EUROPEAN JOURNAL OF MATERIALS SCIENCE AND ENGINEERING
Volume 4, Issue 2, 2019: 67-74 | www.ejmse.tuiasi.ro | ISSN: 2537-4338

EJMSE

DOI: 10.36868/ejmse.2019.04.02.067

A RESEARCH ON THE NEW TYPE SOLAR WATER HEATING TANK WITH ENERGY SAVING

Chun-Te LEE

Department of Leisure and Sports management, Cheng Shiu University

Abstract

Taiwan is a country with quite adequate amount of sunlight; even at the northern highlands solar-powered water heater will still be usable. However, the first generation conventional storage water heater and the second generation improved storage water heater design are not an idea. When hot water is being used, the tank refills itself with cold water, and, thus, resulting in the decrease of water temperature inside tank. This will cause the heater to have an additional heating cycle, also to increase consumption of energy sources. As for the disadvantage of the second generation storage water heater, we have designed the third generation storage water heater, the smart solar water heating tank with a movable "partition disk" inside the tank, to improve and effectively resolve problem of mixing hot and cold water so that the hot water can be fully utilized. And the result is the usage of hot water being twice more efficient than the first generation conventional design, and 1.6 times more than the second generation improved design.

Keywords*: carbon reduction, solar energy, water- heating tank.*

Introduction

In all of the renewable energy, the most eco-friendly, cleanest, and inexhaustible one is solar energy. Taiwan is a country with abundance of sunlight. The solar heater is usable even in the northern high latitudes. However, the conventional solar water heaters are not energy saving because the designs of the water heating tanks are not ideal. The hollow design of tank cannot separate the hot water from refilling cold water so the temperature inside the tank decreases. It causes the heater to have an additional heating cycle and increase energy consumption.

For this disadvantage, we design an intelligent water heating tank to separate cold and hot water completely so that the hot water inside the tank could be fully utilized. It is a new and patent design that the model of the tank is done already. If this new type of solar water heater could be commercialized, it is much cheaper and could save more energy than Heat Pump water heater for public.

Industry Overview

Economic development relies on adequate energy supply. We are in great need of a clean, environmentally friendly, and inexhaustible source of energy. And the best option for that is solar energy. Solar energy from the sun is about 3.845×10^{26} J per second. The energy received by the Earth is 1.743×10^{17} J per second. That is approximately equal to 6.1 million tons of coal combustion heat generated, which is 16,700 times more than the global demand [1]. The conversion and application related to solar radiation is based on the density of solar energy.

For solar water heating systems, solar greenhouse system, solar cold rooms and

Corresponding author: charter@gcloud.csu.edu.tw

refrigeration systems, solar power, and etc. [2], the primary purpose of low temperature applications (<100 ℃) is for water heating and other warming purposes; for medium temperature applications (100 ℃ ~ 200 ℃) it is for industrial heating and air conditioning; in high temperature applications (> 200 ℃ which focuses on solar power is for smelting and poison decomposition purposes [3].

Taiwan (including Penghu, Kinmen and Matsu) is located in the Northern Hemisphere, across the Tropic of Cancer, is situated in a subtropical area; which is a quite sunny place with an average insolation of about 11,746 kJ / m2 per day [4].

However, the majority of solar water heaters are installed in the central and southern part of Taiwan, and northern Taoyuan County. According to the annual report of Solar Power systems installation of 2012, the most installations are 4,965 in Kaohsiung city, 3,858 installations in Tainan city, 3,308 installations in Taichung city, 1,801 installations in Pingtung County, and 1,605 installations in Taoyuan City. There are 706 installations in outlying islands, majority in Kinmen County with 612 installations. The installations of solar heater are increasing rapidly in Kaohsiung city and Kinmen County from the past years that may be related to the subsidy offered by local governments [5].

Solar water heating systems are able to convert solar radiation to thermal energy by solar collectors (flat plate or vacuum tube) in heating water. They had been on the market from as early as 1891. In 2001, the area with solar collector installations was more than seventy million square meters in the world [6].

The most common water heaters are: gas water heaters, power heaters, heat pump water heaters, and solar water heaters. In these four heaters, the heat pump and solar water heaters are most eco-friendly and energy saving ones. The energy efficiency between them is nearly the same depends on different weather and locations. In general, we get an average of half a year's worth of sunshine yearly- about 210 days of sunlight (that is more or less four hours of sunshine a day). So, the use of solar water heaters is more energy saving and money efficient [7]. Conversely, when there is less than 180 days of sunshine, the heat pump water heating system is better an option compared to solar water. But if we consider the price of each system, heat pump system is the most expensive. A regular home-sized heat pump system would cost around forty to fifty thousand NTD, while for a solar heating system costing only around thirty thousand NTD.

