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Solar Water Heating Systems – A Review

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ABSTRACT -In the current period, where we are confronting an emergency, and delayed consequences of exploiting traditional fuel sources like coal, diesel, and gas, switching to green and clean energy choices like solar energy is crucial. We are very fortunate to have such an abundant supply of Solar Energy free of cost. Energy plays a significant role in human life. Solar energy is one of the most promising types of renewable energy. This solar radiation incident on the earth surface has enormous potential and can be used to profit society. Solar energy is used in Solar cookers, Electricity generation, Charging Batteries, Heating and many other things. The size of the SWH depends on the temperature requirement of the user, geographical conditions, availability of solar radiation, so we must design a system as per the above parameters
We will be discussing Solar Water Heating systems in this paper, The types of SWHs, components, types of collectors, working of SWHs, applications of SWHs, advantages and disadvantages.
Keywords- Solar energy, Solar water heating, renewable, thermal, efficiency, energy, collector

I. INTRODUCTION

Solar water heating (SWH) is one of the oldest and most successful solar energy applications; it is a reliable, clean, nature-friendly and cost-effective piece of technology. It is reducing utility bills for a lot of households and industries/businesses. Solar water heating systems are reducing our dependence on fossil fuels by considerable amounts. Heating water takes up nearly 20% of total energy usage for an average family.

A SWHS collects thermal/heat energy from the sun and uses it to heat water used in a household or any industry, rather than using electricity or natural gas to do the same task. Water can be efficiently heated up to a temperature of 60-80 degrees Celsius. A solar water heater of a SWHs of 100-300 litres capacity is suitable for domestic purposes. A 100 litres SWH can be used as a substitute for an electric geyser for residential use; this may save approximately 1500 units of electricity per annum. Also, a 100 litres SWH can reduce 1.5 tons of carbon dioxide emission per year.

II. COMPONENT REVIEW AND WORKING

A solar water heating system consists of the following parts-

Solar Collector- Rays fall on the collector, black absorbing surface (absorber) inside the collector absorbs the solar radiation and transfers the thermal energy to the water flowing through it. The most commonly used collectors are divided into four sub-groups: Flat Plate collectors, Evacuated Tube collectors, Line Focus collectors, and Point Focus collectors. These four types of collectors are discussed in detail further.

Storage Tank- Insulated storage tank stores the water. The circulation of water from the tank through the collector and back to the tank continuous automatically. It is insulated to prevent heat loss.

Connecting pipes

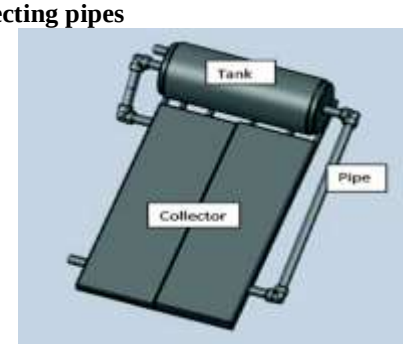

Figure 1- Main components of a Solar Water Heater

2.1 TYPES OF SOLAR COLLECTORS

There are majorly four types of Solar Collectors that are commonly used in solar water heaters.

2.1.1 FLAT PLATE COLLECTOR

There are three main components of a flat plate solar collector – a transparent front cover, a collector housing and an absorber. The absorber can be made from aluminium, copper, and steel materials, and the absorber has a black absorbing surface. The collector housing is made using plastic, metal or wood, and the front cover is made from

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glass. The front cover must be sealed so that dirt, insects and humidity do not enter and the heat does not escape. The collector housing is insulated at the back and sides to reduce the losses.

In this collector, two types of losses are possible – convection and radiation loss. The convection loss is due to air movements because of the temperature difference between the absorber and ambient air. The radiation loss is due to the exchange of heat by radiation between the absorber and the environment. The glass also reflects some parts of the radiation.

