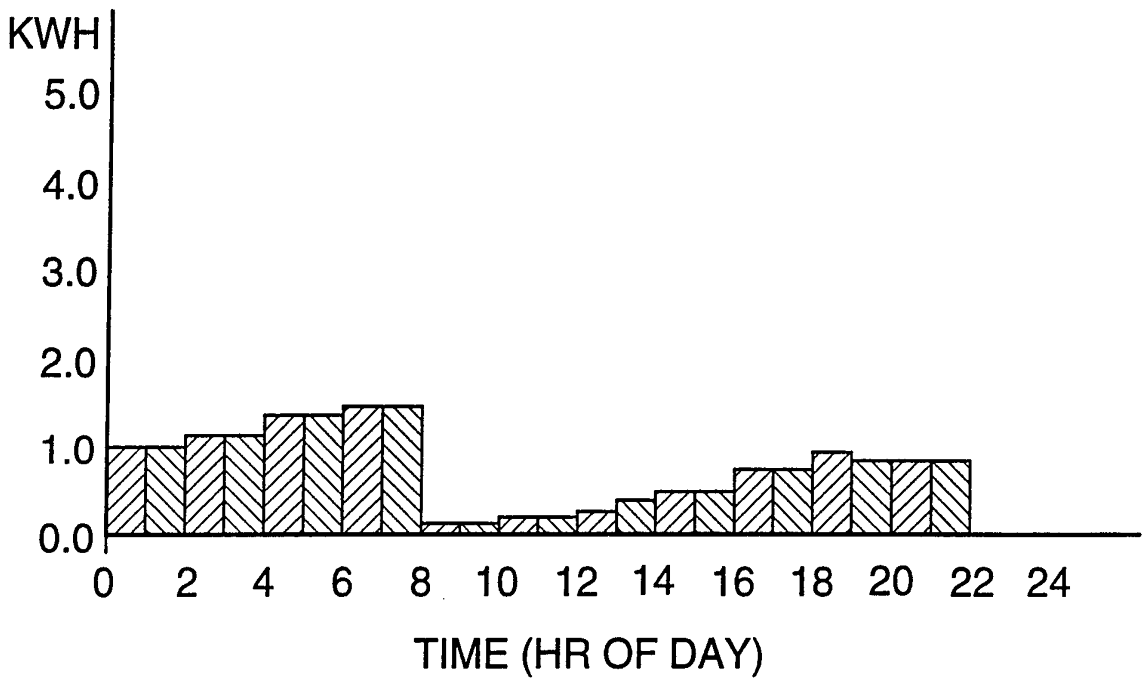
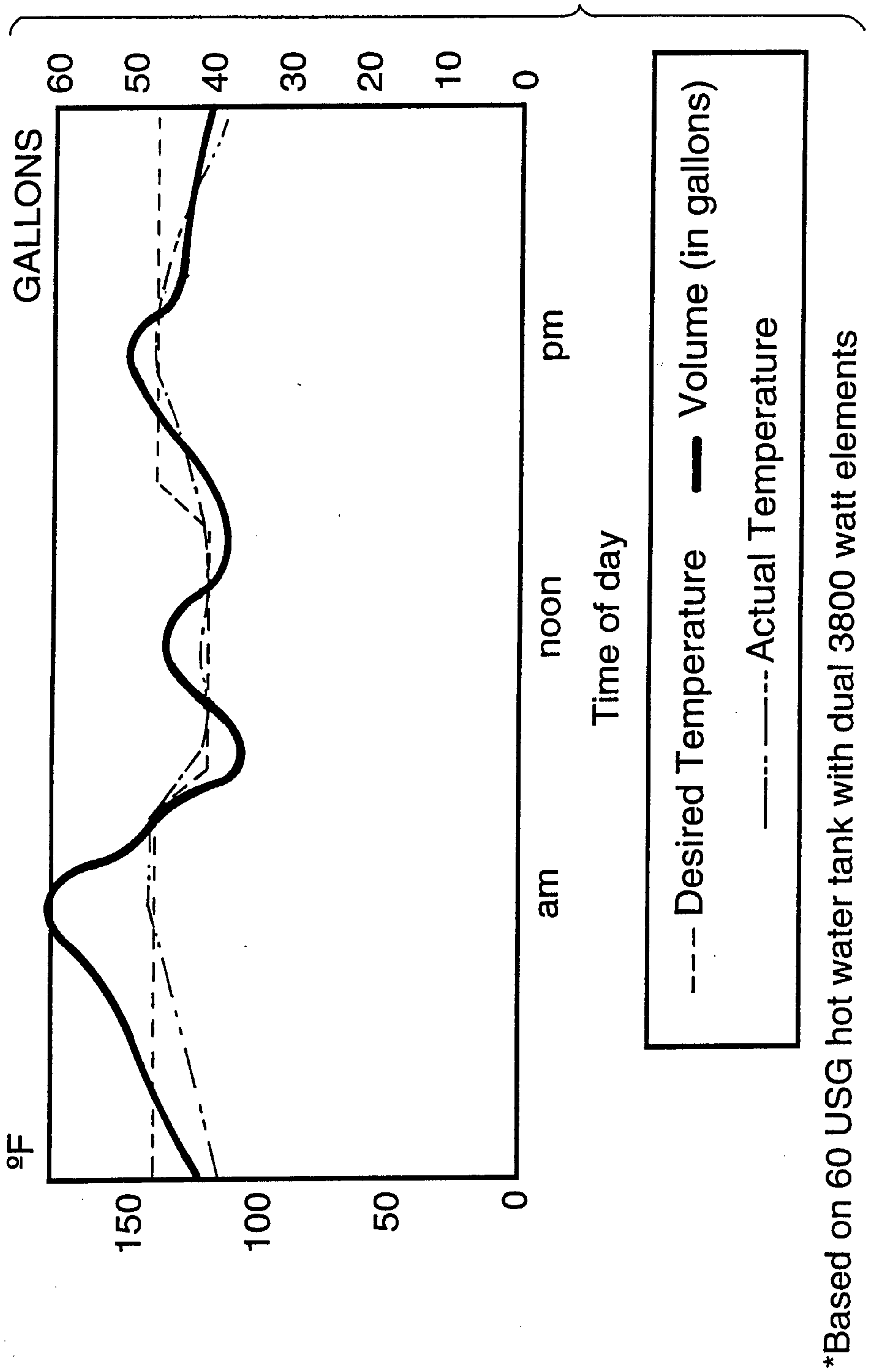


FIG.3.



*Based on 60 USG hot water tank with dual 3800 watt elements

FIG.4.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 93/00455

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 G05D23/19

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)
IPC 5 G05D F24D

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

Electronic data base consulted during the international search (name of data base and, where practical, 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.
A	GB,A,2 203 861 (HORSTMANN GEAR GROUP LIMITED) 26 October 1988 see page 1, line 30 - page 8, line 1; figure 1 ---	1-5
A	WO,A,90 12261 (VOLTAGE REGULATED SYSTEMS OF SOUTH CAROLINA) 18 October 1990 see page 5, line 20 - page 14, line 28; figures 1-7 ---	1-5
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☐ Further documents are listed in the continuation of box C.

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12 January 1994	28.01.94

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
GB-A-2203861	26-10-88	NONE		
WO-A-9012261	18-10-90	NONE		
FR-A-2301146	10-09-76	GB-A-	1543564	04-04-79
		DE-A-	2604368	19-08-76
		NL-A-	7601302	13-08-76
		US-A-	4170729	09-10-79