Design and Experimental Analysis of the Compact Solar Water Heater

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Table of Contents

Table of figures

ABSTRACT

The development of compact solar water heaters is the subject of this report, which begins with an overview of solar water heating and an analysis of its active and passive varieties. A comprehensive evaluation of the literature synthesizes prior research, laying the groundwork for comprehending current developments and pointing out areas that require more investigation. The research goes on to describe the experimental configurations used to evaluate the performance and efficiency of the heaters, providing insightful information on how they might be used in real-world scenarios. It also touches on the current production process in brief, summarizing important factors and procedures without getting too technical. The paper seeks to promote sustainable options for home water heating needs by advancing compact solar water heater technology through the integration of lessons from these disparate fields.

CH#01

INTRODUCTION

Hot water is essential both in industries and homes. It is required for taking baths, washing clothes and utensils, and other domestic purposes in both the urban and rural areas. Hot water is also required in large quantities in hotels, hospitals, hostels, and industries such as textile, paper, food processing, dairy, and edible oil in fact, hot water is required mainly for purposes of hygiene and bathing in homes. For instance, in South Africa, the accepted norm is that each person in a household requires at least 20 l of hot water per day out of which more than one-half is for personal hygiene. Hot water demands appear to be highest within the periods of the day when electric energy demand for other purposes is high. Fig 1illustrates hot water usage trend and its distribution for domestic uses. This figure shows that the hot water usage is highest in the mornings and evenings, with demand for both periods being almost the same, while cooking and bathing present the highest water demanding domestic activity.

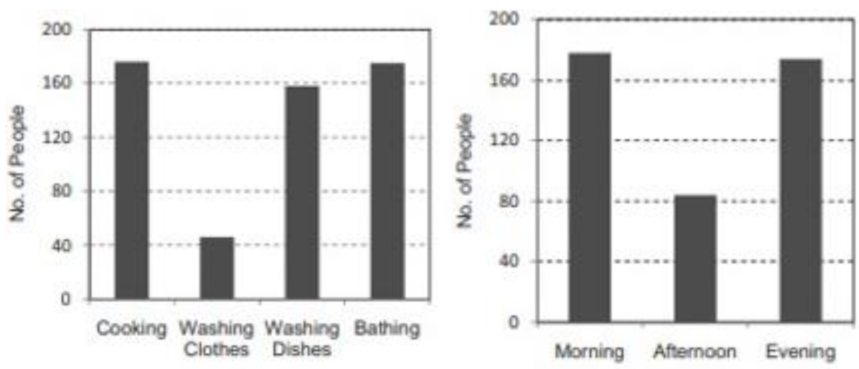

Fig 1.1 Distribution of domestic hot water usage

At present, hot water demands are met mainly fulfil by the use of electric heaters. Unfortunately, rising energy cost, environmental concerns, and the depleting nature of the current primary energy sources in use have made electric heaters less attractive. This is because the primary energy sources of electric energy utilized are mainly the fossil fuels. In addition, the demand for electricity is growing rapidly; thus within those periods when hot water demand is highest the electric energy facilities are often overstretched, resulting in some cases to power shading especially in countries.

These problems can be handled by taking off the energy demand for hot water purposes from electricity. Fortunately, the technical and economic feasibilities of solar hot water systems SHWSs are well established and they have found domestic and commercial applications. These systems use solar energy to generate hot water. The technology employed has been reasonably developed and can be easily implemented at a low cost. Several configurations exist for this purpose. These configurations may be grouped into two, namely, the passive solar hot water system PSHWS and the active SHWS. The solar collectors employed in these configurations could be flat plate, concentrating, or evacuated tube types.

THE ACTIVE SOLAR HOT WATER SYSTEMS

Active solar water heating systems use electric pumps, valves, and controllers to circulate water or other heat-transfer fluids through the collectors. Thus they are more complex and usually more expensive than passive systems.