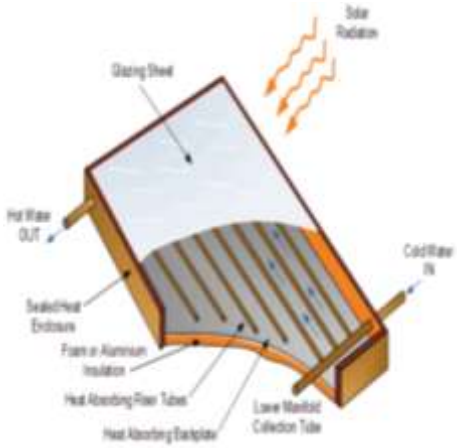

Figure 2- Flat Plate Solar Collector

2.1.2 EVACUATED TUBE COLLECTOR

Evacuated Tube Collectors are of two types – co-axial tube and heat pipe designs. Evacuated type solar collector is made up of a series of tubes to heat water for use. These tubes utilize a vacuum or an evacuated space to capture solar energy while minimizing heat loss to the surroundings. They have an inner metal tube that behaves like an absorber plate; it is collected to a heat pipe to carry the heat collected from the sun to the water. In this heat pipe, the fluid contents are under very particular pressure; at this pressure, the 'hot' end of the tube has boiling liquid in it, while the 'cold' end has condensing vapor. This allows the thermal energy to move more efficiently from one end of the pipe to the other.

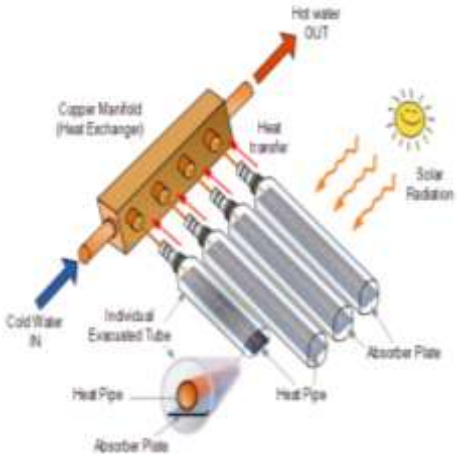

Figure 3- Evacuated Tube Solar Collector

2.1.3 LINE FOCUS COLLECTOR

These collectors are also called parabolic troughs. These use highly reflective materials to collect and concentrate the heat energy from solar radiation. These collectors have parabolically shaped reflective sections connected into a long trough. A pipe carrying water is placed at the centre of the trough so that sunlight collected by the reflective material can be concentrated onto the pipe, this heating the contents. These are high powered collectors. Hence, they are not used in residential applications.

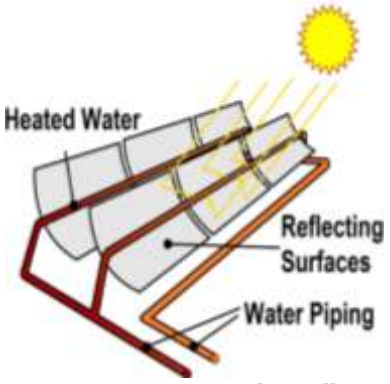

Figure 4- Line Focus Solar Collector

2.1.4 POINT FOCUS COLLECTOR

These collectors have large parabolic dishes composed of some reflective material that focuses the sun's energy to one point. Although very effective at collecting sunlight, they must actively track the sun across the sky to be of any use. These dishes can work alone or can be combined into an array to gather even more energy from the sun.

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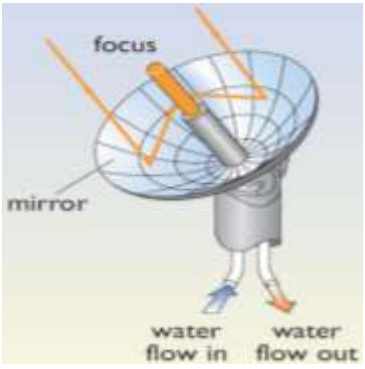

Figure 5- Point Focus Solar Collector

2.2 WORKING

The SWH system is generally installed on the roof, the sidewall of the house, open ground with the collector facing towards the sun, and a continuous water supply. Water flows through the connecting tubes, absorbs solar heat and becomes. The heated water is stored in the insulated storage tank for further use. The SWH uses the following concept – black surfaces have good absorption properties and thus very efficiently absorb heat when left in the sun.

