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Low Cost Efficacious Solar Water Heater from Recycled Components

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Abstract - A solar water heater made from waste plastic bottles is based on the thermosyphon technology. Each row of bottles consists of PVC pipes coated with black mate paint at the centre of bottles. These bottles act as glazing and pipes coated with paint as heat absorber. It is supported with aluminium sheet. This aluminium sheet acts as a casing and reflector for plastic bottles. The main aim of this research work is to prepare best out of waste. This would reduce the wastes of plastic bottles and can be used for preparation of low cost solar water heater. In summer this solar water heater heats the water to 65 ℃. The solar radiation varies as per seasons and so variation in thermal efficiency is observed. This research paper involves the study of the construction of solar water heater, it's thermal efficiency in different months, inclination angle with sun and various other aspects.
Keywords – Solar, Hot Water, Thermal Efficiency, Waste, Thermosyphon, Energy, Fluid, Temperature

I. INTRODUCTION

One of the biggest uses of electricity, gas and oil resources is in the heating of water for homes, offices, schools and hospitals. Solar water heating is a very simple and efficient way to grab energy from the sun and use it. Solar water heaters concentrate diffused solar radiation into thermal energy. Solar water heaters of the natural circulation (thermosyphon) type were used fairly widely in many countries from the beginning of the 20th century till about 1940 until cheap oil and natural gas became available. Now they are being installed again in large numbers because of the decline in the availlibility of natural resources. [1]
A solar water system consists of a solar collector, a separate highly insulated water storage tank, and well insulated pipes connecting the two. The bottom of the tank is atleast 0.3 m above the collector, and no auxiliary energy is required to circulate water through it as the circulation occurs through thermosiphoning. As the water is heated in its passage through the collector, its density decreases and hence it rises and flows into the top of the storage tank whereas the colder water enters from lower heater of the collector for further heating. The density difference between hot and cold water thus provides the driving force for the circulation of water through the collector and the storage tank. After sunset, a thermosiphon system can reverse its flow direction and losses heat to the environment during the night. To avoid reverse flow, the top heater of the absorber is kept atleast 0.3 m above of storage tank. To provide heat during long cloudy periods, an electrical immersion heater can be used as a backup for the the solar system. [2]
Thermosiphon solar water heaters are passive systems and do not require a mechanical pump to circulate the water. Such heaters can be used extensively in rural areas, where electricity is expensive and there is little danger of freezing. In comparison to conventional hot-water heating systems, solar water heater (SWH) can represent an alternative with moderate costs in countries with high energy costs and sufficient irradiation.

II. COMPONENTS AND INSTALLATION

A. Solar water heater consists of of the following components

1) Column of plastic pipes: The grey pipe of size ½ inch of diameter and 40 inch long pipes. Such pipes are connected in series having a gap of 6.5 cm each in between. These pipes are connected with the help of tee and jointer fixed at both the ends. The assembly shown in Fig. 1 becomes easy to follow an order if all the components are put in proper place, taking care to use the adhesive only in the tubes and connections. To avoid leaks the quality of the pipes and connections are essential. Join all parts to form the required columns. Black colour pigment is a combination that absorbs heat and light of all wavelengths. So having something black increases the number of wavelnegths that can effentially increase overall heat absorbivity. [3]

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Fig. 1 Column of plastic pipes

2) Plastic bottles in each column: Transparent plastic bottles of soft drinks like Pepsi and Miranda are used. Length of bottles is 35 cm and are cut 5 cm from its end allowing 10 cm of the bottle to enter in the next bottle, repeating the operation for as many columns required. Then insert these the bottle columns in the pipe coated with black paint which acts as heat absorber. Seal the top bottle of each column so that the heat is not lost and allow the air to enter from bottom. The air gets heated and trapped in the bottles which in turns heats the pipe.

Fig 2. Plastic bottles in each pipe

3) Aluminium reflector sheet: These aluminium sheets are used for reflectors. It is found from the experiment that the presence of reflecting surface increases the thermal efficiency of solar water heater. For experiment purposes and as shown in Fig. 3, aluminium foil has been used. The experiment showed that the presence of aluminium foil takes 15.5 minutes to reach 45 ℃ when measured at early in the morning (around 9:00 am) where as the bottle without the aluminium foil took around 24 minutes to reach the same temperature. This is due to presence of aluminium foil which reflects heat on to the plastic pipes from the the bottom.

Aluminium is a naturally available bright metal but in some cases the reflecting surface has been polished to give increased refelcting power. The reflectivity in such types of aluminium sheet is about 65-75%. [4]

Fig 3. Aluminium Reflector Sheet

4) The storage tank: The storage tank is made of concentric steel cylinders with glassy wool which acts as insulation to prevent the heat loss. the material of concentration is SS316 which is best suited for water storage. The thermal conductivity of glassy wool is 0.03 W/m.K which is sufficient to maintain the temperature for longer periods of time.