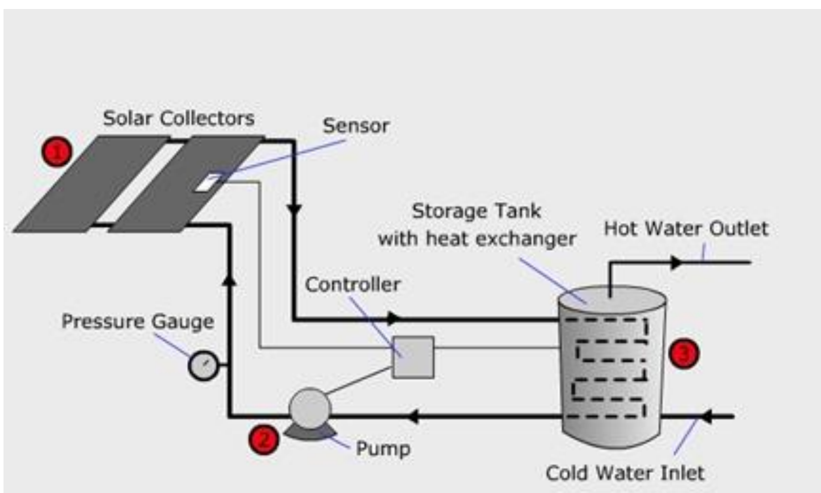

FIG 1.2 Experimental setup of active hot water

THE PASSIVE SOLAR HOT WATER SYSTEMS

The PSHWSs generally transfer heat by natural circulation as a result of buoyancy due to temperature difference between two regimes; hence they do not require pumps to function. They are the most commonly used solar water heaters for domestic application and have been designed and investigated by different researchers

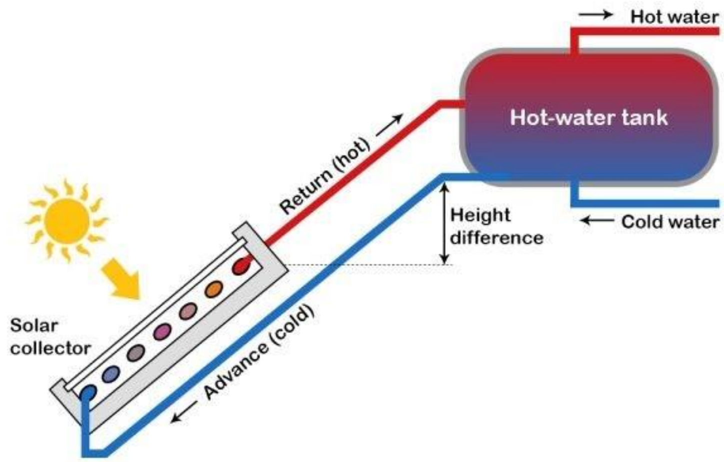

Fig 1.3 Experimental setup of Passive solar hot

1.1 Compact Solar Water Heater

Our project utilizes a passive solar water heating approach to provide hot water for a single room and washroom. A spherical glass dome acts as a greenhouse, capturing sunlight and heating black spiral tubes filled with water that is wrapped around a truncated cone. The cone itself is filled with paraffin wax, a phase change material. During the day, sunlight heats the water in the tubes, transferring that thermal energy to the surrounding paraffin wax which melts to store latent heat. Even after sunset, the warmed wax continues to release its stored heat to the water in the tubes, ensuring a consistent flow of warm water to the storage tank below. This innovative design offers a space-saving and mobile solution for hot water needs, with efficient heat transfer throughout the day and night.