The cost of heat pump water heaters and solar water heaters is nearly the same throughout the year. Why the most eco-friendly and cleanest renewable energy is not the most energy saving one and needs to be heated by electricity or other energy? The problem is the designs of the conventional water heating tanks are not ideal. The hollow design of tank cannot separate the hot water from refilling cold water so that the temperature inside the tank decreases. Our new type (Third generation) tank is equipped with a movable partition disk that can effectively separate hot and cold water, prevent the mixing of hot and cold water, and keep a constant temperature of hot water; therefore the cost will be lower than normal solar water heaters.

The solar water heater is the most eco-friendly one of heating methods. The common solar heating systems are natural cycle and forced cycle (see Fig. 1, Fig. 2).

Natural circulation solar water heater

The process inside the solar collector is as follows: after absorbing heat from the sun, the water temperature rises and density lessens and travels to storage tank. Then, cold water inside collects at the bottom towards the solar collector that makes a natural convection cycle as a system to heat up the water. The natural circulation system is commonly used in household.

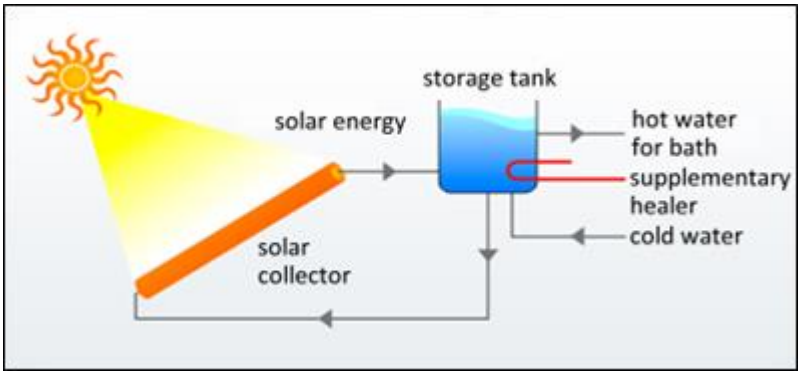

Fig. 1. natural circulation system of solar water heater [8]

Forced circulation solar water heater

The temperature controller forces water inside storage tank to flow through the solar collector and bring solar radiation heat back to the heat storage by using collector circuit pump. This is mainly used in large-scale solar heating systems.

According to Khalifa's research, [9] the efficiency of solar water heating system under forced circulation is higher than those under natural circulation by 35-80%. However, the additional costs for circulation pump, the manner of operation, and maintenance (such as leakage) and other issues must be considered before purchasing the solar water system.

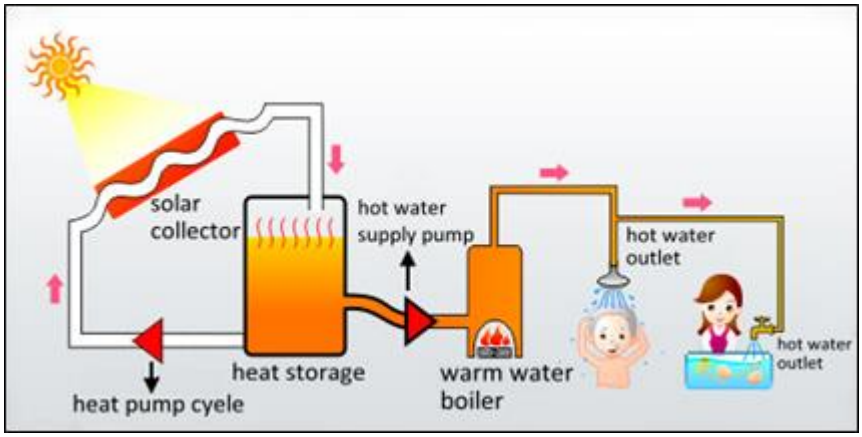

Fig. 2. Forced Cycle type of Solar water Heater [8]

Overview of Previous Products

First generation solar water heating tank

Why the solar heater is not the most energy-efficient way for water heating? It is because the solar heater has to heat by electric energy in cloudy and rainy days. Besides, when hot water is being used, cold water is replenished into the storage tank simultaneously so that the temperature of the stored hot water will decrease. Once the temperature is not hot enough, heating by electric energy is necessary. The Fig. 3 is an analysis chart of the conventional heater storage tank.

