(54) Title: CONTINUOUS FLOW DEMAND CONTROLLED MICROWAVE WATER HEATER

(57) Abstract: A water heater system (10) which includes a microwave generator (24) for heating water in a chamber (22) fed from a water source (12) and discharging hot water at a water outlet (14). An operation controller (30) senses demand at outlet (14) and controls the microwave generator (24) accordingly. The water to be heated may be pre-heated by conduction contact with the Magnetron or other parts of the microwave generator to effect the secondary purpose of cooling. The microwave generator (24) may include plural magnetrons operating at different frequencies. Provision is made for delaying hot water output until a desired temperature is reached, and plural hot-water outlets may be used. The system contemplates making the supply of hot water to the demands of particular appliances connected to the system. Circulation means are provided to maintain uniform hot water temperatures. Demand is detected by; turning on a tap, pressure or temperature sensors. The system, although using a limited storage in the form of a heating chamber is intended for use as a continuous flow water heater.
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
CONTINUOUS FLOW DEMAND CONTROLLED MICROWAVE WATER HEATER

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority on United States Provisional Patent Application No. 60/738,595, filed on November 22, 2005.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to water heater systems and, more particularly, to a system for producing a continuous supply of heated water in an energy-efficient manner for domestic and commercial use.

2. Background Art

There are two broadly used sources of power that are utilized for water heaters, namely, gas (i.e., fossil fuels) and electricity. Two formats of water heaters are well known, namely, conventional (storage tanks) and tankless (or "on demand") units.

The existing methods and products do not fully address the needs of both the consumer and the construction industry. A storage tank system is essentially a large reservoir containing a heating element and a thermostat that regulates the maximum temperature of the water. Water is introduced into the reservoir where a submersed heating element is energized until the thermostat reads that the water has attained the desired temperature. Once it has done so, the heating element turns off.

In a storage tank, the stored water will lose some heat as it is being stored and so the cycle is repeated every time temperature drops below the preset limit. To increase efficiency, insulation is added to the wall of the reservoir or tank. This makes for a
cumbersome and relatively inefficient product, as large quantities of water are heated in anticipation of hot water being needed. Also, the requirement of the consumer to have virtually unlimited access to hot water at any time is, in theory, not possible with any type of storage tank system since, by definition, a storage tank is limited in capacity.

A conventional tankless system does not use a reservoir. Water is heated as and when needed by using gas-powered heaters or resistive electric elements. The sustained volume of hot water required by the consumer for the purpose of conducting simultaneous domestic hot water applications, such as showering and dishwashing, is not possible with existing electric tankless systems.

This would necessitate the modification of consumer behaviour (perform one hot water related task at a time), or the costly alternative of installing multiple tankless devices at various points of use, something that is undesirable for both the consumer and the industry.

The above-mentioned methods of supplying heated water in both domestic and commercial locations at present are also inherently inefficient in terms of power consumption expended to produce said heated water. This is primarily due to two factors:

1) Water is heated and stored in a finite quantity, where it will be utilized at unpredictable intervals. By definition then, the water will be heated and then reheated needlessly, thus resulting in a waste of energy.

2) The amount of power required to heat the water is directly related to the size and thermal insulation of the storage tank, the type and efficiency of the heating element and associated control circuitry, and the actual quantity of hot water consumed. At no
time can the volume of use of hot water exceed the actual capacity of the storage tank.

At present, and particularly true in colder climates, tankless water heaters are not widely considered as viable alternatives to storage units due primarily to the extreme variances in inlet water temperature induced by the changes in seasons and weather. Consequently, the described deficiencies of conventional storage systems apply almost all circumstances, as tankless systems are often disregarded as an alternative.

A conventional hot water tank not only requires a considerable amount of space but, in addition, the temperature of the water that has been heated and stored is by definition inconsistent due to the fact that, as water is being utilized and new cold water is entering the water tank, the average temperature of the water contained within the tank decreases as the amount of hot water remaining decreases in proportion to the amount of cold water entering the tank.

An improvement to this reality is described in U.S. Patent No. 6,633,726, issued to Bradenbaugh on October 14, 2003, resulting in a storage tank system of improved efficiency.

Furthermore, U.S. Patents No. 6,606,452, issued to Came on August 12, 2003, and No. 6,410,886, issued to Julien on June 25, 2002, relate to the reduction or elimination of premature water heater failure resulting from, amongst other things, impurities contained within the water and prolonged periods of disuse.