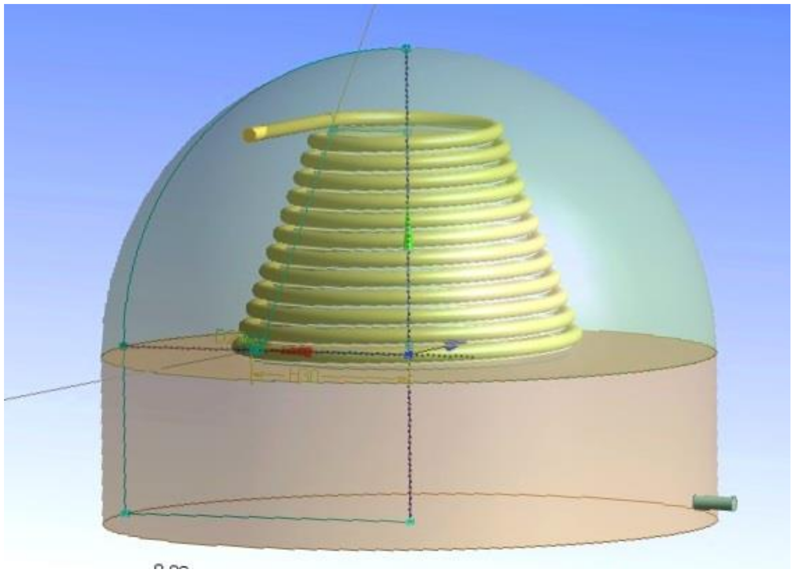

Fig 1.4 Designed solar water heater

1.2 Problem Statement

Conventional solar water heaters, while a sustainable solution, have limitations that hinder their use in many homes. Their large, fixed size can be a challenge for rooftops with limited space or aesthetics in mind, and these bulky collectors can block scenic views or sunlight for windows below. Furthermore, in densely populated areas, finding suitable roof space for conventional systems can be difficult, limiting accessibility to solar hot water for a significant portion of the population. Finally, conventional solar water heaters can overheat during intense sunshine, leading to inefficiencies and potential damage. Your innovative design offers a compelling alternative by addressing these shortcomings.

1.3 Aims and Objective

The main objective of this study is following

- Design of compact solar water heater with thermal storage system.
- Short term heat storage for stable outlet temperature of the water heater

- Minimize effect of solar fluctuation
- Compact in size
- Manufacturing of the design
- Arrangement of experimental setup for experimentation
- Comparison with the result of conventional solar water heater

CH#02

LITERATURE REVIEW

2.1 Solar Water Heaters.

Energy consumptions in certain developing countries, particularly in Asia, were still growing. Furthermore, the depletion of fossil fuels due to overuse of primary energy sources means that, with current proven reserves, there will only be 119 years of coal production, 46 years of oil production, and 63 years of natural gas flow left in the ground. According to the law of supply and demand for energy, growing energy costs will have an effect on how the world economy develops as long as fossil fuel reserves are depleted. However, the burning of fossil fuels for transportation, industry, and energy has resulted in a major rise in the amount of greenhouse gases released into the atmosphere. The majority of scientists concur that this expansion is what is primarily responsible for global warming. The global temperature has already increased by 1.4 1C over the last 30 years of the 20th century, and it will climb further over the ensuing decades. Significant changes in sea levels, ecosystems, and weather patterns brought about by this warming may endanger people's health and way of life and result in irreversible extinctions of both plant and animal species.[1]

Hot water is necessary for families and businesses alike. In both urban and rural locations, it is necessary for bathing, cleaning clothes and utensils, and other household tasks. Additionally, a lot of hot water is needed in hospitals, hostels, hotels, and businesses that produce textiles, paper, dairy, edible oil, and food processing.1. In actuality, households primarily need hot water for bathing and cleanliness. For example, it is standard practice in South Africa that every member of a home needs at least 20 liters of hot water per day, of which more than half is used for personal hygiene.2. Demands for hot water seem to be highest during the times of the day when other uses of electricity are high. Currently, electric heaters are the primary means of meeting hot water demands. Unfortunately, electric heaters are becoming less appealing due to increased energy costs, environmental concerns, and the depletion of the principal energy sources now in use. The reason for this is that the main energy The primary electric energy sources that are used are fossil fuels. Furthermore, the need for electricity is increasing quickly, which means that during times when hot water demand is at its peak, electric energy infrastructure is frequently overextended, sometimes leading to power shadowing, particularly in developing nations.[2]