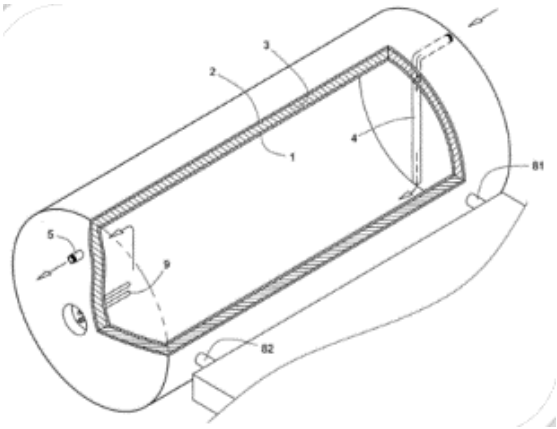

Fig. 3. Schematic representation of a conventional first-generation solar water heater storage tank [10]

On both sides of the conventional storage water tank are inlet pipe (4) and outlet pipe (5). When hot water is being used, hot water flows out from the outlet pipe (5), and cold water is being replenished through the inlet pipe (4) (there is some water that is poured in by pressurized motor). The replenished cold water will mix with hot water, which results in dropping of the water temperature. In order to maintain the range of the predetermined temperature, power heater (9) is installed together to keep heating the water at the desired temperature. However, due to the large capacity of the tank (usually at 400L), the water heater would consume more electrical energy and heating time. Instead of saving, it wastes energy for users.

Second generation solar water heating tank

According to the government's policies on carbon reduction, some manufacturers have proposed solutions to improve the aforementioned issues of storage tank such as the dropping of temperature, additional consumption of energy and time. The solution they have brought up is to equip a partition disk inside the tank that separates the tank into two parts (hot water on the left and the buffer zone on the right) which are connected with a tube. This equipment results buffering time for cold water flowing into the buffer zone and out to the hot water zone and slowing down the speed of hot and cold water mixing. As shown in Fig. 4:

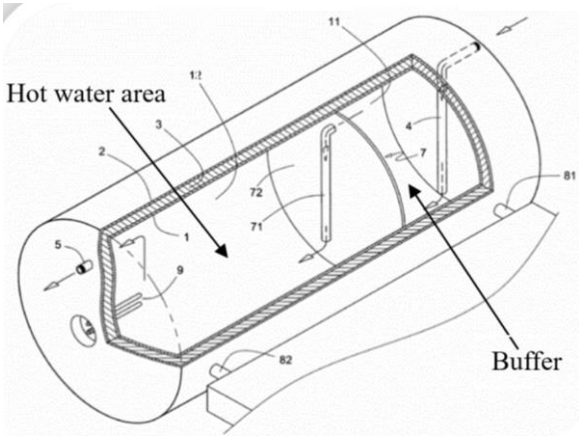

Fig. 4. Schematic representation of the second generation solar water heating tank [10]

Third generation solar water heating tank

Although the aforementioned design is able to improve the problem of water temperature reduction, the cold water can still flow in and mix with hot water through the connecting tube. It can only slow down the speed of the hot and cold water mixing. For this reason, our research team innovated and developed the "smart solar water heating tank". This Design can be completely separate the hot and cold water without mixing. As shown in Fig. 5、6.