Fig 4. The storage tank

B. Angle of Inclination and the Installation of Solar Water Heater

Solar Water Heater installed on the roof of our college in Surat (a city in Gujarat, India) is shown in Fig. 5. The panel must be placed at least 30 cm below the tank and be sited on a sout facing wall or roof. To optimize the heat of adsorption, the panels must be mounted at the angle of our latitude plus 10 degrees [2]. For Surat city the angle of latitude is 22 degrees [5], and so the angle of inclination for our solar water heater is 32 degrees for this place.

Over time the plastic bottles become opaque which reduces the heat caption. To overcome this, the pipes can be repainted but it is adviced that once the bottles become opaque they should be replaced and the used bottles should be send to recycle dump.

Fig 5. Solar Water Heater – Final Installation

III. CALCULATIONS

A. Calculations for Energy Gained and Efficiency

The Surface Area of Solar Collector is 0.75 m^2

The amount of energy required from the sun to heat the water is given by the equation –

$Q = M.Cp.(T_{OUT}-T_{IN})$ [6] [Refer Nomenclature in the end]

Mass flow rate of water = M = 15 gram/second

Specific heat of water = Cp = 4.2 J/gm°C

Applying Q = M.Cp.(T_{OUT}-T_{IN}) for various timings of different months, the following table can be tabulated:

TABLE 1 ENERGY GAINED AND EFFICIENCY CALCULATIONS

Timings of Sunlight Received	Energy Gained (W) February 2014	Efficiency (%)	Energy Gained (W) March 2014	Efficienc y (%)	Enery Gained (W) April 2014	Efficienc y (%)	Enery Gained (W) November 2014	Efficienc y (%)
08:00 am	400	8.00	378	7.56	441	8.82	252	5.04
09:00 am	756	15.12	693	13.86	1323	26.46	504	10.08
10:00 am	1260	25.2	1638	32.76	1827	36.54	1008	20.16
11:00 am	1827	36.54	1953	39.06	2268	45.36	1575	31.5
12:00 noon	2394	47.88	2457	49.14	2583	51.66	2142	42.84
01:00 pm	2646	52.92	2583	51.66	2835	56.7	2394	47.88
02:00 pm	2835	56.7	2772	55.44	2898	57.96	2646	52.92
03:00 pm	2835	56.7	2772	55.44	2898	57.96	2646	52.92
04:00 pm	2583	51.66	2772	55.44	2626	52.52	2331	46.62
05:00 pm	2205	44.1	2205	44.1	2257	45.14	1953	39.06
06:00 pm	2016	40.32	2016	40.32	1890	37.8	1764	35.28

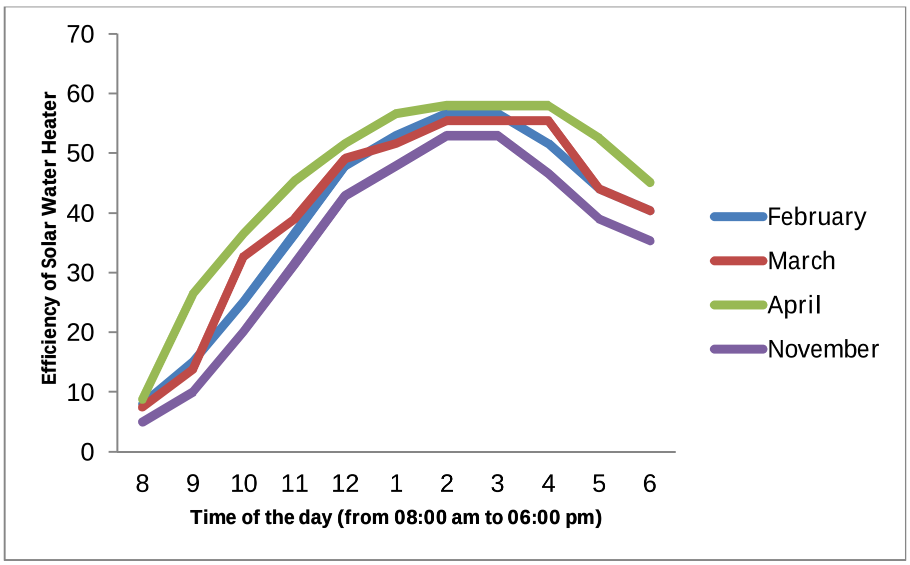

Fig 6. A graph of Efficiency of Solar Water Heater versus Time of the Day (from 08:00 am to 06:00 pm) for the months of February, March, April and November 2014

B. Comparision Studies and Calculations on Cost Savings

TABLE 2 COMPARISION WITH CONVENTIONAL SOLAR WATER HEATER

Properties	Conventional Solar Water Heater (For 100 litres capacity) [7]	Solar Water Heater from Recycled Components (For 15 litres capacity)
MOC	Copper Pipes	PET Bottles and Grey Pipes
Maximum Heat Capacity	3450 W	2898 W
Average temperature	65	50
Cost	□ 18900	□ 800

In order to calculate the electricity saved in comparison with an electric geyser, we make the following calculations based on an Electric Geyser working with a very high efficiency of 95% and the solar water heater working with an efficiency of 50%.