In Brazil, the common practice of using electrical showerheads to heat water for home usage results in a load curve that peaks early in the evening, placing a significant strain on utilities involved in production, transmission, and distribution. These 3–8 kW electrical resistance showerheads are typically used by over 73% of Brazilian households. Over 90% of residential buildings in some of the more moderate temperature parts of the country's south, where the majority of Brazil's population is concentrated, have electricity showers. The issue has gotten worse in recent years because these devices' nominal powers have steadily climbed from an average of 3 kW to a range of 4.4 kW to 6.5 kW, and in some more expensive models, 8 kW. One of the major energy issues the power sector in Brazil is dealing with is the use of electricity for direct water heating.[3]

In four different areas—electric power generation, hot water production, fuel transportation, and rural (off-grid) power services—renewable energy sources have the potential to significantly outperform fossil fuels. The utilization of solar technologies has grown at a pace of roughly 30% since 1980. According to 2010 research by Renewable Energy Policy Network, around 70 million homes currently use solar water heating. (SWH) networks globally. The major ways that using SWH can assist the economy are by reducing fuel costs for water heating and by addressing environmental concerns. SWH systems are becoming more common and have a big impact on the industrial and home sectors in a number of nations. At the moment, China leads the world market for solar thermal products. In 2009, Chinese companies produced 28 million square meters of solar systems, accounting for more than 80% of the world's solar hot water and heating market. Germany, Turkey, Brazil, and India are the global leaders for solar hot water, excluding China. The majority of the European Union's (EU) percentage of the built SWH capacity that is still available.[4]

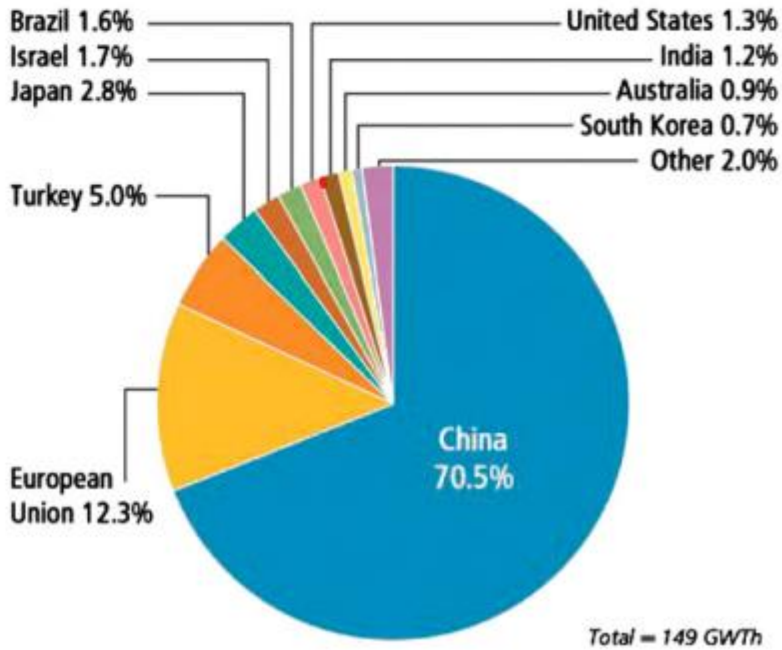

Fig 2.1 Solar thermal products around the globe

2.2 Portable solar water heater

A compact solar water heater was the subject of extensive experimental research to assess the heater's performance and establish the ideal storage tank depth. The trials were carried out with single and double glazing at tank depths of 5, 10, and 15 cm. According to experimental results, the heater can raise the temperature by roughly 68 °C in July at a storage tank depth of 10 cm. The ideal depth for the tank to provide hot water for a full day is 10 cm. While the double-glazed system is more effective at maintaining higher temperatures, the single-glazed system causes the water temperature to rise somewhat more than the double-glazed system.[5]

A theoretical and experimental investigation on a tiny solar heater was carried out by Garg and Rani. Energy balance equations that were transformed into finite difference form and computersolved comprised the theoretical portion of the research. The Fourier Series is used to describe both the ambient temperature and solar radiation. In that method, the loss of stored energy during the dark or times of low insolation created an issue. An insulated baffle plate within the tank next to the absorber plate and an insulating cover helped to reduce the amount of energy lost.[6]

2.3 PCM (Phase Change Material)

Energy should be stored and used as needed if solar energy is to be utilized throughout the day. One potential solution for solar water heating systems' thermal energy storage is Phase Change Material (PCM). Its high energy storage density and isothermal behavior during charging and discharging are its advantages. The most effective method of storing thermal energy for use in heating water for home use at night is to use a solar water heater that uses phase change materials (PCMs) in the storage tank. Sensible heat was absorbed by the phase-changing substance, and any remaining heat was latently stored.