Additional inefficiencies associated with storage tanks have been identified where heat is lost due to heated water remaining within the water pipes routed from the tank to the tap. This water will cool
down while waiting to be used, resulting in cold water temporarily emanating from the hot water tap instead of hot water. The water then gets progressively warmer and then hot at the point of exit as hot water makes its way from the tank to the plumbing fixture being used. When the fixtures' valve is closed, a considerable volume of hot water is trapped in the pipes, which will cool down (and be wasted) if not "used rapidly. This is described in U.S. Patent No 5,944,221, issued to Laing et al. on August 31, 1999, along with a functional solution therefor for use with conventional storage tanks.

Lastly, a health risk has been identified in situations where heated water remains dormant, such as in the case of present storage tank systems. A method for resolving this is described in U.S. Patent No. 5,882,588, issued to Laberge on March 16, 1999. It describes a method to remove harmful micro-organisms such as Legionella pneumophila from hot water systems.

The heating of water in a typical Canadian household represents a non-negligible portion of their overall energy use. Also, with the advent of home offices, the availability of an electric appliance for most household tasks and what has been coined as being active lifestyles, the importance of a flexible system to provide hot water at any time of the day in an efficient manner is highly desirable. A historical response to this challenge has been to overestimate capacity in order to have hot water available at any time. Thus, a household that could get by with a 20-gallon tank will typically install a 40- or 60-gallon unit. This not only takes more space, but also consumes more energy, as much more water is being heated than needs to.
SUMMARY OF INVENTION

It is therefore an aim of the present invention to provide a water heater system that addresses issues associated with the prior art.

Therefore, in accordance with the present invention, there is provided a water heater system comprising: a heating chamber positioned between a water source and a water outlet; an operation controller detecting a demand for water from the water outlet; and a microwave generator connected to the controller to be actuated as a function of the demand for water from the water outlet so as to heat the water passing through the heating chamber by microwave generation.

BRIEF DESCRIPTION OF DRAWINGS

Having thus generally described the nature of the invention, reference will now be made to the accompanying drawings, showing by way of illustration a preferred embodiment thereof and which:

Fig. 1 is a block diagram of a water heater system used in association with a water source, constructed in accordance with a preferred embodiment of the present invention;

Fig. 2 is a graph illustrating a dielectric relaxation time of supercooled water;

Fig. 3 is a front view of a flow inducer of the water heater system of Fig. 1; and

Fig. 4 is a perspective view of a magnetron of a microwave generator of the water heater system of Fig. 1.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to the drawings, and more particularly to Fig. 1, a water heater system in association with a water supply system is generally
shown at 10. The water supply system typically has a water source 12 providing pressurized water to a water outlet 14. A cold water tap 16 is handled to regulate the outlet of cold water through the water outlet 14.

The water heater system 10 supplies hot water to the water outlet 14, such that water of a selected temperature is supplied as a function of the actuation of the cold water tap 16 and a hot water tap 20. It is pointed out that, although illustrated as being interrelated in Fig. 1, the cold water tap 16 and the hot water tap 20 may have independent water outlets 14.

The hot water tap 20 is part of the water heater system 10. More specifically, the hot water tap 20 controls the flow of a hot water supply from the heating chamber 22.

The heating chamber 22 is typically a pipe in which the cold water supplied by the water source 12 will be heated to a suitable temperature. Therefore, as illustrated in Fig. 1, the water source 12 is in fluid communication with the heating chamber 22 so as to supply cold water thereto.

A microwave generator 24 is provided in association with the heating chamber 22, so as to heat the water that is in the heating chamber 22. The microwave generator 24 is a source of microwaves, and is typically a magnetron.

It is widely known that a magnetron, a primary component used to convert electricity into microwave energy, is approximately 70% efficient at performing this conversion, whereby the resistive elements currently used in existing water heaters have a greater efficiency at converting electricity into heat.

It is possible to solely rely upon efficient generation of heat, but also considered to allow for this heat to be applied into the water of varying temperatures in the most effective way possible.
It is known that a microwave generator 24, such as a magnetron, increases the temperature when producing microwaves. Accordingly, a heat-exchange configuration 26 is provided between the heating chamber 22 and the microwave generator 24. Although a magnetron is only approximately 70% effective at converting electricity to microwave energy, one parameter to consider is that microwave energy at 2.4 GHz, for example, is extremely effective at heating water uniformly up to a specified depth determined by numerous factors. Comparably, an immersed electric element relies solely upon thermal transfer to conduct heat within the water which it is immersed.