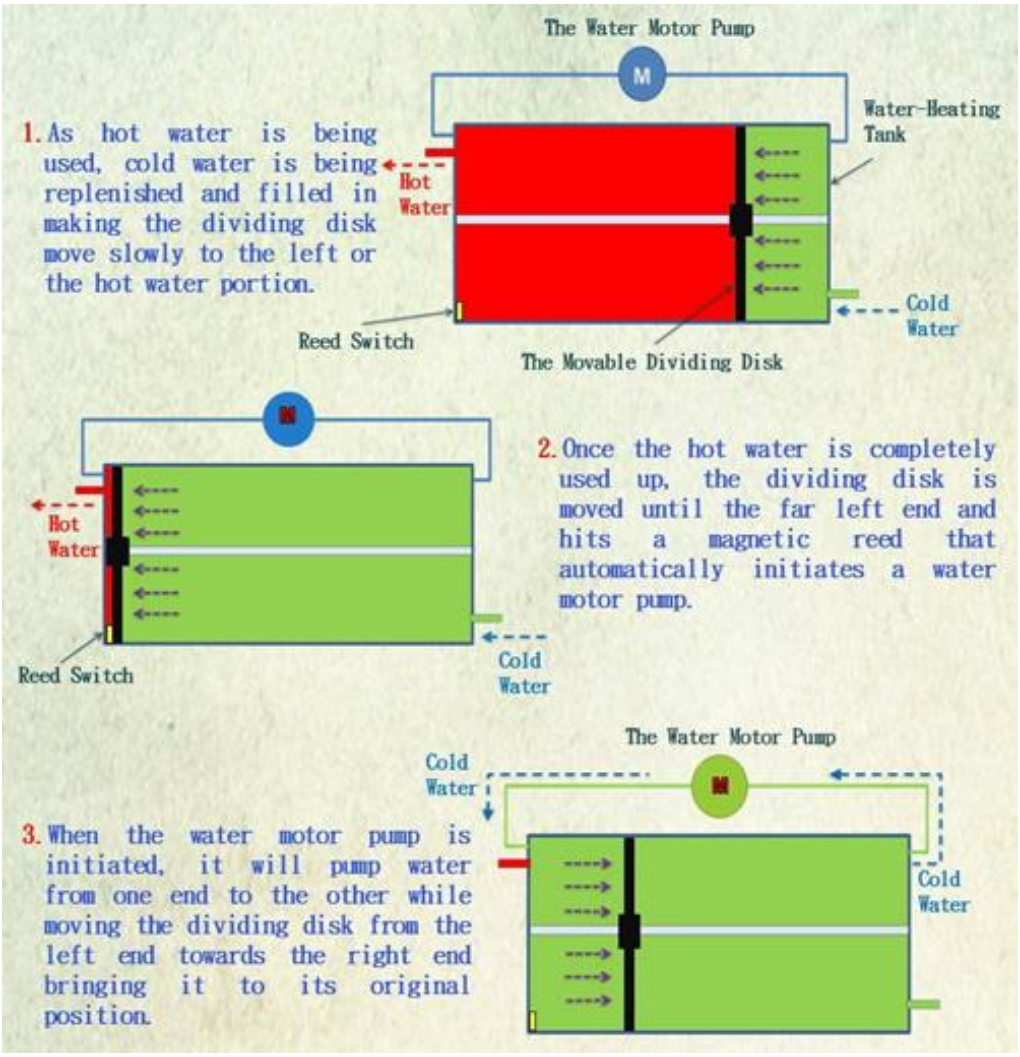

Fig. 5. Analysis diagram of smart solar water heating tank

The new design of partition disk is movable and at the far right side. When hot water flows out from the outlet pipe and cold water flows in from the inlet pipe, the partition disk will move towards the left side slowly by the water pressure to prevent the issue of water mixing. When the partition disk reaches the end of left side, it will activate the motor pump immediately to transfer the cold water from the right side to the left and pushing the partition disk back to the far right side at the beginning for water heating in the next day.

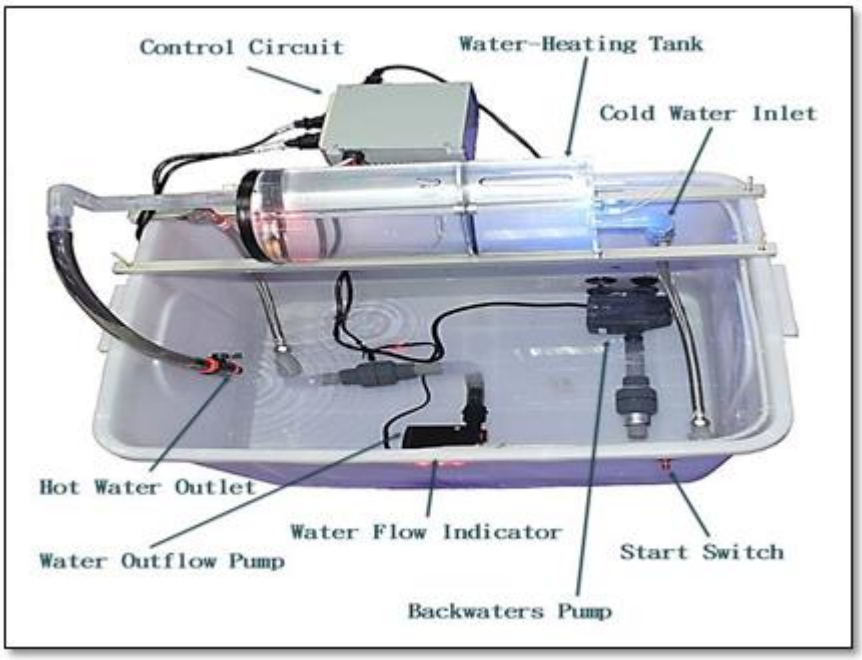

Fig. 6. Model of solar water heating tank

When hot water runs out, the motor pump will be activated to push the partition disk back to the far right side. At this time, the whole tank of water would be heated by heating tube. However, it's hardly being used because the whole tank of hot water is 100% available. Furthermore, the electricity consumption of motor pump that activates to push the partition disk back to the far right side costs only 0.0953kWh (take WALRUS water pump TP320P as a sample). Comparing to the electricity consumption in heating 400 liter cold water from 23 degrees to 60 degrees (electricity consumption costs around 19.88 kWh), it could be almost omitted.