Kumar [9] created a system for latent heat storage. In order to meet the hot water needs in the evening and morning, a box-type solar collector has been used for further development and performance evaluation. The system comprised of three heat exchangers with fins. A heat-storage material in the system was paraffin wax, which has a melting point of 54°C. It was discovered that paraffin wax performed exceptionally well in the desired temperature range of hot water (15 and 20 liters).Shukla has built two water heating systems based on paraffin of the two systems, one used a tank for tank-style storage, while the other used two systems based on a 24-hour cycle. The systems' respective efficiencies were found to be 45% and 60%. Carbazole et al.'s water heating system was developed both with and without conventional PCM. After comparing the two systems further, it was discovered that the heat storage tank with the PCM had an outlet temperature that was 6°C higher than the system without a PCM.

[7]

2.3.1 PCM Categories

The two main categories of PCMs are organic and inorganic substances. The majority of organic PCMs have low vapor pressure, a high latent heat per unit weight, little to no subcooling, are compatible with most building materials, and are non-corrosive and chemically stable. Their flammability, significant volume fluctuations upon phase shift, and limited thermal conductivity are drawbacks. Compared with organic chemicals, inorganic compounds are less expensive and non-flammable, and they possess a higher latent heat per unit volume and high thermal conductivity. They do, however, corrode most metals and experience subcooling and disintegration, which can alter their phase change characteristics. Since the melting point is the most crucial factor, a PCM with an easily changeable melting point would be required[8]

CH#03

EXPERIMENTAL SETUP

The designed compact solar water heater will be sufficient for a single room or an office. Our experimental setup featured a compact solar water heater incorporating a dome-shaped solar collector, a storage tank, and a helical coil containing phase change material (PCM). The PCM placed inside the dome to maximize solar absorption and increase thermal storage efficiency.