2.3 WAYS TO TRANSFER HEAT TO WATER

2.3.1 DIRECT CIRCULATION SYSTEMS

The pumps circulate water for household work into the home through the collectors. These will work well in climates where it rarely freezes.

2.3.2 INDIRECT CIRCULATION SYSTEMS

The pumps circulate a non-freezing heat transfer fluid through the collectors and heat exchange. This heats the water, which then flows through pipes into the house. These are primarily used in an area where the climate is prone to freezing temperatures.

III. SOLAR WATER HEATER DESIGNS

There are two types of solar water heating systems- Active, these have circulating pumps and controls, and the other is passive.

3.1 ACTIVE SOLAR WATER HEATING SYSTEMS

3.1.1 FORCED CIRCULATION TYPE SOLAR WATER HEATER

This system uses an external element which can be an electric pump, to circulate water. The water is actively pumped from the storage tank through the collectors and back to the tank. The components needed for this are- an electronic controller, small pump, valves. In this setup, the collector and storage tank can be installed separately. Also, no height difference between tank and collector is needed. Two temperature sensors monitor the temperature of the collector and tank.

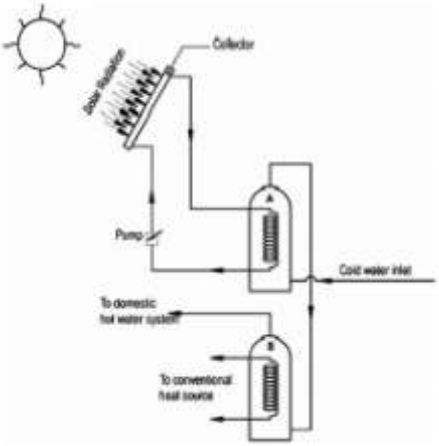

Figure 6- Forced Circulation Type Solar Water Heater

3.2 PASSIVE WATER HEATING SYSTEMS

It is less expensive than active systems but not as efficient. However, passive systems can be more reliable and last longer. There are two basic types of passive systems-

3.2.1 THERMOSYPHON SOLAR WATER HEATER

This system works on the principle that cold water has a higher density than warm water. Thus, cold water will sink because it will be heavier. Because of this reason, the collector is mounted below the storage tank so that cold water from the insulated tank reaches the collector via a descending water pipe. The collectors absorb the solar radiation and convert it into heat energy, and thus energy is transferred to the water. The density of water decreases as its temperature rises. This establishes a circulation that helps the tank water to get heated continuously. In a thermosyphon system, the tank must be placed well above the collector, or else the cycle can run backwards at night and thus cool down all the hot water. This system only works properly if the height difference between the top of the collector and the bottom of the tank is at least 30 cm.

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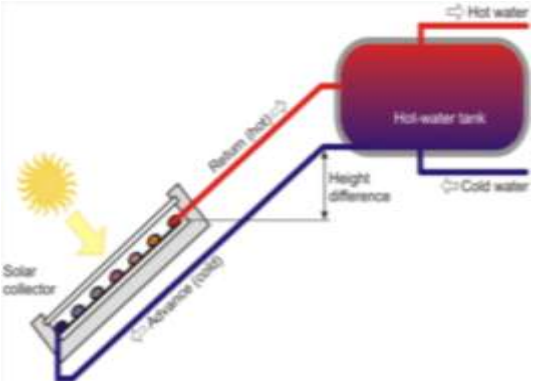

Figure 7- Thermosyphon Solar Water Heater

3.2.2 BUILT-IN-STORAGE SOLAR WATER HEATER

These are also known as "Integral collector-storage systems", these systems combine a flat-plate collector and a storage tank in one unit. Built-in-storage SWHs can be divided into two subgroups-