The partition disk is made by HIPS which is high impact and heat-proof, is the best choice of material for partition disk. The aperture between partition disk and tank must be smaller than 1mm during fabricating to avert the problem of leaking and slow down moving speed. In fact, the partition disk cannot segregate the hot and cold water entirely because of the aperture; however, the amount of permeating water is extremely minimal.

The following is the comparison table in every kind of solar water heating tank.

Table 1. Comparison in every kind of storage tank (take 400 liters as an example)

Storage Tank	Traditional (1st generation)	Improved (2nd generation)	Smart (3rd generation)
Advantages	Low manufacturing cost	Slower mixing speed of hot and cold water	Separating hot and cold water completely
Disadvantages	Consuming of time and energy	Heating by electric is necessary	Additional set of motor
Available water for use	200L of hot water	250L of hot water	400L of hot water
No. of hot showers 50L/person	4 people	5 people	8 people

Source: Research Findings

Table 2 assumes that hot and cold water is fully mixed and heated to 50 degrees during winter. When half of the hot water (200L) is used up, the temperature of the newly replenished cold water temperature is 20 degrees, so the temperature at this time is reduced to (50 + 20) / 2 = 35 degrees. The water is not hot enough at this temperature to most people. Therefore, the available hot water in a traditional design storage tank with 400L is only half of the content, which is approximately 200L. The remaining water has already been mixed with cold water resulting in a not hot enough temperature for hot baths.

As for the improved design of storage tank (2nd generation), it can slow down the speed of mixing water of hot and cold water; however, it still needs to be heated by electricity and waste energy. Under our calculations, the estimate amount of the available hot water is more than half of its storage content, around 250L. According to the experimental data (see table 3, the data is derived from an imitating tank which is 2000ml), we could find the assumption of available hot water we estimate is correct. The smart solar water heating tank could separate the hot and cold water completely; therefore, the available hot water is 400L.

According to the hot showers in table 2, we could find the result as follows: the number of hot showers of traditional storage tank is 4, improved one is 5, and smart one is 8. Thus, the efficiency of smart storage tank is 2 times higher than traditional one, and is 1.6 times higher than improved one.

Conclusion

As we know from the above, comparing to the tradition and improved ones, the capacity of available hot water in smart storage tank for using is much. The efficiency of our smart storage tank is the best because of the design of the movable partition disk which is the most important hallmark.

However, there is still a problem to solve in smart solar heating tank which is, “if we still have the demand for hot water which runs out, how can we solve this problem?” The solar heaters on the market would heat the whole tank of water by heating tube or equip a small tank for heating. However, it will consume more energy and material cost. This is the goal we have to endeavor.

References

[1] *Taiwan service center energy-saving plan*, http://blog.udn.com/escos/8612177.

[2] National Cheng Kung University Research Development Foundation, *Solar water heating systems industry skilled workshop*, Tainan, 2013.

[3] ITRI energy resources, *Solar hot water system of professional and technical personnel workshops*, Taipei, 2001.

[4] Ou Wen Wen Sheng, He Ming Jin, Chen Ruei Ling, Chen Jian Fu, Luo Shr Chi , *Taiwan solar design studies use standard insolation*, **Architecture**, **64**, 2008, pp. 103-118.

[5] Jang Ke Chin, Li Tsung Sheng, Jung Guang Min, *Subsidy Programs on Diffusion of Solar Water Heaters in Taiwan*, **Renewable Energy**, Taiwan, 2010.

[6] Tang Jen Chen, Jang Wen Wen Shr, Jang Mei Ying, "*Summary of Israeli law and solar reflection*, **Solar and new energy Journal**, **8**, 2003, pp. 13-15.

[7] *Comparative analysis of solar water heaters and heat pump water heater energy efficiency*, http://tw.myblog.yahoo.com/ mrsaving /arti.

[8] *National Cheng Kung University Energy Research Center - Solar water heater types*, http://solar.rsh.ncku.edu.tw/t01_kind.php.

[9] Khalifa, A.N., *Forced versus Natural Circulation Solar Water Heaters: A Comparative Performance Study*, **Renewable Energy**, **14(1)**, 1998, pp. 77-82.
[10] Chen Rung Bin, *The Improvement on Solar Water Heating Tank*, Patent Publication, M396945.

Received: February 2, 2019
Accepted: April 18, 2019