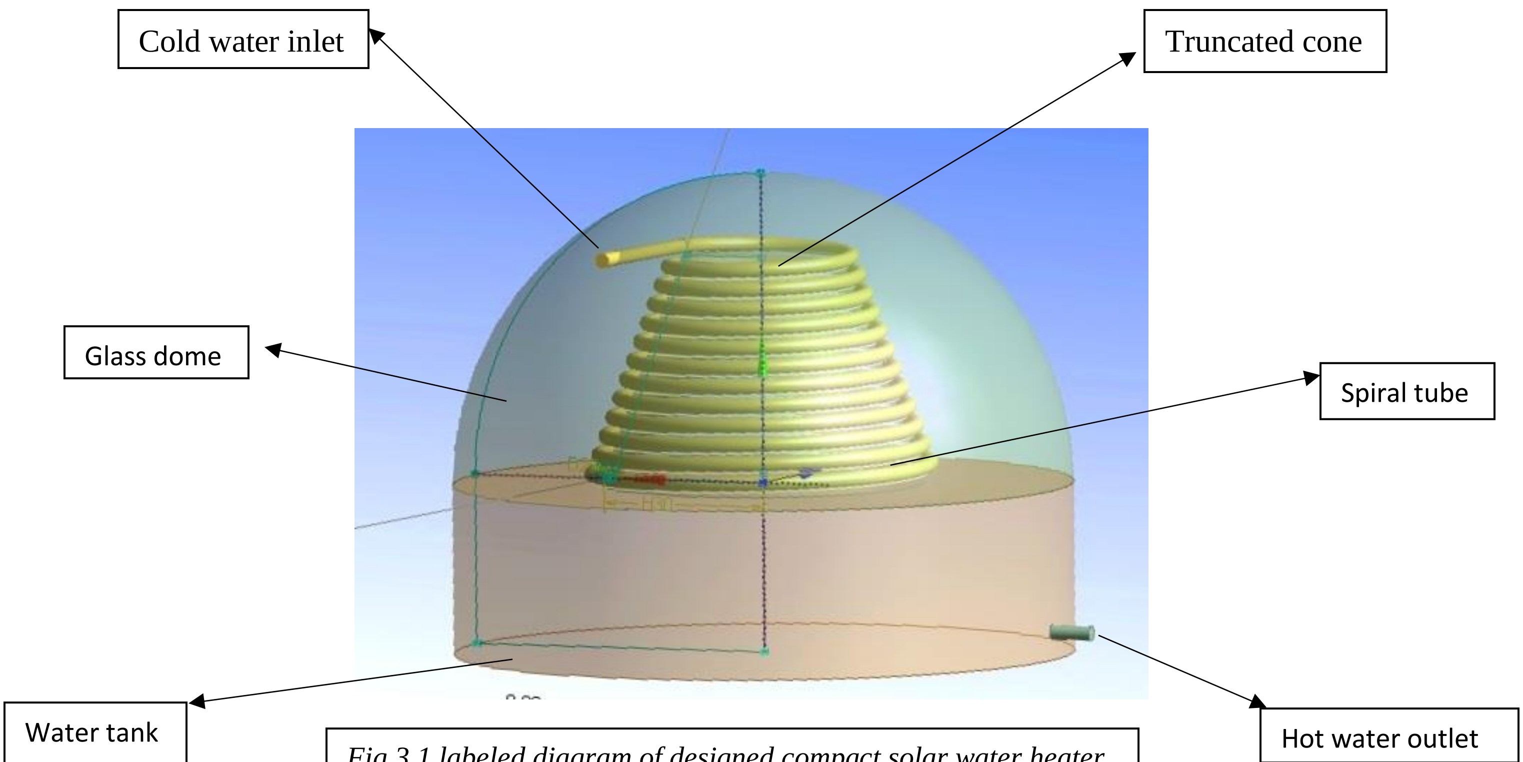

Fig 3.1 labeled diagram of designed compact solar water heater

3.1 EXPERIMENTAL EQUIPMENTS

1.**Glass Dome**: This spherical dome made of glass allows sunlight to pass through and traps inside the system.

2.Spiral Tubes: Black, water-filled spiral tubes wound within the truncated cone. They absorb solar energy and transfer heat to the surrounding PCM.

3.Truncated Cone: This cone-shaped container is filled with the phase change material (paraffin wax).

4.Phase Change Material (PCM): Paraffin wax within the truncated cone absorbs and stores thermal energy as latent heat during the day.

5.Water Tank: This insulated tank located below the truncated cone stores the heated water for later use.

6.Hot Water Outlet: This is the pipe or outlet where hot water exits the tank for use.

7.Cold Water Inlet: This is the pipe or inlet where cold water enters the bottom of the tank.

A spherical glass dome acts as a greenhouse, capturing sunlight and heating black spiral tubes filled with water that snake through a truncated cone. The cone itself is filled with paraffin wax, a phase change material. During the day, sunlight heats the water in the tubes, transferring that thermal energy to the surrounding paraffin wax which melts to store latent heat. Even after sunset, the warmed wax continues to release its stored heat to the water in the tubes, ensuring a consistent flow of warm water to the storage tank below. This innovative design offers a space-saving and mobile solution for hot water needs, with efficient heat transfer throughout the day and night.

3.2Testing Methodology:

1. Positioning the solar water heater in a location with good sunlight exposure.

2. Measuring the initial water temperature in the tank.

3. Monitoring water temperature in the tank and wax temperature in the cone throughout the day under varying sunlight conditions.

4. Recording the ambient temperature for comparison.

5. Potentially testing the system at night to assess heat retention from the PCM.

CH#04

Manufacturing process

4.1 Manufacturing:

Manufacturing of experimental setup is in process and will be completed with in next 1 to 2 months.

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