Thus electricity saved every day =

Solar Irridiation X Area X Efficiency of Solar Water Heater / Efficiency of Geyser [1]

$= (5\ kW/m^2 \times 0.75\ m^2 * 0.50) / 0.95 = 1.97\ kWH$

Taking the cost of electricity to be □ 5.20 per unit in India [8], amount saved per day = 1.97 X 5.20 = □ 10.244
Therefore, reduction in monthly electricity bill = □ 10.244 * 30 = □ 307.32

IV. CONCLUSIONS

The results obtained stipulates that the water temperature increases during the daylight hours and reaches to the maximum value in the middle of the day and then decreases. This project was set up and observed from the months of January to April. This water heater heats the water upto 65 ℃ in summer season and 45 ℃ in winter season. This heated water is collected in the insulated tank of SS316 with the insulation of glass wool of 20mm thickness. This is sufficient to store the water for longer period of time during night hours.This project have been made under nominal price so that this type of water heater can be used for poor areas and indigent people.

V. ACKNOWLEDGMENT

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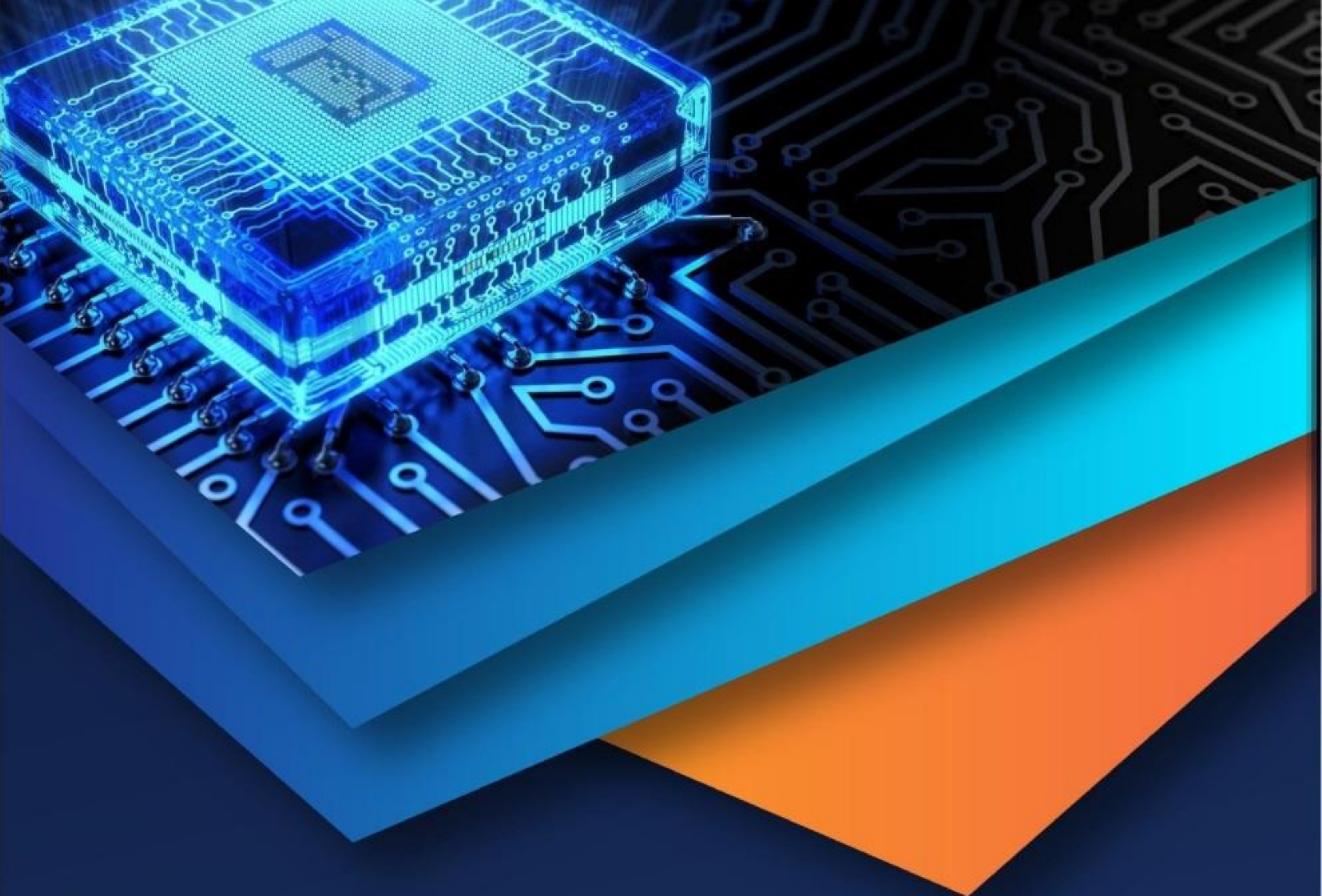
Nomenclature:

Q	-	Heat Capacity
M	-	Mass Flow Rate
Cp	-	Specific Heat
Tout	-	Out Temperature of Water
Tin	-	In Temperature of Water
W	-	Watts
m	-	meters
K	-	Degree Kelvin
℃	-	Degree Celcius
J	-	Joules
gm	-	grams



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