The unwanted byproduct of a magnetron, a major portion of the 30% waste, is in the form of heat, which is a reason why microwave ovens are equipped with fans to cool the magnetron. It is, therefore, considered to recuperate this lost heat by cooling the magnetron with the water to be heated, so as to further heat the water through thermal transfer. The heat-exchange configuration 26 therefore increases the efficiency of the microwave generator 24.

In Fig. 4, the microwave generator 24 having a heat-exchange configuration 26 is illustrated. It is pointed that all necessary precautions are taken in order to avoid electrical hazards when directing water for heat exchange with the magnetron.

In addition to the challenge of extracting the most heat possible through the conversion of electricity into microwave energy and extracting thermal energy while cooling the magnetrons, other challenges present themselves.

A method used in microwave ovens to compensate for non-uniform heating is to place a temperature-sensing probe into the item to be heated. By measuring the centre of the item, it is theoretically assured that
the coolest part of the item will be at the correct temperature.

This depth is determined by the concentration of water in the item being heated, initial temperature of the item and the frequency of the magnetron being used. Leaving the item in the microwave item for an extended period of time may result in the entire item becoming warm or hot, but this is only as a result of thermal transfer of heat emanating from the periphery of the heated object as it is conducted throughout the object (thermal transfer) eventually reaching the centre.

Anomalous dielectric behaviour of water is found over a range of microwave frequencies between about 2 and 100 GHz, whereby the real ($\varepsilon_1$) and/or the imaginary ($\varepsilon_1'$) part of the complex dielectric constant increase then decrease with increasing temperature. Examples at two close frequencies for liquid (including supercooled) water are shown in Fig. 2. This may be understood by noting the shifts with temperature of the maximum frequency of microwave absorption and the dielectric permittivity.

Since, as a result of their high frequency, magnetrons are quite directional in nature, it is difficult to disperse the microwave energy evenly. A relative movement is therefore induced in the element to be heated. For instance, in microwave ovens, a plate holding the item to be heated is rotated to compensate for the directionality of magnetrons. The principle used is that changing the position of the item in relation to the microwave energy field will compensate for the directionality of the microwave energy.

It is considered to use more than one magnetron in the microwave generator 24. More specifically, using multiple magnetrons operating simultaneously on different frequencies will increase
the efficiency of the system by allowing for attenuation
by being aware of its impact as a function of the
characteristics of water pertaining to absorption and
temperature. By using this technique, microwave energy
is effectively transferred into the water being heated
as the water is absorbed differently at different depths
and at different temperatures.

The advantages of employing this technique can
be better understood by practical examples.

A) Attenuation: electromagnetic penetration
is infinite in a perfectly transparent substance and
zero in reflective material (e.g., metals). At the
microwave frequency of 2.45 GHz, most energy is absorbed
by water. The attenuation (a) is given by:

\[ a = \frac{2\pi}{\lambda} \sqrt{\frac{\varepsilon_r (1+\tan^2 \delta) - 1}{2}} \]

\[ A_s = \frac{\sqrt{\frac{1+\tan^2 \delta}{(1+\tan^2 \delta)^2}}} \frac{\tan \delta}{1+\tan^2 \delta} \]

It can be approximated that attenuation is
directly proportional to the loss factor and inversely
proportional to the wavelength times the square root of
the relative dielectric constant:

\[ \alpha = \frac{\pi \lambda \varepsilon_r (1+\tan^2 \delta) - 1}{\lambda \varepsilon_r} = \frac{\pi \lambda \tan \delta \sqrt{\varepsilon_r}}{\lambda} \]

For a plane wave, incident microwaves decrease
to 1/e (0.36788; i.e. 63% absorbed) in a penetration
distance \( D_p \) given approximately by:

\[ D_p = \frac{1}{2\alpha} = \frac{\lambda}{2\pi \tan \delta \sqrt{\varepsilon_r}} \]

At 2.45 GHz:

\[ D_p = 1.947 \times \frac{\sqrt{\varepsilon_r}}{L_f} \text{ cm} \]

Thus, using water at 25°C; \( \varepsilon_r^\lambda = 78; \) \( L_f = 12, \)
\( \tan \delta = 0.15 \) and \( D_p = 1.4 \) cm.