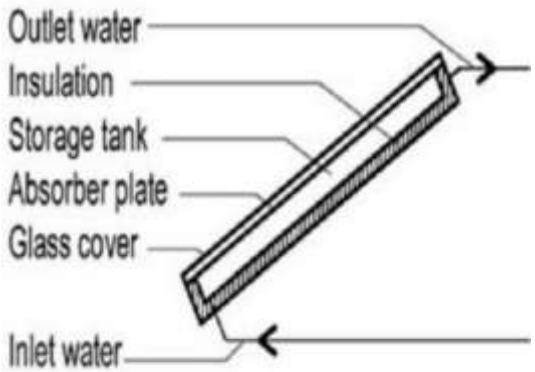

Figure 8- Built-In Storage Solar Water Heater

3.2.2.1 PLAIN BUILT-IN-STORAGE WATER HEATER

Its structure involves a rectangular box-like structure with the top side painted black and enclosed behind a single or double sheet of glass. The back and side surfaces are adequately insulated, and the entire structure is titled at a suitable inclination. This system has many advantages. Firstly, it operates at very high efficiency during the day because no heat losses occur during water circulation. Secondly, the intimate contact between water and the absorber plate results in a better heat transfer. These heaters have a compact size and cheap due to their simplicity of construction. In this system, heat is transferred from a heated plate at the top to a cooler body of water residing under it. This is an inefficient convection process.

3.2.2.2 FINNED BUILT-IN-STORAGE WATER HEATER

The only difference between plain type and finned type systems is only fins connected with the thermal collector plate. The importance of fins is that they act as a support for the top absorber plate, thus avoiding the bulging due to hydrostatic pressures exerted by the stored water within the heater. Secondly, the fin enhances the heat transfer process between the absorber plate and the innermost layers of water.

IV. ADVANTAGES AND DISADVANTAGES

4.1 FEATURES OF A GOOD SOLAR WATER HEATING SYSTEM

The storage tank should be double-walled and have insulation between the inner and outer tank. The inner tank should have a long life, making up of copper or stainless steel. The outer tank should be made of a stainless-steel sheet, aluminium or a painted steel sheet. The collector area should be sufficient as per the requirement. The system should be mounted on a tough and rigid support that should be firmly fixed on the roof to prevent damage by high winds.

4.2 ADVANTAGES

SWHs, along with term investment, can help in saving fuel and electricity- a 100 litres SWH can replace an electric geyser and save up to 1500 units of electricity per annum. SWHs come in a variety of sizes so we can choose according to our needs. These require lesser space as compared to photovoltaic panels. An SWH of 100 litres can prevent the emission of 1.5 tons of carbon dioxide per year. The total life of an SWH is approximately 15-20 years if it is adequately maintained. They are easy to install and are highly suitable for varying water conditions. SWHs are ideal for pressurized applications like Rainfall Showerheads. SWHs have a payback period ranging from 3 to 6 years depending upon the energy source that it has replaced. 3-4 years for electricity, 4-5 for furnace oil and 5-6 years when coal is replaced. Some SWHs do not require electricity to operate, so the hot water supply is secure even during a power outage. They have almost zero operating costs.

4.3 DISADVANTAGES

Scaling occurs when minerals are suspended in domestic water, these then build up as calcium deposits in the system. Corrosion is another problem. Oxygen can rust any iron or steel part. The plumbing components are more resistant because they are made of copper, bronze, stainless steel, plastic. A lot of roof space is taken to accommodate a SWH. The efficiency is affected during rainy, foggy, cloudy and cold days.

V. APPLICATIONS

- SWHs can be used in homes, community centres, swimming pools, hospitals, hotels and many industries (food and beverage, textile, processing)
- In process industries, to preheat boiler feedwater.
- In the domestic sector, it is used for bathing, washing of clothes and utensils.
- Solar heating for steam generation in a dairy plant.
- For a steam generation in Solar dishwasher.
- SWHs using ETCs have a high operational temperature to be used for heat and steam generation.

VI. CONCLUSION

Solar water heating is an energy-efficient, nature friendly and cost-effective renewable energy technology. It has vast potential in domestic and industrial applications. Due to their many favourable features, solar water heating systems are becoming increasingly popular across the world. India is a land of limitless potential, but the potential is not getting used to its total capacity. However, there exist many opportunities further to improve the systems in terms of cost-effectiveness and efficiency. Research and development centres should be opened to explore the potential of solar water heating further. As we discuss the environmental issues, global warming is the most dangerous one. So, people need to be motivated to use renewable sources, and SWHs are basic and approachable. The efficiency of active SHWSs is about 35%–80% higher than that of the passive system.

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