The amount of power (\( P \), in watts m\(^{-3} \)) that is
absorbed is given by:

\[ P = 27r f e_0 L_f E^2 \]
where \( e_0 = 8.854 \times 10^{12} \text{ F m}^{-1} \), \( f \) is the frequency \((\text{Hz}, = \omega / 2 \tau)\), and \( E \) is the potential gradient \((\text{V m}^{-1})\).

B) Compensation for varying temperatures and the anomalous dielectric behavior of water: By using magnetron(s) operating on different frequencies simultaneously, the effects of the behavior of water are minimized and thus temperature variation compensated for.

In order to compensate to some degree for the directionality of microwave energy from the magnetron(s), the heating chamber 22 is provided with a specific architecture. For instance, an S-shaped architecture is given to the internal cage of the heating chamber 22 and performs two functions. Firstly, the architecture allows for a sufficient delay for the water to be processed, i.e. enter cold and exit hot. Secondly, the relative position of the water contained within the tube of the heating chamber 22 forming the S-shaped architecture changes as it flows, so that the exposed portion of the water varies from one pass to the next, where a "pass" is defined as exposure to the magnetron(s) array(s).

In order to uniformly distribute the temperature variation in the water of the heating chamber 22, a flow-inducer 28 is in fluid communication with the water of the heating chamber 22, so as to create a mixing action in the heating chamber 22 to enable a generally uniform temperature distribution in the heating chamber 22. For instance, the flow inducer 28 is a passive impeller contained within the tube, as illustrated in Fig. 3, serving to reorient or mix the water prior to entering each pass of the heating chamber 22.

As a plurality of electrical devices are provided in the water heater system 10, an operation
controller 30 is provided so as to control these electrically powered devices. The operation controller 30 is connected to the hot water tap 20, so as to sense a demand for hot water. Typically, the operation controller 30 has pressure sensors to detect any pressure drop in the piping relating the heating chamber 22 to the hot water tap 20. Alternatively, the operation controller 30 uses limit switches on the tap 20 to identify a demand for hot water. Therefore, the operation controller 30 senses that hot water is demanded, whereby it actuates the microwave generator 24 that will create the microwave energy. The microwave energy will heat the water in the heating chamber 22, whereby hot water exiting the heating chamber 22 will be supplied through the hot water tap 20 to the water outlet 14, whether or not it is mixed with the cold water passing through the cold water tap 16.

A water-saving device 32 is optionally provided between the heating chamber 22 and the hot water tap 20. More specifically, the water-saving device 32 is typically at least slowing down the supply of hot water through the hot water tap 20, so as to avoid a waste of water. More specifically, it is known that when a hot water tap 20 is just opened, the water in the piping leading to the hot water tap 20 may be cold. Accordingly, as the heating chamber 22 is in proximity to the hot water tap 20, the water saving device 32 is used to delay the delivery of water, so as to enable the water in the heating chamber 20 to be heated up to suitable temperature. The operation controller 30 is connected to the water-saving device 32, so as to ensure that the water-saving device 32 is operative to delay the supply of hot water.

Water is never heated until needed, thus eliminating the need for a storage tank or wasted energy. The system 10 takes up considerably less space
than a Standard storage tank, resulting in cost-effectiveness from a real-estate standpoint. Accordingly, the system 10 may be positioned closer to the outlets (e.g., tap 20), to reduce the amount of piping in which hot water loses its heat. The water does not sit stagnant and at high temperatures, thus eliminating the risk of breeding bacteria and disease. With the system 10, a generally constant temperature of water supplied is provided regardless of the quantity of water used, as new cold water is not mixed with a reservoir of heated water. A virtually unlimited supply of hot water is readily available and, depending upon plumbing architecture, the delay between the opening of the tap 20 and the delivery of hot water is minimized.

Longevity of the water heater system 10 with respect to storage tanks is improved, since there is no specific requirement for a submersible heating element that would be prone to corrosion or a storage tank that would be prone to scaling and other forms of deterioration.

The system 10 may be located as a replacement to existing water heaters (at a central point in the plumbing system, i.e. "point of entry") or, as an alternate, one or several smaller units may be placed at various points of use. This configuration would reduce the installation cost of existing plumbing systems as only one cold water feed would be required to the point of use versus the present storage tank configurations for which separate cold and hot water pipes run to each point of use. In addition, this would result in a quick and ready supply of heated water at the point of use, as well as reduce installation time and handling costs associated with storage-type water heaters.

The system 10 is ideally suited for and may also be used at the point of use to superheat water that is required by a specific household or commercial device.
such as a dishwasher, thus improving the performance of the appliance.

A need exists in which different hot water applications require different temperature set points. For example, washing of dishes in an automatic dishwasher generally requires water to be of a temperature of 140°F or above in order to properly interact with both the machine and the detergents used. Using a lower temperature may result in energy savings but will not allow the machine to function as it has been optimally designed to do so when water is at the correct temperature.

Consequently, existing water heaters are generally set to operate at a temperature that is equivalent to the temperature required for the most demanding application. In addition to a waste of energy a danger from scalding exists as a result of this practice. One of the contemplated configurations of the system 10 takes this into account and provides a solution to this problem. This is done by providing multiple outputs to the system 10, such as with additional appliance output 34 associated with the hot water tap 20. The primary output of the hot water tap 20 provides hot water for all applications through the water outlet 14 except for dishwashing or applications requiring water of a temperature in excess of 120°F. The appliance output 34 provides water at another preset temperature (e.g., through the action of the operation controller 30 sensing a demand through the appliance outlet 34, generally in excess of the temperature used at the primary output of the hot water tap 20. Either temperature may be regulated independently by a manual temperature regulator associated with the tap 20. One or a plurality of flow sensors and temperature sensors may be employed in such a feedback loop.
The system 10 will fit comfortably in the trunk of a car and represents a negligible weight when compared to a storage tank. The impact to the construction professional will be reduced costs associated with storage and installation on this particular product type and, of course, cost and energy savings relating to the transportation due to its size and weight.
CLAIMS:

1. A water heater system comprising:
   a heating chamber positioned between a water source and a water outlet;
   an operation controller detecting a demand for water from the water outlet; and
   a microwave generator connected to the controller to be actuated as a function of the demand for water from the water outlet so as to heat the water passing through the heating chamber by microwave generation.

2. The water heater system according to claim 1, further comprising a conduction heat-exchange configuration between the heating chamber and the microwave generator so as to heat the water in the heating chamber by cooling the microwave generator.

3. The water heater system according to claim 1, wherein the microwave generator has two magnetrons operating at different frequencies.

4. The water heater system according to claim 1, wherein the heating chamber is a pipe having an S-shaped configuration.

5. The water heater system according to claim 1, further comprising a water-saving device associated with the operation controller and positioned between the microwave generator and the water outlet, the water-saving device being actuated to retain water in the heating chamber until the water reaches a suitable temperature for being discharged through the water outlet.
6. The water heater system according to claim 1, wherein the heating chamber is associated to two of the water outlet, with the operation controller determining a temperature of the water to be reached by actuation of the microwave generator as a function of the water outlet being used.

7. The water heater system according to claim 6, wherein one of the water outlets is associated with appliances such that the microwave generator heats the water fed to the appliance as a function of a requirement of the appliance.

8. The water heater system according to claim 7, wherein another of the water outlets is a tap and the water fed to the appliance is heated at a greater temperature than the water fed to the tap.

9. The water heater system according to claim 1, further comprising a flow inducer associated with the heating chamber so as to circulate the water in the heating chamber to ensure a generally uniform temperature of the water.

10. The water heater system according to claim 9, wherein the flow inducer is actuated by the operation controller.

11. The water heater system according to claim 1, wherein the heating chamber is positioned adjacent to the water outlet.

12. The water heater system according to claim 1, wherein the operation controller has a pressure sensor monitoring a pressure in the heating chamber to detect a demand for water.
13. The water heater system according to claim 1, wherein the demand for water results from the manual actuation of a tap at the water outlet.
Dielectric changes with temperature

Fig. 2
A. CLASSIFICATION OF SUBJECT MATTER
IPC: F24H 1/12 (2006.01) . F24H 9/12 (2006.01) . F24H 9/20 (2006.01)
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: F24H 1/12 (2006.01) . F24H 9/12 (2006.01) . F24H 9/20 (2006.01)
USC: 392/480, 392/483

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Delphion, WEST, Canadian Patents Database. (Keywords : "water heater micro-wave controller outlets cooling sensor circulate pre-heat"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>US 4358652 A ((KAARUP) 09 November 1982 (09-1 1-1982) (See column 1, line 65; column 3, line 55 and Figure 2.)</td>
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[ ] Further documents are listed in the continuation of Box C.  [X ] See patent family annex.

*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

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50 Victoria Street
Gatineau, Quebec K1A 0C9
Facsimile No.: 001-819-953-2476

Authorized officer
Charles W. Wootton 819-997-2763
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